

THE IMPACT THE 5E LEARNING CYCLE MODEL HAS ON  
STUDENT ACHIEVEMENT AND ENGAGEMENT  
IN A MIDDLE SCHOOL SCIENCE CLASS

by

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A professional paper submitted in partial fulfillment  
of the requirements for the degree

of

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in

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## ABSTRACT

The purpose of this study was to evaluate the impact the use of an inquiry based approach to science instruction has on students' engagement and understanding of content in a middle school physical science course. The 5E Learning Cycle was the inquiry model that was used. Students' level of engagement was monitored using journaling and classroom observations. To track changes of students' understanding of content material a pre and post-test was administered over the course of two units. The results of the study found that the 5E Learning Cycle had a positive impact on both engagement and understanding of content.

## INTRODUCTION AND BACKGROUND

Cut Bank Middle School (CBMS) is located in Cut Bank, Montana. Cut Bank is a small community in north central Montana on the border of the Blackfeet Indian Reservation. Cut Bank has a population of 2,963 with 77% of residents identifying as Caucasian, 16.5 % American Indian, 3% Hispanic, and less than 1% each as Asian and African American (city-data.com, 2012). CBMS is part of the Cut Bank Public Schools District #15 and serves students in grades six, seven, and eight. The total enrollment for CBMS during the 2014-2015 school year was 140 students. Out of the 140 students 59.3% were American Indian or Alaska Native, 37.9% were Caucasian, 2.1% were Hispanic/Latino, and 0.7% were African American. There were 55% of the students who qualified for Free or Reduced Lunch (Infinite Campus, 2015). It is also important to note that for a variety reasons the Cut Bank School District experiences a high turnover rate in its student population.

Over the past five years, I have taught sixth, seventh, and eighth grade science at Cut Bank Middle School. In that time I have experienced a wide range of success in student achievement and engagement. The majority of my instruction followed a traditional approach to teaching science. I frequently used strategies such as assigned readings from the textbook, lecture and note taking sessions, and highly-structured lab activities to present the content of my science classes. While this approach was effective for some students, there seemed to be a significant gap in student achievement that stemmed from this approach. Students were either both very engaged and excelled, or they appeared disconnected from the class and struggled greatly.

As I gained experience as an educator, my confidence began to grow, and I became more comfortable trying new instructional approaches. With each new approach I observed a variety of positive and negative impacts that resulted from the changes in my instruction, but I always reverted to the traditional methods I was most comfortable with. Each time I returned to the traditional methods, the gap in student achievement would soon become apparent again, and so I would once again begin my search for a new approach.

In my search for a more effective instructional approach I came across the concept of inquiry and the 5E Learning Cycle. Of all the approaches I had tried the inquiry approach seemed to have the most positive impact, and my comfort level with the 5E Learning Cycle was greater than with other strategies I had used. This led to the creation of my focus statement: *How does the implementation of an inquiry based approach to instruction affect student achievement and engagement in a middle school science class?* The following sub-questions will also be researched.

1. How does the 5E Learning Cycle impact student achievement?
2. What impact does the 5E Learning Cycle have on student engagement?
3. What impact does the 5E Learning Cycle have on teaching practices?

## CONCEPTUAL FRAMEWORK

Inquiry in a science classroom is an approach to education that is derived from the constructivist theory. A constructivist classroom is based on three key principles: learning should be active and discovery based, peer interactions should be frequent, and

conceptual change should be promoted and students should test their theories for inconsistencies in their thinking (Llewellyn, 2007). Ackay and Yager's (2010) research suggests that student achievement is greatly increased and students' attitude towards science is positively impacted when an inquiry approach is utilized as compared to student achievement and attitude when traditional teaching methods are used. In recent years, inquiry has become a popular term for describing the focus of science pedagogy.

Despite the rise in the popularity of the term inquiry, it remains an underutilized approach in most science classrooms (Crawford, 2007). Research by Cartier, Passmore, and Stewart (2009) suggests one reason for underutilization of inquiry is a lack of clarity about what exactly inquiry is. The National Research Council defines inquiry as a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results (NRC, 1996).

