

TO WHAT EXTENT DO GRAPHIC ORGANIZERS INFLUENCE THE ACADEMIC
ACHIEVEMENT OF NINTH-GRADE CHEMISTRY STUDENTS?

by

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DEDICATION

This paper is dedicated with great appreciation and love to Yoko, my enduring and supportive wife. Your encouragement made a world of difference to my progress and achievement.

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ABSTRACT

This study investigated the effect of graphic organizers on the academic achievement of ninth-grade chemistry students ($N = 22$). Data was collected on their ability to design and use concept maps, mind maps, Vee diagrams, and Venn diagrams. The results showed that there was a positive correlation between the use of graphic organizers and students' test scores. The findings also revealed that the students were more engaged and took greater responsibility for their learning in the post-mapping period.

INTRODUCTION AND BACKGROUND

For the past three years, I have been teaching chemistry to grades 9 through 12 at Frankfurt International School in Oberursel, Germany. My school is home to nearly 60 nationalities and is spread over two campuses. There are currently 1781 students and the predominant ethnicities are American (30%), German (18%), South Korean (13%), and British (6%). Approximately 30 native languages are spoken within the wider school community. In grades 9-12, there are 523 students with approximately 130 students at each grade level. About a third of our students usually go to college in North America, one-third matriculate to the United Kingdom, and another third of them enter universities in the rest of the world (Alec Aspinwall, Director of Admissions, August 1, 2014). The school attracts students of varying abilities and needs. Over 95% of our students successfully complete the International Baccalaureate Diploma by the end of Grade 12 (Daniel Toyne, IB Coordinator, August 17, 2015).

Chemistry is one of the popular subjects at our school as many of our students aspire to major in science, technology, engineering, and mathematics (STEM) disciplines in college. Based on my conversations with them, their aspirations are shaped by their parents and siblings' successful careers. The students are highly driven and love to be challenged both inside and outside the classroom. It wouldn't be an exaggeration to say that students' test performance and grades are the driving forces behind that enthusiasm and motivation. As a chemistry educator, my goal is to keep that student energy and enthusiasm alive on a daily basis and make sure that their efforts are appropriately

rewarded. It is in this context that I view graphic organizers as a critical tool to enhance their conceptual understanding.

Graphic organizers have been used in classrooms worldwide for quite a long time. Educational researchers, students, and teachers view them as valuable tools to provide pedagogical structure, understand the connections between big ideas, and review a topic or unit summatively.

My research goal was to investigate if graphic organizers have a significant impact on their learning of high school chemistry. Concept maps, mind maps, Vee diagrams, and Venn diagrams were consistently used in each of the chemistry lessons and both qualitative and quantitative data will be collected. To engage my students better, I'll be encouraging them to use a few applications to design these organizers.

About 30% of my ninth graders struggle to answer integrated questions that would involve synthesizing information from two or more units as was evident from their performance on summative tests and exams. They also find it difficult to apply information to answer complex conceptual questions. So, the rationale of my study was to establish if ninth grade chemistry students could successfully answer higher order reasoning questions, especially those that would involve synthesizing concepts across the curriculum in the post-mapping period. I collected data relating to pre- and post-test scores and my students' responses to attitudinal surveys. I processed it to determine statistical correlations, which would then be used to draw inferences on students' conceptual understanding vis-à-vis graphic organizers. In the past, I had positive

experiences with using graphic organizers, but this time, I formally quantified their performance during pre- and post-testing period and looked for conclusive evidence.

The main focus question for this project is; to what extent do graphic organizers, such as concept maps, mind maps, Vee, and Venn diagrams, influence the achievement of ninth-grade chemistry students? In addition, the following sub-question was researched: are some organizers more effective in deepening students' conceptual understanding than others?

CONCEPTUAL FRAMEWORK

Graphic organizers are visual displays that teachers and students use to organize information to make it easier to understand and learn (Meyen, Vergason & Whelan, 1996). Graphic organizer roots lie in schema theory. We encode, store, and retrieve information based on this system (Slavin, 1991). When people learn something new, they must retain it for later use. The teacher's task is to ensure that the child has prior knowledge related to the concept and to provide a means to assist each child in making the necessary connections between what is being taught and the child's prior knowledge (Dye, 2000).

Concept mapping has been extensively used as a graphic organizer to facilitate learning in the classroom (Novak & Gowin, 1984). It lists information and distributes ideas in a hierarchical manner and labels relationships between adjacent concepts (MacKinnon & Keppell, 2005). Concept mapping can be used in several unique ways in the classroom. For instance, a teacher can ask students to design a concept map at the beginning of a unit to assess their prior knowledge (Novak, 1990). In addition, a teacher

can enable students in designing a pre- and post-concept map for a unit of study (Zineddine & Abd-El-Khalick, 2001). Also, a teacher can engage students' to gradually develop the concept map as the unit content unfolds (MacKinnon, 2001; Odom & Kelly, 1998). As educators ponder on ways to improve achievement, concept mapping holds promise in enhancing meaningful learning.

Concept mapping is a flexible tool that can be applied in many frameworks (Stewart, Van-Kirk, & Rowell, 1979). They can play a critical role in curriculum development, evaluation, learning, and teaching in many disciplines (Novak, 1984). Concept maps are useful in science curriculum planning for segregating significant curricular principles from trivial examples (Starr & Krajcik, 1990).

In a study conducted on 60 tenth graders in a Lebanese school, concept mapping was used as a homework tool. It provided significant results concerning its differential effect on different genders. Female students earned higher scores than males on the chemistry test, especially for questions testing their knowledge and comprehension. Moreover, the results showed that concept mapping, when used as homework, helped low-achievers perform better in chemistry (BouJaoude, S., & Attieh, M., 2008).

In another study carried out on 40 students in two classes of high school chemistry in Palo Alto area, concept maps were used as assessment tools (Ruiz-Primo & Shavelson, 1997). These students were asked to map the concepts associated with *Chemical Reactions and Matter* and the goal of the exercise was to investigate if concept maps could be used to predict the cognitive structures of students. The researchers concluded that these maps provided some information about students' knowledge

structures based on some improvements on their multiple-choice test scores in the post-mapping period. They also concluded that through practice, better maps could be designed and as a result, more information could be collected about students' knowledge structures.

Additionally, six sophomore students' who had recently finished studying high school chemistry were asked to map concepts relating to paper chromatography (Pendley & Bretz, 1994). Even though these students were able to answer interview questions based on the individual concepts of chromatography, they were not able to show the right connections on a concept map. However, in the post-instructional period of the same content, these students were able to draw more accurate concept maps. Concept maps can be useful tools to illustrate change, or lack of change, in a student's conceptual understanding.

Mind mapping is another graphic organizer in which information is structured hierarchically (Buzan, 1974). Mind maps are designed by applying these rules. Unlike a concept map, in a mind map, the topic is usually placed in the center of the paper, usually as a colored image. If a picture is not suitable, an appropriate keyword is chosen. From the topic, a main branch for each of the major ideas is drawn. The keywords representing the main ideas are written directly on the lines. Starting from the main branches, further lines can be drawn for secondary and tertiary ideas or sub-topics. In contrast to a concept map, a mind map is usually drawn using a variety of colors.

In a study conducted on middle school students, technology-assisted mind maps were investigated for their role in the understanding of science concepts and efficiency as

opposed to hand-drawn ones (Balim, 2013). The students were initially instructed to draw mind maps on paper, after which they learned to use software to design the same. All students involved in the study said that these maps enabled them to make stronger conceptual connections, as they were able to repeat drawing them using a variety of examples. They also stated that this computer-based activity was more fun, thereby engaging them better with the lessons involved.

In another investigation, researchers studied the effect of constructivist-visual mind maps on the science achievement of 140 ninth graders in Brunei. These maps were designed using a student-centered approach with little help from the instructor. One-half of this group was taught magnetism using a traditional approach and the other group learned using a constructivist-enriched mind mapping method for four weeks. The students in the latter group evaluated concepts more critically than those in the former. Students engaged in the constructivist mind mapping method developed a strong understanding of curricular concepts and made deeper connections than those taught by the traditional methods (Dhindsa & Anderson, 2011). In a different study carried out on 62 eighth grade science students in Kenya, students who participated in mind mapping methods scored higher on the multiple-choice tests based on central themes and major concepts than those in the non-participant group (Abi-El-Mona & Adb-El-Khalick, 2010).

Akinoglu and Yasar examined the effects of mind map-based note taking on the attitudes, academic achievement and concept learning of primary school students. In this study, both quantitative and qualitative research methods were adapted. The research was

performed on 81 randomly chosen 6th grade students from public schools in the district of Fatih. The application period took 21 course hours in total. The open-ended questions used in the research were qualitatively encoded by means of open-codification method. On the basis of the data collected during the study, it was determined that there was a significant positive difference in students' conceptual learning, overcoming misconceptions, academic achievement and attitudes towards science courses by taking notes through the mind-mapping method (Akinoglu & Yasar, 2007).