Further exploration of defining inquiry in the classroom reveals that inquiry includes three distinct areas: the student, the teacher, and the physical environment (Llewellyn, 2007). Each of these distinct areas of inquiry has its own unique set of characteristics. The students' characteristics in an inquiry based classroom include acting as researchers, working in groups, using critical thinking skills, and demonstrating an interest in science (Llywellyn, 2007).

The characteristics demonstrated by the teacher in an inquiry based classroom include: using national standards to choose content topics; limiting the use of lecture time and direct instruction only to situations that cannot be achieved through inquiry based instruction; being flexible and allowing lessons to follow the direction of student questions; using students' prior knowledge as a basis for introducing new concepts; being aware of students' misconceptions, basing instruction on students' interests; using investigations to anchor concepts to prior knowledge; facilitating class discussions through effective questioning techniques; using questioning techniques to allow students to answer their own questions as opposed to providing answers to questions; providing positive reinforcements, asking follow up questions to student answers; maintaining effective classroom management during investigations; and establishing routines to promote productive learning (Llewellyn, 2007).

Common characteristics of the physical classroom include: "What if" and "I wonder" questions posted throughout the classroom; students' desks arranged in small groups; student work displayed throughout the classroom; expectations clearly displayed in the classroom; various resources made readily available for student use; and materials and tools made easily accessible for students' investigations (Llewellyn, 2007).

The characteristics best describing an inquiry based classroom focus on creating a classroom that is generally student-centered. This can be achieved in a variety of ways. Inquiry learning can take an open-ended approach, or a project-based approach, the latter approach is often referred to as a guided-inquiry approach. Each approach contains the essential elements of inquiry learning, but each also has its own drawbacks. For

example, the open-ended approach provides students with the opportunity to truly be in control of where their learning will lead them, but as a result can be difficult to implement in a classroom setting due to factors such as time restrictions and requirements to meet specific content standards. A drawback to a guided inquiry approach is that it loses some of the student-centeredness and can be more of a teacher-centered approach to instruction. Effective guided inquiry provides students with specific content topics that they can easily relate to their own lives and experiences. Effective guided inquiry can be achieved through the use of strategies such as learning-cycle lessons, journaling, teacher facilitated structure, questioning and discussion, and performance assessments (Jones & Eick, 2006).

According to Akcay and Yager (2010) the advantages of an inquiry based approach over a traditional approach include science concept mastery levels equal to or greater than traditional methods, enhanced student ability to apply concepts, increased creativity, more positive student and teacher attitudes, greater development of process skills, and a better understanding of the nature and history of science.

The Learning Cycle is one of the most familiar and effective models for science instruction. Originally the Learning Cycle consisted of three phases. The original phases of the Learning Cycle were Exploration, Invention, and Discovery. The cycle began with students experiencing a phenomena. In the middle phase students were introduced to terms related to important concepts. In the final phase students used the terms and concepts in a new situation (Bybee, 2006). As more emphasis has been put on following a constructivist approach to instruction, it has been expanded to include five stages

(Llewellyn, 2007). In the development of the 5E Instructional Model, the original three phases of the Learning Cycle were adapted to make up the three middle sections of the 5E model which are Explore, Explain, and Elaborate. In addition two new phases were added, Engage and Evaluate (Bybee, 2006).

In the Engage phase the focus is on activating and assessing students' prior knowledge. It is also an opportunity to present students with learning expectations stating what they should know and be capable of doing by the end of the lesson (Llewellyn 2007). In this phase students focus on an object, problem, situation, or event in an attempt to make connections to past experiences and expose misconceptions. Appropriate activities to engage students include asking a question, defining a problem, using a discrepant event, or acting out a problematic situation (Bybee, 2006).

In the Exploration phase students are provided an opportunity to engage in the inquiry process. This stage is essential because it allows develop their own thoughts and questions about the content without direct influence from the teacher. It is serves as a common experience for students to draw on as they move through the lesson. In a classroom setting where students come from a wide variety of backgrounds and have a wide range of life experiences, having a common experience to connect to, is a very valuable tool (Llewellyn 2007). In the Exploration stage the teacher takes on a facilitator role and provides students with opportunities to have concrete experiences and use tangible materials to begin investigating students' own ideas about phenomena (Bybee, 2006). This is an important step in the learning cycle model. According to the National Science Teacher Association (NSTA) position statement on elementary school science

students learn science best when they are given the opportunity to experience science first-hand.

The next stage in the 5E Learning Cycle is the Explain stage. In this portion of the lesson the teacher moves from a facilitator role to a more direct-instruction role. In the stage teacher-led activities take place. Skills such as data-processing strategies are commonly included in the Explain stage. This is also an appropriate time for teacher-led instruction explaining the content associated with the activities in the other stages of the Learning Cycle (Llewellyn 2007).

The fourth E in the 5E Learning Cycle is the Elaborate stage. In the Elaborate stage the content and concepts are reinforced through new applications. This can be done through open-inquiry activities, exploration of questions generated in the Engagement stage, or by building off content presented in the Explanation stage (Llewellyn 2007). The primary goal of the Elaborate stage is to generalize the concepts, processes, and skills addressed in the lesson. It also provides an opportunity for students to work collaboratively in small groups to share their understanding and receive feedback from classmates with a similar level of understanding (Bybee, 2006).

The final stage in the 5E Learning Cycle is the Evaluate stage. In this stage the teacher ties together concepts and helps students to assess the knowledge they have gained through the lesson. Often the Evaluate stage will include activities that compare students' pre lesson understanding with their post lesson knowledge (Llewellyn 2007). The Evaluation stage can take many different forms and can occur in different places in the 5E cycle. Evaluations can be done informally throughout the cycle, or can appear as

a formal assessment after the Elaborate stage. The Evaluation stage can serve as an opportunity for the teacher to assess student's educational outcomes (Bybee, 2006).

Due to the 5E Learning Cycle being a relatively new approach to science instruction compared to earlier learning cycle models there are fewer studies on its effectiveness on students' overall learning. The studies that have been done on the 5E Learning Cycle suggest that it is an effective approach and in some cases found that it is more effective than other methods. Three areas of student learning that studies have shown the 5E Learning cycle to be an effective method of instruction are subject mastery, scientific reasoning, and interest and attitude towards science (Bybee, 2006).

## METHODOLOGY

The purpose of this action research was to explore the impact instructional methods have on student achievement and engagement. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A). During the intervention period, three sections of an eighth grade physical science course participated in the research ( $N = 40$ ). During the intervention period the sample population fluctuated between 40 and 36 students. Not all students who began the intervention completed it. All sections received inquiry modeled instruction following the 5E Learning Cycle model for the entire intervention period. The intervention took place over two units. The first unit focused on the structure of matter. It was taught over six sessions. The second unit focused on chemical reactions and was taught over ten sessions. All sessions for both units were 55 minutes long. At the end of the intervention

period I was able to determine whether the use of the 5E Learning Cycle had a positive impact on students' attitude towards science and their understanding of the science content.

At the beginning of the intervention period students completed the Student Attitude Survey (Appendix B). The survey consisted of 12 statements related to students' feelings about science. After each statement students circled the choice that best reflected their feelings about the statement from either *Strongly Agree*, *Agree*, *Neutral*, *Disagree*, or *Strongly Disagree*. Students also had the option of providing a short explanation of their response for each of the 12 survey items. The data collected from the pre-survey was analyzed by tallying the frequency of responses for each item and identifying themes that developed in the responses. The frequencies of responses and themes were then compared with the post-intervention survey results to determine if there was any change in students' attitude towards science after receiving instruction following the 5E Learning Cycle model.

The Structure of Matter Test (Appendix C) was used to assess students' prior knowledge for the content of each unit. The pre-test consisted of 17 multiple choice items, 7 fill in the blank items, and 6 true or false items. The Chemical Reactions Test (Appendix D) consisted of 25 multiple choice items, 9 fill in the blank items, and 6 True or False items. At the conclusion of each unit a post-test was given. The post-test consisted of the same set of questions as the pre-test. The pre-tests and post-tests were analyzed by totaling the number of correct responses for the individual test items as well as calculating the average overall test scores. These scores were used to measure student

growth in content knowledge by comparing them to the post test scores. Growth from pre-test to post-test was measured using a normalized-gain analysis.