Vee diagrams are techniques for analyzing the knowledge structure of a problem (Novak & Gowin, 1984). They are similar to concept maps in the sense that they engage students in making explicit connections between prior knowledge and newly acquired information. These diagrams separate theoretical thinking on the left of the Vee diagram from the practical elements of inquiry on the right of the Vee diagram. They enable learners to examine a piece of knowledge and come away with a deeper understanding of how knowledge is constructed by showing how the concepts, events, and records of the events are formulated when attempting to create new knowledge (Afamasaga-Fuata'i, 2008).

A study was carried out on 42 freshmen in Turkey to investigate the effect of Vee diagrams on their experiential learning in the chemistry laboratory (Morgil et al., 2005). These researchers concluded that Vee diagrams minimized rote learning in students and theoretical knowledge turned out to be more meaningful in the minds of students. There were also some academic gains evident in small increases in their post-test scores. In another study, novice undergraduate students in chemistry were asked to classify

particulate matter and to provide justifications for their actions (Stains & Talanquer, 2007).

A separate study compared the effectiveness of the use of Vee Diagrams against that of concept maps in learning chemistry concepts (Polancos, 2009). This investigation involved two classes of third-year students of Liceo de Cagayan University High School in Cagayan de Oro City in 2009. Before the intervention, two similar tests were designed, the pre-test (PRT) and the post-test (POT). The POT results showed that there was no significant difference in students' achievement between these two approaches: Vee diagrams and concept maps. Both types of graphic organizers helped students develop an integrated system of concepts and promoted an internalization of conceptual connections.

In another investigation, the treatment group received instruction in Vee diagramming and wrote the pre-laboratory requirements in Vee diagrams, while the control group completed conventional pre-laboratory requirements (Polancos, 2009). Evaluations of student achievements included post-lab questions and problems, laboratory quizzes, and the comprehensive laboratory final exam. The students in the treatment group performed consistently better than the students in the control group on both the informal and formal assessments. These results supported the premise that adopting a Vee diagram as a pre-laboratory requirement can increase students' understanding and performance and provide a structure on which students can rely for the effective organization of background knowledge.

Venn diagrams are used to show all the logical relationships between a finite number of sets (Venn, 1880). In relation to science, Venn diagrams may be used to

collect and sort data and to compare and contrast different features of molecules, types of matter, plants, and animals (Moore, 2003). Activities involving the use of Venn diagrams foster science process skills and bring students closer to ways in which scientists' sort and analyze data. Venn diagrams reduce the abstractness of science concepts and students enjoy placing items into categories. These diagrams can also be completed in collaborative groups (Moore, 2003).

Graphic organizers such as Vee and Venn diagrams can help students sort and organize information so that they can draw meaningful inferences, whereas concept maps and mind maps help students to think deductively so that they can apply concepts and test hypotheses to solve new problems. In classroom teaching, visual organizers simplify the thinking process, allowing access and understanding on the part of different students with different attitudes and abilities. They provide opportunities to students to criticize and synthesize information. They provide a social context for students' internal thoughts, asking them to explain how they see what they see and also compare their vision to the vision of others (Clarke, 1991).

METHODOLOGY

This investigation followed the effect of graphic organizers on the chemistry achievement of ninth graders ($N=22$). The students who took part in this study were informed that their participation would not affect their grades. The ninth-grade students ($N=22$) took a series of Content Pre- and Post-Tests, Pre- and Post-Mapping Surveys, and a Post-Mapping Interview to evaluate the effect of graphic organizers on their chemistry achievement. The methodology research process involving human subjects received an

exemption from the Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

The students felt consistently challenged to apply their theoretical knowledge and understanding to successfully answer test questions when they simply consulted their notes. Graphic organizers were then introduced to provide structure and clarity for students to not only review effectively for these tests, but to perform at a higher level on these assessments. The students were given a Pre-Mapping Survey before the commencement of this exercise (Appendix B). It contained four-item Likert-style questions where students were asked to choose *strongly agree*, *agree*, *disagree*, or *strongly disagree* to evaluate the effect of graphic organizers on their ability to make accurate conceptual connections. The results from this survey were analyzed to determine the median to measure the central tendency, which was in turn used to answer the primary focus question: to what extent do graphic organizers influence the academic achievement of ninth grade chemistry students? The students were given a Post-Mapping Survey to quantify the degree of their conceptual change (Appendix C). The results were again used to determine the median. The Content Pre- and Post-Test medians were compared to understand the effects of using graphic organizers on their ability to organize concepts and map connections between them. The number of students and their choices (*agree*, *disagree* etc.) in the pre- and post-mapping period were plotted as a bar chart to determine the students' level of agreement with the positive impact of graphic organizers on their chemistry achievement.

A chi-square test was performed to analyze the statistical significance between the groups of students who agreed and disagreed about the significance of graphic organizers in the improvement of their chemistry test scores. The confidence level chosen for this statistical analysis was 95%.

The students were given four Content Pre-Tests on physical chemistry topics, namely thermochemistry, kinetics, equilibrium, and acids and bases (Appendices D-G). These assessments enabled students to respond to a wide range of questions involving both lower and higher order thinking. They were then asked to organize content using the same organizers, namely concept maps, mind maps, Vee diagrams, and Venn diagrams in each of the four units. They took the Content Post-Tests, which were same as the Content Pre-Tests, in the post-mapping period. The Content Pre- and Post-Test scores were used to determine normalized gains. Normalized gains are an approximate measure of effectiveness of a course in enhancing the conceptual understanding. If the normalized gain is less than 0.3, it is considered to be low, whereas that between 0.3 and 0.7 is said to be of medium value and gains above 0.7 are said to be of larger significance (Hake, 1998).

A box-and-whisker plot was drawn to determine the variability in the upper and lower quartiles of the test score distribution. Since there were only 22 students in the research study, their Content Pre- and Post-Test scores were analyzed using the Wilcoxon Signed-Rank Test. The test statistic, the lower absolute value of the two signed rank sums, was compared to the critical value for a 95% level of confidence. If the test statistic was lower than the critical value, we can reject the null hypothesis and conclude that there is a

significant difference between pre- and post-test scores. The results were used to answer the primary focus question.

The students were also given a set of 10 open-ended Interview questions in the post-mapping period (Appendix H). These questions written were similar in structure and content to Pre- and Post-Mapping Survey questions to gain deeper insights into students thinking about the impact of graphic organizers on their academic achievement. They were asked to explain if the organizers enabled them to map concepts better and understand connections between them. The students' responses were categorized into helpful and not helpful groups to answer the primary focus question. The students also compared different graphic organizers for their efficiency based on their ability to see the big picture in their lessons and understand the conceptual connections. Their qualitative responses were separated into those that helped them perform better on tests and the ones that did not. The number of students agreeing to be helpful about each of the graphic organizers were converted to percentages and plotted as a bar chart to answer the sub-question.

Teacher journals were used for a three-month period, between December 2016 through February 2017, to record observations about levels of student engagement, the accuracy of design, and the time taken by them to complete creating the graphic organizers.

The students' quantitative performance on the Content Pre- and Post-Tests and their qualitative responses to Pre- and Post-Mapping Survey and Post-Mapping Interview questions along with the students' artifacts, such as concept maps, mind maps, Vee and

Venn diagrams, and teacher's observations were triangulated to support both the primary focus and sub-questions (Table 1).

Table 1
Data Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3	Data Source 4
<i>Primary Question:</i> To what extent do graphic organizers influence the chemistry achievement of ninth grade chemistry students?	Students' scores on the Content Pre- and Post-Tests	Students' responses to Pre- and Post-Mapping Surveys and Post-Mapping Interviews	Teacher's observations	Students' artifacts, such as concept maps, mind maps, Vee and Venn diagrams
<i>Sub-Question:</i> Are some organizers more effective in deepening students' conceptual understanding than others?	Students' scores on the Content Pre- and Post-Tests	Students' responses to Pre- and Post-Mapping Surveys and Post-Mapping Interviews	Teacher's observations	Students' artifacts, such as concept maps, mind maps, Vee and Venn diagrams

DATA AND ANALYSIS

Results from the Pre- and Post-Mapping Survey were compared ($N=22$) (Figure1). In the Pre-Mapping Survey, 18% of the students indicated, *I understand connections between concepts better when I use a graphic organizer*. After three months of using graphic organizers, this percentage of students rose to 68% in the post-mapping period. Similarly, in the Pre-Mapping Survey, 23% students reported, *I do better on tests*

when I review with a graphic organizer. In the Post-Mapping Survey, this number rose to 68%.