The post-intervention data was collected using the Student Attitude Survey, the Structure of Matter Post-Test, and the Chemical Reaction Post-Test. The content of the post-survey and post-test contained the same as the content of the pre-survey and pre-test. The scores collected from the pre- and post-tests were analyzed using a two-tailed test for dependent means.

During the intervention period changes in student attitudes were monitored using the Student Interest Interviews (Appendix E) and Student Reflective Journal Entries (Appendix F). Responses to the Interest Interviews were sorted and organized by similar responses. Themes in the responses were then identified. The Reflective Journal Entries were color coded into three sections: pre-intervention, mid-intervention, and post-intervention. Entries were analyzed by categorizing responses as having a positive, neutral, or negative tone, and then changes in students' attitudes from the beginning of the intervention to the end were identified.

To determine the impact the inquiry lessons had on me as the teacher I recorded daily entries in the Teacher Reflective Journal Entries. During each session I observed the classes looking for cues that indicated students' level of engagement in the lesson and understanding of the concepts being taught. Cues that indicated students were disengaged from the lesson included off-topic discussion with peers, head down on their table, day dreaming, doodling in notebook, and other general off-task behaviors. Students' understanding was observed through questioning and formative assessments of

the activities from the lessons. At the end of each day I made note of positive and negative behaviors that stood out during the day's lessons. The entries were analyzed for trends in teacher observations and reflections on each phase of the lesson.

Additional information on my teaching was gathered using the Colleague Observation Rubric (Appendix G). A colleague observed lessons being taught at three times during the intervention period. Observations were conducted at the beginning, midway through, and at the conclusion of the intervention period. At the end of the observed period, the colleague completed the Colleague Observation Rubric. The rubric was used to assess students' engagement in the lesson, their apparent understanding of the content covered, and the effectiveness of the teacher's role in the lesson. Data from the rubric was used to identify trends. Themes from Teacher Reflective Journal Entries and the Colleague Observation Rubric were compared and used to assess teaching practices. The focus questions and data sources are summarized in the Data Triangulation Matrix (Table 1).

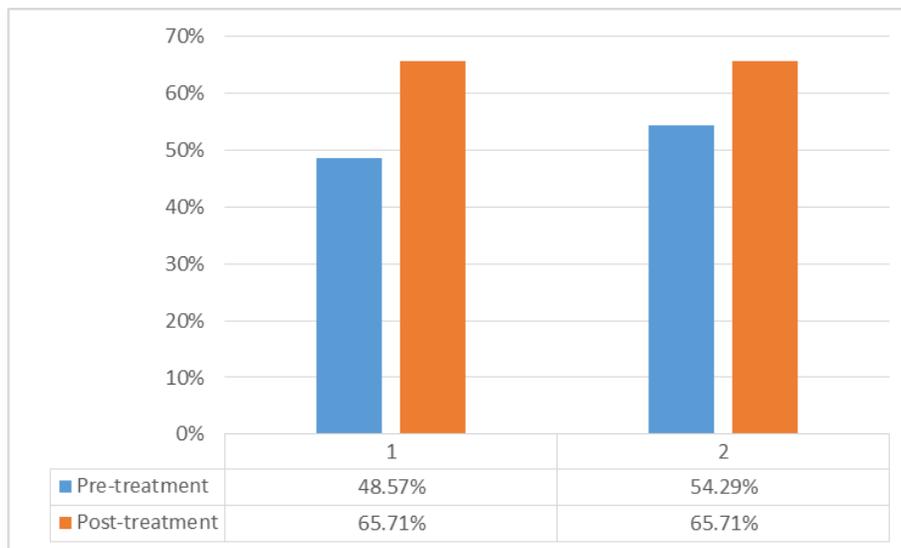
Table 1  
*Data Triangulation Matrix*

Research Question	Data Source 1	Data Source 2	Data Source 3
How does the 5E Learning Cycle impact student achievement?	Structure of Matter Pre-/Post-intervention Test	Chemical Reactions Pre-/Post-intervention Test	
What impact does the 5E Learning Cycle have on student engagement?	Student Interest Interviews	Student Reflective Journal Entries	Pre- and Post-Intervention Survey