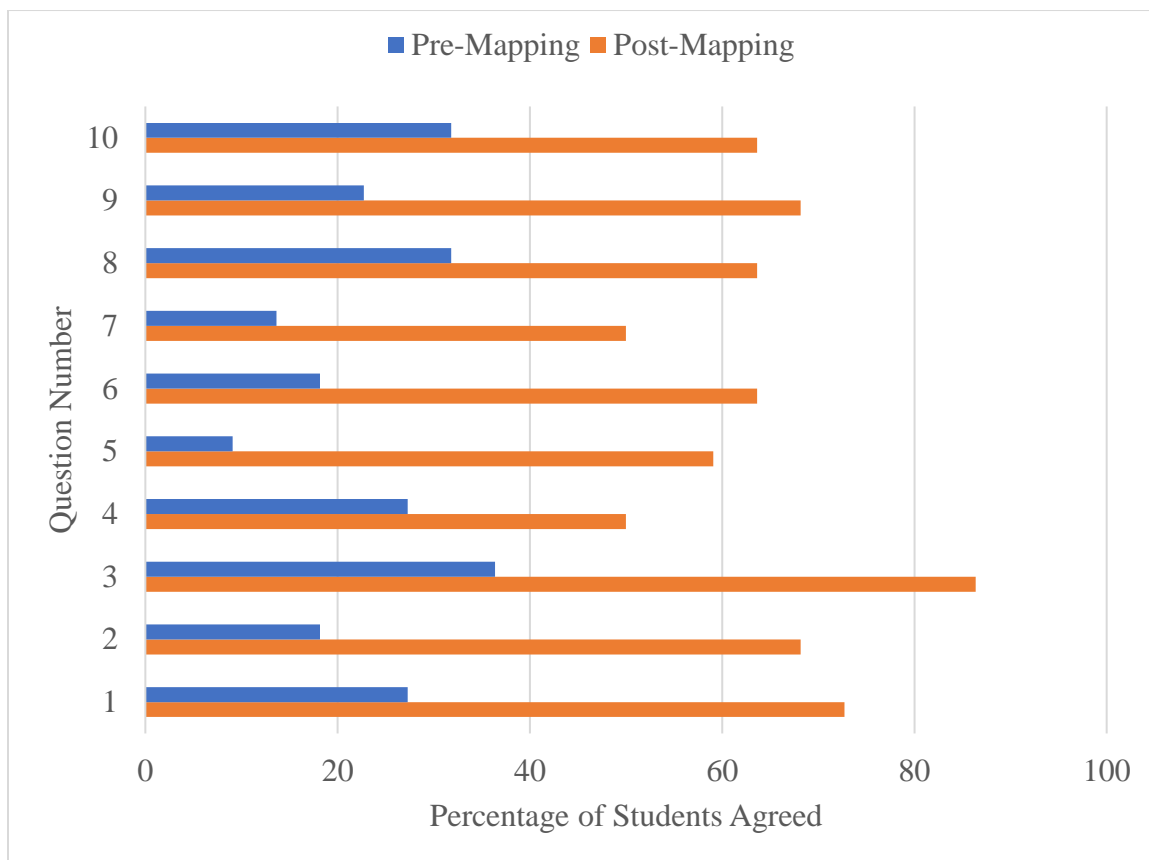


Figure 1. Pre- and Post-Mapping Survey results. ($N=22$). Pre- and Post-Mapping Survey results, where questions numbers 1-10 refer to those on the survey, ($N=22$). Q1: I map concepts after I review my lesson. Q2: I understand connections between concepts better when I use a graphic organizer. Q3: I refer to graphic organizers to complete my homework. Q4: When I am confused in class, I usually revisit my graphic organizers. Q5: I think logically when I draw a concept map. Q6: I think both creatively and logically when I draw a mind map. Q7: I solve chemistry problems correctly when I draw a Vee diagram. Q8: I mostly get ‘compare and contrast’ questions right when I draw Venn diagrams. Q9: I do better on tests when I review with a graphic organizer. Q10: I am more enthusiastic about chemistry after learning to use graphic organizers.

The number of students who disagreed about the positive impact of graphic organizers on their chemistry achievement was 54%. On the other hand, in the Post-

Mapping Survey, the number of students who agreed that the graphic organizers had a significant impact on their increased test scores was 75%.

A chi-square test was carried out on the two groups of students who agreed and disagreed with the statement, “I do better on tests when I review with a graphic organizer.” The chi-squared values in the pre- and post-mapping period were 6.54 and 4.52, respectively. The critical value was 3.84 for one degree of freedom. The chi-squared values were greater than the critical value for 5% level of significance.

A thermochemistry Pre-Test was given to grade nine students ($N=22$) in the pre-mapping period and a Post-Test, same as the Pre-Test, was given in the post-mapping period. The resulting data was analyzed for normal distribution. As shown in Figures 2 and 3, the distribution of students’ scores was not normal for the Content Pre- and Post-Tests, respectively. This means that the scores were not distributed symmetrically on either side of the bell curve.

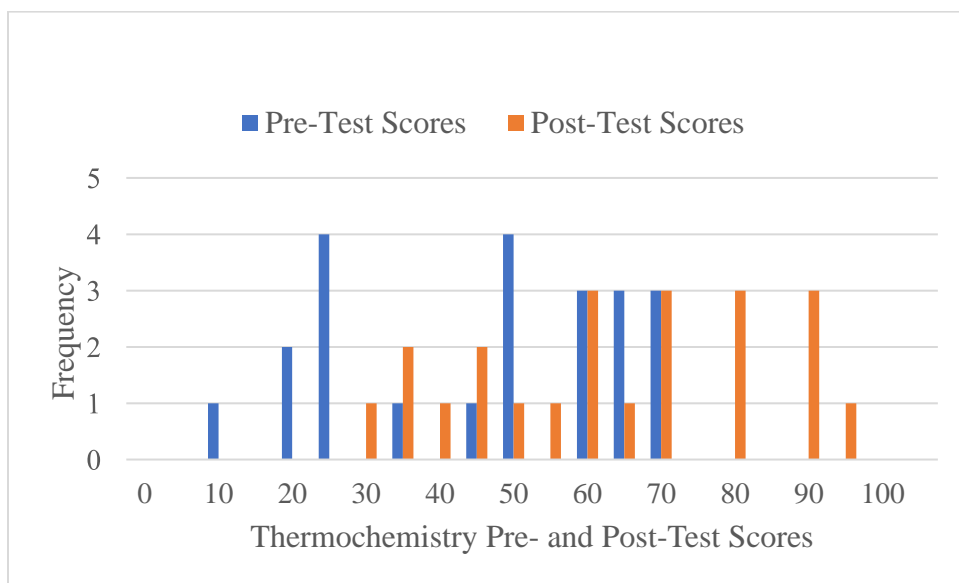


Figure 2. Frequency diagram showing thermochemistry Pre- and Post-Test scores, ($N=22$).

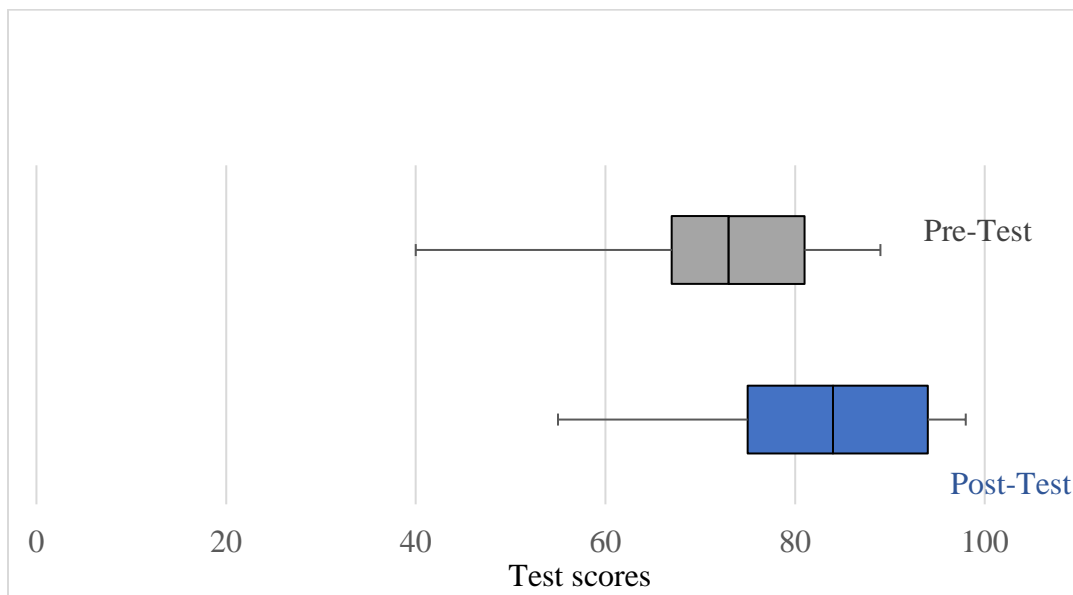


Figure 3. Box-plot showing the thermochemistry test scores in the pre- and post-mapping period, ($N=22$).

There were 22 students in the testing sample and the distribution of their scores was not normal. This means that the scores did not exhibit predictable traits and characteristics. A non-parametric test, such as the Wilcoxon Signed-Rank Test was employed to determine the statistical significance of using graphic organizers in students' academic achievement. The test statistic in this operation is the absolute lower value of the positive and negative sums and it was calculated as 17. The critical value for 5% of 22 student sample for a two-tailed test was found to be 75. This means that the graphic organizers had a statistical significance in the chemistry achievement of the students.

The average of the normalized gains for the Content Pre- and Post-test scores on the physical chemistry units, thermochemistry, kinetics, and acids and bases were found to be 0.33, 0.35, and 0.42, respectively. These values were found to be of *medium* significance (Hake, 1998).

In the Post-Mapping Interview, 77% of students said that the graphic organizers, such as concept maps, mind maps, Vee diagrams, and Venn diagrams played a positive role in their understanding of chemistry. 55% of students agreed that concept maps were more helpful in understanding conceptual connections, 36% of them preferred mind maps, and 9% used neither. In case of Vee diagrams, 25% of students viewed them positively for their role in problem-solving. 15% of students said that they used Venn diagrams to review compare and contrast features in their chemistry lessons, whereas 45% preferred drawing a table. 40% of them simply browsed through their notes.

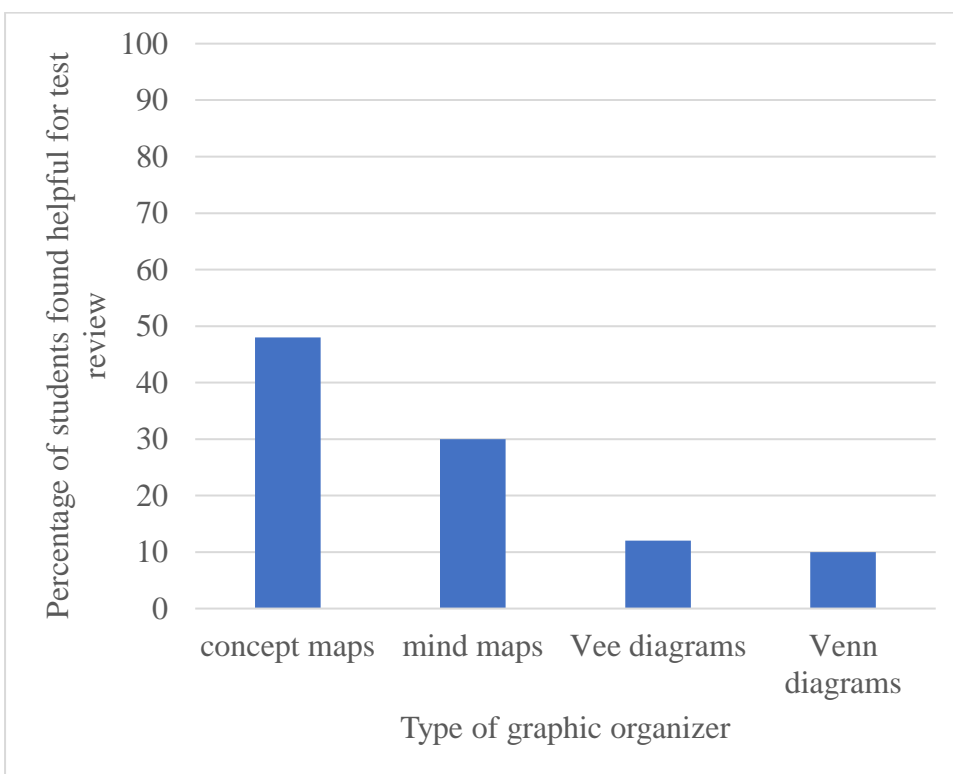


Figure 4. Post-Mapping interview results, (N=22).

In matters of test review, 76% of students said that they revisited one or more graphic organizers to understand the conceptual connections and 24% of them reviewed their notes and worksheets only. When they were asked about which graphic organizer

has been most helpful, 48% voted for concept map, 30% chose mind map, 12% preferred Vee diagrams, and 10% were in favor of Venn diagrams (Figure 4).

Students artifacts relating to concept maps, mind maps, Vee and Venn diagrams in the pre- and post-mapping period were used to determine the degree of their understanding of connections between the big ideas in their lessons. Several students felt Vee diagrams clarified many things about writing lab reports and complex numerical problems. One student said, “I was able to write a better conclusion on my lab report using a Vee diagram.” Another student commented, “Vee diagrams are cool. I can see the big picture now.” Majority of them agreed that they love the “Mindomo” app used to draw these graphic organizers as it really saved them time and made the whole process quite efficient. One student said, “This app has more features than my Google app.”

Graphic organizers created by the same student in the pre-mapping period were less structured and lacked in details as opposed to those in the post-mapping period (Figures 5-10). The graphic organizers created in the post-mapping period reflected a nuanced understanding of the content by the students as they were able to clearly distinguish between characteristics that are not inherent to a given concept.

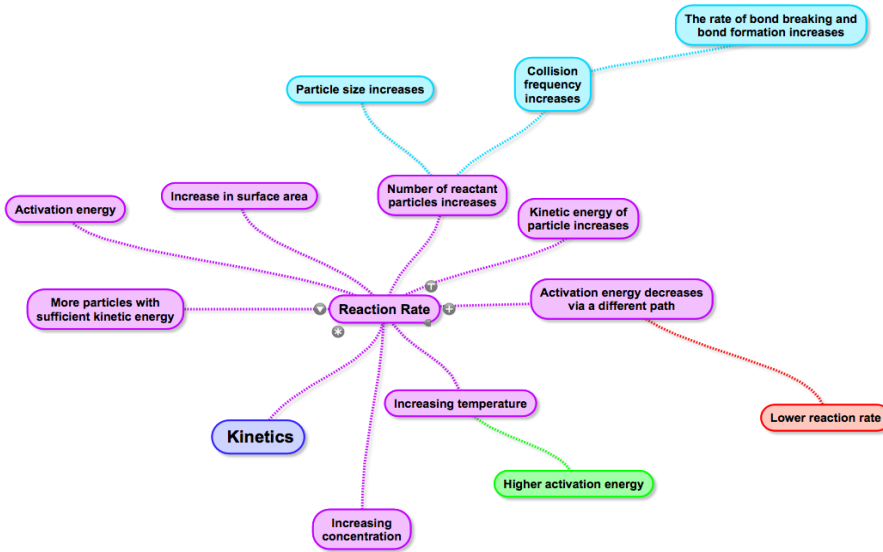


Figure 5. Kinetics concept map in the pre-mapping period.

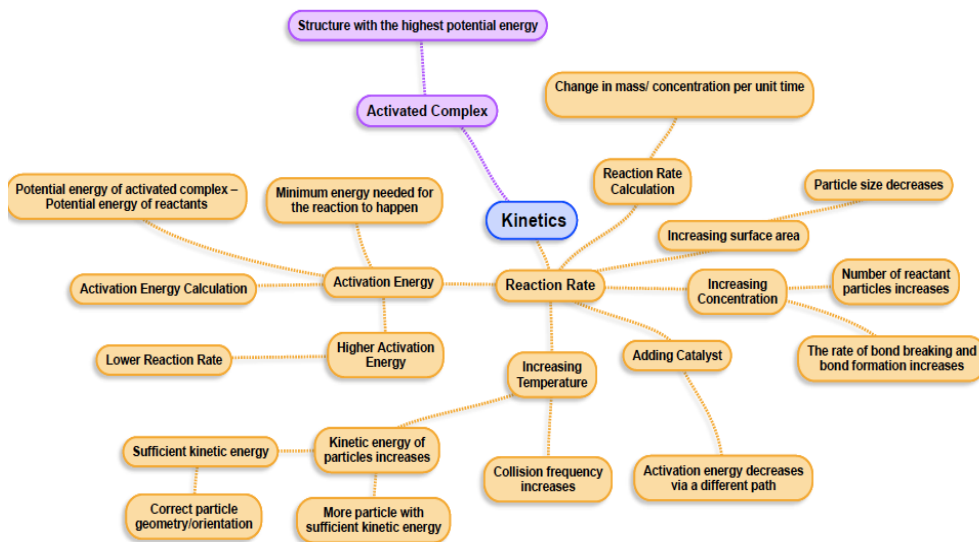


Figure 6. Kinetics concept map in the post-mapping period.

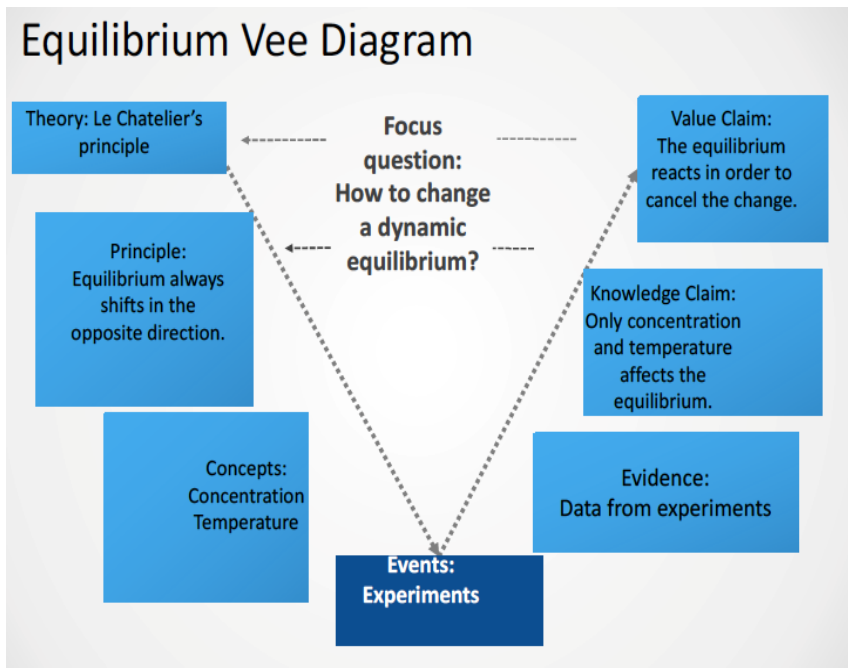


Figure 7. Equilibrium Vee diagram in the pre-mapping period.

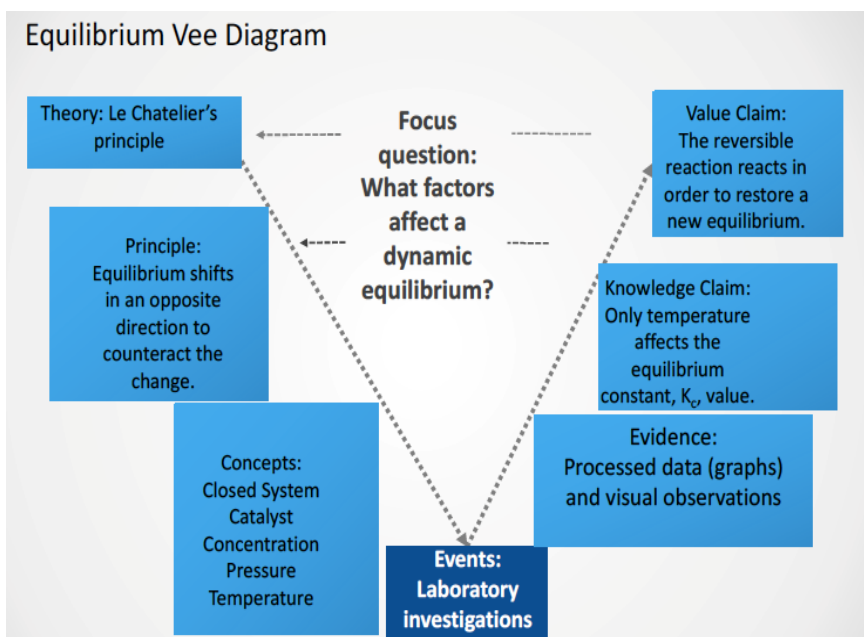


Figure 8. Equilibrium Vee diagram in the post-mapping period.

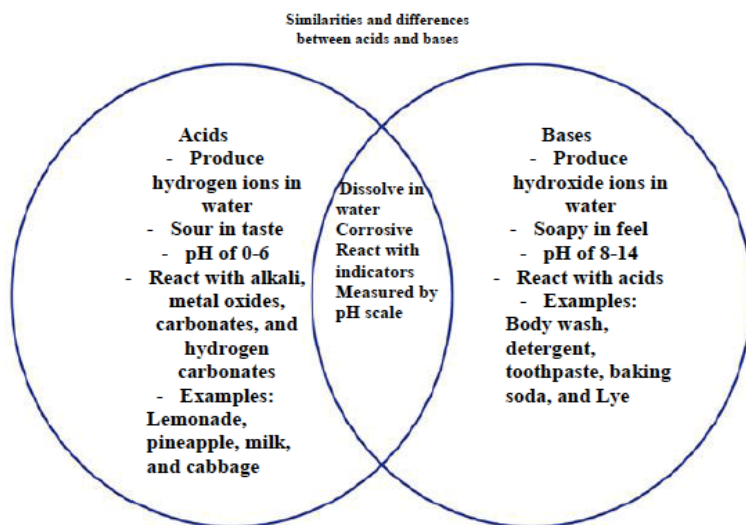


Figure 9. Acids and bases Venn diagram in the pre-mapping period.

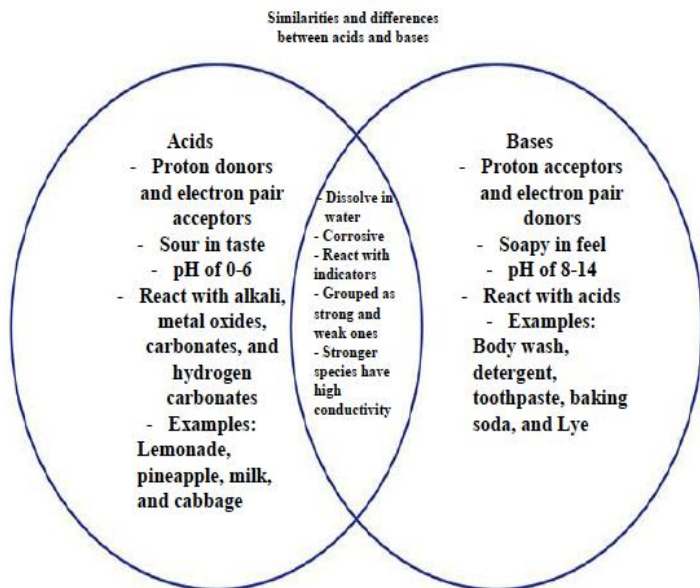


Figure 10. Acids and bases Venn diagram in the post-mapping period.

INTERPRETATION AND CONCLUSION

The ninth graders who participated in this study were quite enthusiastic and they took greater ownership of their learning in the post-mapping period. This was evident from the teacher's observations over the three-month period. The students asked fewer questions during their assessments and they were more engaged on their learning and assessment tasks.

To answer the primary focus question of my project, to what extent do graphic organizers, such as concept maps, mind maps, Vee, and Venn diagrams, influence the achievement of ninth-grade chemistry students? it is critical to understand the above-mentioned statistical analysis. Results from the chi-square test confirm that there was a statistical significance between the groups of students who agreed and disagreed with the questions posed in the Pre- and Post-Mapping Survey. There was a 45% increase in the number of students in the post-mapping period who agreed that the graphic organizers played a positive role in their improvement of test scores.

The student claims in the above-mentioned surveys were reinforced by the results from their Content Pre- and Post-Tests. Since the test statistic in Wilcoxon Signed-Rank Test was smaller than the critical value, it was concluded that there was a significant difference between the Content Pre- and Post-Test scores and the use of graphic organizers, namely concept maps, mind maps, Vee diagrams, and Venn diagrams.

Another source of evidence to verify students' claims on the Pre- and Post-Mapping Surveys stem from the average of the normalized gains for the Content Pre- and Post-Test scores. Students' values for the physical chemistry units, thermochemistry,

kinetics, and acids and bases were found to be 0.33, 0.35, and 0.42, respectively. This means that the students gained 33%, 35%, and 42% of the possible points they could have gained which were of medium significance (Hake, 1998).

The students' academic gains in the post-mapping period were further reinforced by their median test scores on thermochemistry, kinetics, and acids and bases. These scores increased by 13%, 16%, and 22%, respectively in the post-mapping period thus showing that the graphic organizers positively influenced their assessment outcomes.

The students' improved test scores in the post-mapping period were validated by their responses to Post-Mapping Interview questions. 18% of the students viewed concept maps as a more effective graphic organizer than mind maps to understand the conceptual connections. They mentioned that the concept map is comprehensive and helped them understand the connections better. They also felt concept maps enabled them to successfully answer application questions on the test.

The increase in test scores in the post-mapping period and their responses to Post-Mapping Interview questions were clearly complimented by the students' artifacts. The concepts maps, mind maps, Vee diagrams and Venn diagrams created in the post-mapping period illustrate a more insightful understanding of content and in-depth conceptual connections made by the students as opposed to those in the pre-mapping period.

However, it is important to note that the Vee diagrams and Venn diagrams were not used as frequently as concept maps or mind maps for holistic review due to their design limitations.

In conclusion, it could be inferred that the statistical evidence from the aforementioned analysis all point towards a positive correlation between the use of graphic organizers, such as concept maps, mind maps, Vee diagrams, and Venn diagrams and the academic achievement of ninth-grade chemistry students ($N=22$). It could also be stated that based on the Post-Mapping Interview results and students' artifacts, they found concept maps to be more effective to review and comprehend curricular connections than mind maps, Vee diagrams, and Venn diagrams. Also, based on the students' artifacts, it could be concluded that the concept maps created by the students in the post-mapping period were far more comprehensive and elaborate than any of the above-mentioned graphic organizers, thus enabling them to gain meaningful understanding of the subject.

VALUE

I expected a positive impact of graphic organizers on my students' chemistry achievement. However, I was surprised that 48% preferred concept maps for test review as I always thought mind maps were easier to draw and use. From my students' perspective, they looked at concept maps as more intricate tools that helped them look beyond the peripheral connections. They were more successful when they used concept maps to answer higher order thinking questions. Four students questioned, "How is a concept map different from a mind map?" Several students stated that they have never drawn graphic organizers prior to this study and they would love to use them in other subjects as well.

The academic gains of the students were found to be reasonably significant and a sustained use of graphic organizers in the chemistry classroom could ease some of the conceptual stress associated with the learning of abstract content. Student-designed concept maps, mind maps, Vee diagrams, and Venn diagrams can give a concrete peek into their curricular struggles and achievements. Reflective practitioners know how to help their students synthesize complex ideas and apply their understanding. Rather than teaching concepts in isolation, teachers could take advantage of graphic organizers to successfully weave graphic organizers into the curriculum to strengthen and deepen conceptual understanding of students.

This study transformative as the results clearly challenged several of my perceptions about student learning. This research made me think deeper about students' struggles to internalize abstract content and apply their knowledge and understanding to successfully answer test questions involving higher order thinking skills. As a result, I now invest more time to plan and design high quality lessons to provide concrete learning and closure opportunities. This graphic organizer project gave my students a clear sense of curricular direction in not only understanding the bigger picture, but in navigating the complex waters of chemistry. My students take pride in the graphic organizers they created and a vast majority of them reported successfully using them in both the pre- and post-assessment period. As John Dewey rightly said, "Give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking; learning naturally results."

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APPENDICES

APPENDIX A
IRB APPROVAL



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: Veeraiah Kummari and John Graves
FROM: Mark Quinn *Mark Quinn esj*
DATE: November 9, 2016
SUBJECT: "To What Extent Do Graphic Organizers Influence the Academic Achievement of Ninth Grade Chemistry Students?" [VK110916-EX]

The above research, described in your submission of November 9, 2016, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B
PRE-MAPPING SURVEY

Student Name: _____

Date: _____

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

Instructions:

- This assignment is not graded.
 - Please mark an 'X' on the correct letter.
-
1. I map concepts after I review my lesson.
a. Strongly agree b. Agree c. Disagree d. Strongly disagree

 2. I understand connections between concepts better when I use a graphic organizer.
a. Strongly agree b. Agree c. Disagree d. Strongly disagree

 3. I refer to graphic organizers to complete my homework.
a. Strongly agree b. Agree c. Disagree d. Strongly disagree

 4. When I'm confused in class, I usually revisit my graphic organizers.
a. Strongly agree b. Agree c. Disagree d. Strongly disagree

 5. I think logically when I draw a concept map.

- a. Strongly agree b. Agree c. Disagree d. Strongly disagree
6. I think both creatively and logically when I draw a mind map.
- a. Strongly agree b. Agree c. Disagree d. Strongly disagree
7. I solve chemistry problems correctly when I draw a Vee diagram.
- a. Strongly agree b. Agree c. Disagree d. Strongly disagree
8. I mostly get 'compare and contrast' questions right when I draw Venn diagrams.
- a. Strongly agree b. Agree c. Disagree d. Strongly disagree
9. I do better on tests when I review with a graphic organizer.
- a. Strongly agree b. Agree c. Disagree d. Strongly disagree
10. I'm more enthusiastic about chemistry after learning to use graphic organizers.
- a. Strongly agree b. Agree c. Disagree d. Strongly disagree

APPENDIX C
POST-MAPPING SURVEY

Student Name: _____

Date: _____

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

Instructions:

- This assignment is not graded.
 - Please mark an 'X' on the correct letter.
-
1. I map concepts after I review my lesson.
a. Strongly agree b. Agree c. Disagree d. Strongly disagree

 2. I understand connections between concepts better when I use a graphic organizer.
a. Strongly agree b. Agree c. Disagree d. Strongly disagree

 3. I refer to graphic organizers to complete my homework.
a. Strongly agree b. Agree c. Disagree d. Strongly disagree

 4. When I'm confused in class, I usually revisit my graphic organizers.
a. Strongly agree b. Agree c. Disagree d. Strongly disagree

 5. I think logically when I draw a concept map.

- a. Strongly agree b. Agree c. Disagree d. Strongly disagree
6. I think both creatively and logically when I draw a mind map.
- a. Strongly agree b. Agree c. Disagree d. Strongly disagree
7. I solve chemistry problems correctly when I draw a Vee diagram.
- a. Strongly agree b. Agree c. Disagree d. Strongly disagree
8. I mostly get 'compare and contrast' questions right when I draw Venn diagrams.
- a. Strongly agree b. Agree c. Disagree d. Strongly disagree
9. I do better on tests when I review with a graphic organizer.
- a. Strongly agree b. Agree c. Disagree d. Strongly disagree
10. I'm more enthusiastic about chemistry after learning to use graphic organizers.
- a. Strongly agree b. Agree c. Disagree d. Strongly disagree

APPENDIX D

THERMOCHEMISTRY PRE- AND POST-TEST

Student Name: _____

Date: _____

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

Section A: Multiple choice

Instruction to students: Use a pencil and mark an 'X' on the correct letter.

1. What is the specific heat capacity of a substance if 2.41×10^4 J are needed to change the temperature of 105.0 g of it from 25.0°C to 250.0°C ?
 - a. 1.02×10^{-4} J/g $^\circ\text{C}$
 - b. 9.18×10^{-4} J/g $^\circ\text{C}$
 - c. 0.918 J/g $^\circ\text{C}$
 - d. 1.02 J/g $^\circ\text{C}$

2. Which statement about enthalpy is true?
 - a. Heat is given off to the surroundings in endothermic reactions.
 - b. Some substances have a negative specific heat capacity.
 - c. Specific heat capacity is the same for all liquids.
 - d. The sign of ΔH is always negative in exothermic reactions.

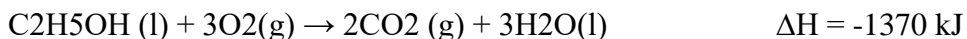
3. What happens to the value of ΔH for a thermochemical reaction if the reaction is reversed?

- a. ΔH has the same numerical value, and the sign changes.
- b. ΔH has the same numerical value, and the sign remains the same.
- c. ΔH is the reciprocal of the original value, and the sign changes.
- d. ΔH is the reciprocal of the original value, and the sign remains the same.

4. Which is an exothermic process?

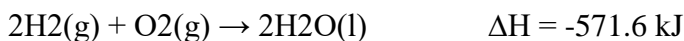
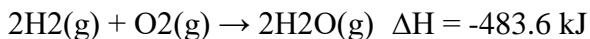
- | | |
|------------------|----------------------------|
| a. Ice melting | c. Water evaporating |
| b. Water boiling | d. Water vapour condensing |

5. Which statement is true for the combustion of ethanol?



- a. The enthalpy change would be the same if gaseous water were produced.
- b. The potential energy of the products is less than the potential energy of the reactants.
- c. The products of the reaction occupy a larger volume than the reactants.
- d. The reaction is endothermic.

6. What is the energy required to evaporate two moles of liquid water given the following equations?

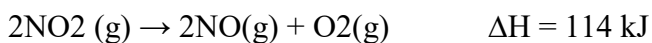


- | | | | |
|------------|------------|-------------|--------------|
| a. 44.0 kJ | b. 88.0 kJ | c. 527.6 kJ | d. 1055.2 kJ |
|------------|------------|-------------|--------------|

7. Which statement correctly describes an endothermic chemical reaction?

- a. The products have higher potential energy than the reactants, and the ΔH is negative.
- b. The products have higher potential energy than the reactants, and the ΔH is positive.
- c. The products have lower potential energy than the reactants, and the ΔH is negative.
- d. The products have lower potential energy than the reactants, and the ΔH is positive.

8. Given the thermochemical equation:



what is the ΔH for the reaction $\text{NO}(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{NO}_2(\text{g})$?

- a. -114 kJ b. -57 kJ c. +57 kJ d. +114 kJ
9. A substance increases in temperature by 255°C when a 983 g sample of it absorbs 83 200 J of heat. What is the specific heat capacity of the substance?
- a. $0.332 \text{ J/g}^\circ\text{C}$ b. $0.450 \text{ J/g}^\circ\text{C}$ c. $21.6 \text{ J/g}^\circ\text{C}$ d. $321 \text{ J/g}^\circ\text{C}$
10. What is the ΔH value for an exothermic energy change?
- a. Always negative
- b. Always positive
- c. Could be positive or negative
- d. Depends on the potential energy of the reactants

11. Which of the following statements is true?
- In an endothermic process heat is transferred from the surroundings to the system.
 - In an exothermic process heat is transferred from the surroundings to the system.
 - The surroundings will feel cooler in an exothermic process.
 - The surroundings will feel warmer in an endothermic process.
12. Calculate the ΔH for the following reaction using the bond energies given below:
- $$\text{H-H (g)} + \text{I-I (g)} \rightarrow 2\text{H-I (g)}$$
- Bond energies: H-H = 436 kJ/mol, I-I = 151 kJ/mol, H-I = 297 kJ/mol
- +290 kJ
 - 290 kJ
 - +7 kJ
 - 7 kJ

13. Which of the following processes is exothermic?
- Ether evaporating
 - Ice melting
 - Steam condensing
 - Water decomposing
14. The addition of 9.54 kJ of heat is required to raise the temperature of 225.0 g of a liquid hydrocarbon from 20.5°C to 45.0°C. What is the heat capacity of this hydrocarbon?
- 0.94 J/g°C
 - 1.73 J/g°C
 - 1.88 J/g°C
 - 9.42 J/g°C

Section B: Short Answer Questions

Instruction: Answer all questions in the space provided.

1. The specific heat of iron metal is $0.450 \text{ J/g}\cdot\text{K}$. How many J of heat are necessary to raise the temperature of a 1.05 kg block of iron from 25°C to 88.5°C ? [2]

2. How much heat energy, in Joules, is absorbed when 150 grams of water is warmed from 34.8°C to 96.3°C ? [2]

3. A chunk of silver has a heat capacity of $42.8 \text{ J/g}\cdot^\circ\text{C}$. If the silver has a mass of 181 grams , calculate the specific heat of silver. [2]

APPENDIX E
KINETICS PRE- AND POST-TEST

Student Name: _____

Date: _____

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

Section A: Multiple choice

Instruction to students: Use a pencil and mark an 'X' on the correct letter.

1. Which of the following units could be used to express the reaction rate?

- A. mL/s
- B. mL/g
- C. g/mL
- D. mL/mol

2. Consider the reaction: $\text{Zn(s)} + 2\text{HCl(aq)} \rightarrow \text{ZnCl}_2\text{(aq)} + \text{H}_2\text{(g)}$

The rate of production of ZnCl_2 , can be increased by

- A. decreasing the $[\text{HCl}]$.
- B. increasing the temperature
- C. increasing the volume of H_2 .
- D. decreasing the surface area of Zn.

3. The statement, the minimum energy needed for a successful collision, defines
- A. enthalpy.
 - B. activation energy.
 - C. the ΔH of the reaction.
 - D. the activated complex.
4. As an activated complex changes to products,
- A. potential energy changes to kinetic energy.
 - B. kinetic energy changes to potential energy.
 - C. kinetic energy changes to activation energy.
 - D. potential energy changes to activation energy.
5. Which of the following is most likely to have the greatest rate at room temperature.
- A. $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l})$
 - B. $2\text{Ag}^+(\text{aq}) + \text{CrO}_4^{2-}(\text{aq}) \rightarrow \text{Ag}_2\text{CrO}_4(\text{s})$
 - C. $\text{Pb}(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{PbCl}_2(\text{aq}) + \text{H}_2(\text{g})$
 - D. $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$
6. Consider the following PE diagram for an uncatalyzed and catalyzed reaction
- Which of the following describes the forward catalyzed reaction?

Activation Energy (kJ) ΔH (kJ)

A.	10	-15
B.	10	15
C.	25	-15
D.	25	15

7. A substance that increases the rate of a reaction without appearing in the equation for the overall reaction is a(an)

- A. product
- B. catalyst
- C. reactant
- D. intermediate

8. Activation energy can be described as the

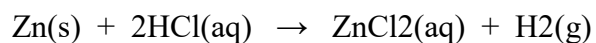
- A. energy of motion
- B. energy of the activated complex.
- C. energy difference between the reactants and the products.
- D. energy difference between the reactants and the activated complex.

9. What effect does a catalyst have on a reaction?

- A. It changes the ΔH of a reaction.

- B. It increases the kinetic energy of the reactants.
- C. It decreases the potential energy of the products.
- D. It provides a reaction mechanism with a lower activation energy.

10. Consider the following reaction involving 1.0 g of powdered zinc:



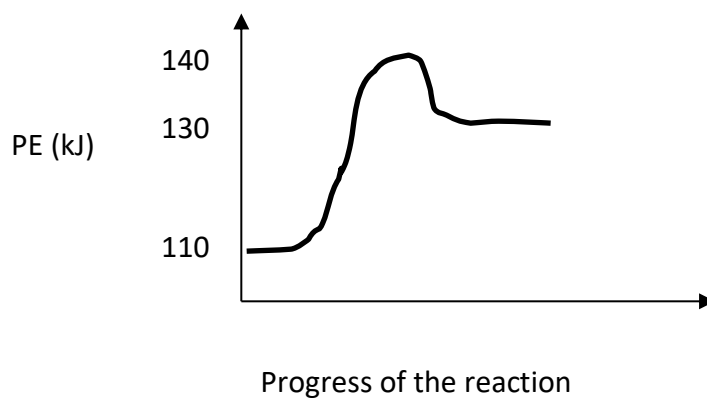
Trial	Temperature (0C)	Concentration of HCl
1	40	3.0
2	20	3.0
3	40	6.0

The rates in order of fastest to slowest are

- A. 1, 2, 3
- B. 2, 1, 3
- C. 3, 1, 2
- D. 3, 2, 1

11. Consider the following potential energy diagram for a reversible reaction:

Which of the following describes the system above?



	Reaction	Activation Energy (kJ)	ΔH (kJ)
A.	reverse	10	-20
B.	reverse	10	-30
C.	forward	30	+10
D.	forward	20	+30

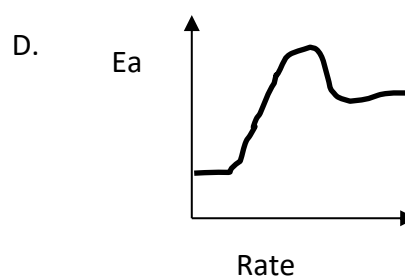
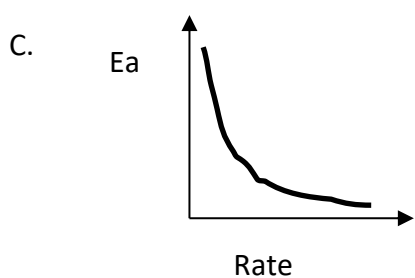
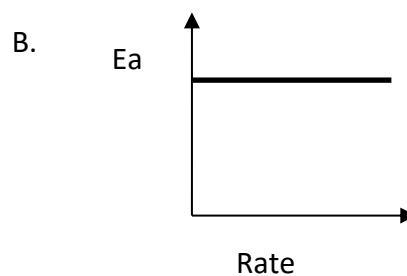
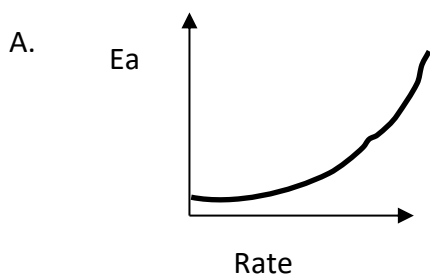
12. An activated complex is a chemical species that is

- A. stable and has low PE.
- B. stable and has high PE.
- C. unstable and has low PE.
- D. unstable and has high PE.

13. Consider the reaction: $\text{Ca(s)} + 2\text{H}_2\text{O(l)} \rightarrow \text{Ca(OH)}_2\text{(aq)} + \text{H}_2\text{(g)}$

At a certain temperature, 2.05 g Ca reacts completely in 30.0 seconds. The rate of consumption of Ca is

- A. 0.00208 mol/min
 - B. 0.0833 mol/min
 - C. 0.102 mol/min
 - D. 5.00 mol/min
14. Increasing the temperature of a reaction increases the reaction rate by
- I. increasing frequency of collision
 - II. increasing the kinetic energy of collision
 - III. decreasing the potential energy of the collision
- A. I only.
 - B. I and II only.
 - C. II and III only.
 - D. I, II, and III.
15. A certain reaction is able to proceed by various mechanisms. Each mechanism has a different E_a and results in a different overall rate. Which of the following best describes the relationship between the E_a values and the rates?

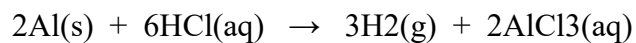


16. For collisions to be successful, reactants must have
- favorable geometry.
 - sufficient heat of reaction only.
 - sufficient potential energy only.
 - sufficient kinetic energy and favourable geometry.

Section B: Short Answer Questions

Instruction: Answer all questions in the space provided.

1. An experiment is done to determine the rate of the following reaction;



The following data are collected:

Time (s)	Mass of Beaker + Contents (g)
0.0	270.230
30.0	270.200
60.0	270.170

Calculate the rate of consumption of Al in moles/min

[2]

2. A student wishes to monitor the rate of the following reaction:



Identify two properties that could be used to monitor the rate of the reaction. Describe and explain the changes that would occur.

[4]

Property 1

Change and explanation

Property 2

Change and explanation

3. Sketch the potential energy diagram for an endothermic reaction in the space below.

On your diagram clearly label:

[3]

- i) the energy of the activated complex
- ii) the activation energy
- iii) ΔH

APPENDIX F
EQUILIBRIUM PRE- AND POST-TEST

Student Name: _____

Date: _____

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

Section A: Multiple choice

Instruction to students: Use a pencil and mark an 'X' on the correct letter.

1. The rate of a chemical reaction is equal to the slope of the line with axes labelled

	x-axis	y-axis
A.	time	rate
B.	mass	time
C.	volume of gas	time
D.	time	concentration

2. Which of the following describes the energy of colliding particles as reacting molecules approach each other?

	KE	PE
A.	decreases	increases

- | | | |
|----|------------------|------------------|
| B. | increases | decreases |
| C. | decreases | remains constant |
| D. | remains constant | increases |

3. The average kinetic energy per molecule can be increased by

- A. adding a catalyst
- B. increasing pressure
- C. increasing temperature
- D. increasing reactant concentration

4. Consider the following reaction: $C(s) + 2H_2(g) \rightleftharpoons CH_4(g)$ $\Delta H = -74.8 \text{ kJ}$.

Which of the following will cause an increase in the value of the K_{eq} ?

- A. increasing $[H_2]$
- B. decreasing the volume
- C. finely powdering the $C(s)$
- D. decreasing the temperature

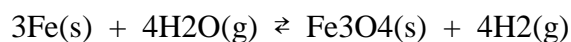
5. Chemical equilibrium is said to be dynamic because

- A. the reaction proceeds quickly
- B. the mass of the reactants is decreasing
- C. the macroscopic properties are constant
- D. both forward and reverse rates are occurring

6. The value of the K_{eq} can be changed by

- A. adding a catalyst
- B. changing the temperature
- C. changing the reactant concentration
- D. changing the volume of the container

7. What is the K_{eq} expression for the following equilibrium?



- A. $K_{eq} = [\text{H}_2]^4$
- B. $K_{eq} = \frac{[\text{H}_2]}{[\text{H}_2\text{O}]}$
- C. $K_{eq} = \frac{[\text{H}_2]^4}{[\text{H}_2\text{O}]^4}$
- D. $K_{eq} = \frac{[\text{Fe}_2\text{O}_3][\text{H}_2]^4}{[\text{Fe}][\text{H}_2\text{O}]^4}$

8. Consider the following equilibrium:



A stress was applied at time t_1 and the data plotted on the following graph:

The stress imposed at time t_1 is the result of

- A. the addition of HCl
- B. decreasing the temperature

- C. the addition of NaCH₃COO
 - D. increasing the volume of the container
9. Addition of a catalyst to an equilibrium system
- A. increases the value of the K_{eq}
 - B. increases the yield of the product
 - C. has no effect on the rates of the reaction
 - D. increases the rates of formation of both reactants and products

10. Ammonia, NH₃, is produced by the following reaction:



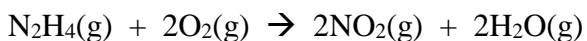
Which of the following would result in the highest concentration of ammonia at equilibrium?

- A. increasing the temperature and increasing the pressure
- B. decreasing the temperature and increasing the pressure
- C. increasing the temperature and decreasing the pressure
- D. decreasing the temperature and decreasing the pressure

Section B: Short Answer Questions

Instruction: Answer all questions in the space provided.

1. Consider the following equilibrium:



APPENDIX G

ACIDS AND BASES PRE- AND POST-TEST

Student Name: _____

Date: _____

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

Section A: Multiple choice

Instruction to students: Use a pencil and mark an 'X' on the correct letter.

1. An aqueous solution of which of the following reacts with magnesium metal?

- A. Ammonia
- B. Hydrogen chloride
- C. Potassium hydroxide
- D. Sodium hydrogencarbonate

2. Which of the following is/are formed when a metal oxide reacts with a dilute acid?

- I. A metal salt
 - II. Water
 - III. Hydrogen gas
- A. I only B. I and II only
- C. II and III only D. I, II and III

3. Four aqueous solutions, I, II, III and IV, are listed below.

I. $0.100 \text{ mol dm}^{-3} \text{ HCl}$

II. $0.010 \text{ mol dm}^{-3} \text{ HCl}$

III. $0.100 \text{ mol dm}^{-3} \text{ NaOH}$

IV. $0.010 \text{ mol dm}^{-3} \text{ NaOH}$

What is the correct order of increasing pH of these solutions?

A. I, II, III, IV

B. I, II, IV, III

C. II, I, III, IV

D. II, I, IV, III

4. Which substance can be dissolved in water to give a 0.1 mol dm^{-3} solution with a high pH and a high electrical conductivity?

A. HCl

B. NaCl

C. NH_3

D. NaOH

5. The pH of a solution is 2. If its pH is increased to 6, how many times greater is the $[\text{H}^+]$ of the original solution?

A. 3

B. 4

C. 1000

D. 10 000

6. Which is not a strong acid?

A. Nitric acid

B. Sulfuric acid

C. Carbonic acid

D. Hydrochloric acid

7. Which is a Brønsted-Lowry acid-base pair?

A. H_2O and O^{2-}

B. CH_3COOH and CH_3COO^-

C. NH_4^+ and NH_2^-

D. H_2SO_4 and SO_4^{2-}

8. Which species can act as a Lewis acid?

A. BF_3

B. OH^-

C. H_2O

D. NH_3

9. Which substance, when dissolved in water, to give a 0.1 mol dm^{-3} solution, has the highest pH?

A. HCl

B. NaCl

- C. NH₃
- D. NaOH

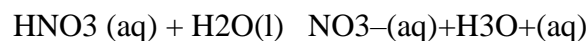
10. Which methods will distinguish between equimolar solutions of a strong base and a strong acid?

- I. Add magnesium to each solution and look for the formation of gas bubbles.
 - II. Add aqueous sodium hydroxide to each solution and measure the temperature change.
 - III. Use each solution in a circuit with a battery and lamp and see how bright the lamp glows.
- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III

Section B: Short Answer Questions

Instruction: Answer all questions in the space provided.

1. The reaction of nitric acid with water can be represented by the following equation:



a. Define the terms Brønsted-Lowry acid and base, and identify two examples of each of these species in the equation. [4]

b. Identify two conjugate acid-base pairs in the above reaction. [2]

2. a. Write the chemical formulas of the following: [2]

i. Sulfuric acid _____

ii. Ammonia _____

b. Give a name for the following: [2]

i. CH_3COOH _____

ii. $\text{Ba}(\text{OH})_2$ _____

APPENDIX H
POST-MAPPING INTERVIEW

Student Name: _____

Date: _____

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

Instructions:

- This assignment is not graded.
- Please answer the following questions in as much detail as possible.

1. What is the role of graphic organizers in your understanding of chemistry?

2. Do you prefer a concept map or a mind map or both to understand conceptual connections? Explain why.

3. Are Vee diagrams helpful in solving chemistry problems? Explain with a reason.

4. When do you draw a Venn diagram?

5. How often do you use a graphic organizer to review the content?

6. Which graphic organizer has been the most and least helpful so far in understanding chemistry concepts? Give a reason.

7. Do you use an app or free-hand drawing to design your organizer? Explain why.

8. How often did use a graphic organizer to review for a test?

9. Did you perform better on tests when you reviewed with a graphic organizer?

10. What else do you want me to know about your experience with graphic organizers?