What impact does the 5E Learning Cycle have on teaching practices?	5E Learning Cycle Lesson Plans	Teacher Reflective Journal Entries	Colleague Observation Rubric
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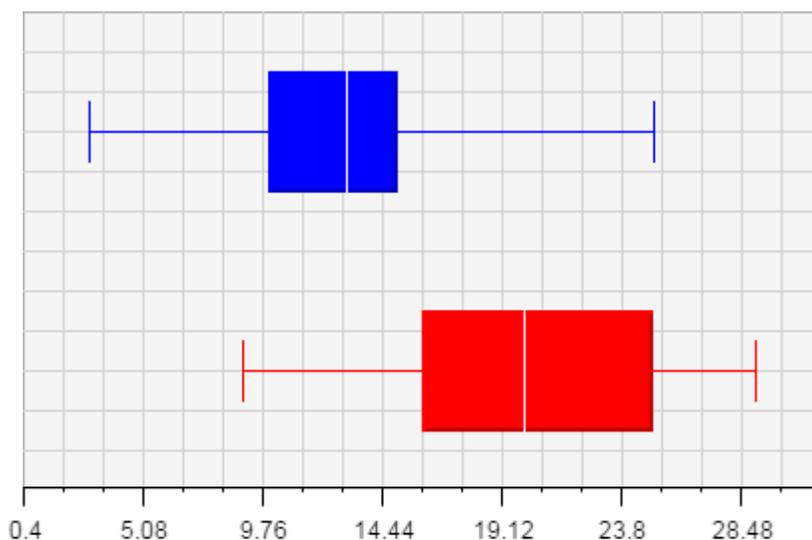
### DATA AND ANALYSIS

The results of the Student Attitude Survey and Student Interviews indicated a positive change in students' attitude towards science. A comparison of pre-intervention and post-intervention response to the statements "I enjoy science" and "I find the concepts taught in science classes to be interesting" showed an increase in positive responses (Figure 1). One student stated, "Most of the stuff we do in here I have an interest in" and another student said, "Science can be fun and I understand things better when we do hands on activities."



*Figure 1.* "I enjoy science" (1) and "I find the concepts taught in science classes interesting" (2) pre-intervention and post-intervention responses, (N=35).

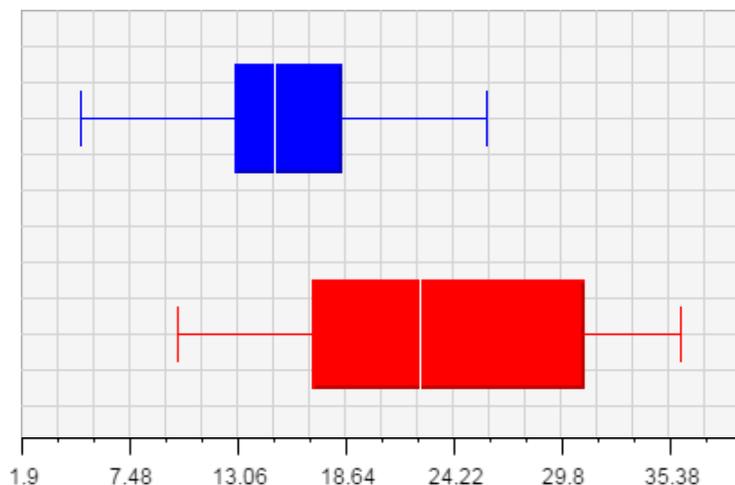
Pre-test scores on the Structure of Matter Test showed a mean score of 13.27 correct responses out of a possible 30 with a median score of 13, a range of 22, and a standard deviation of 5.15 ( $N=36$ ). The post test results showed a mean score of 23.79, a median score of 22.5, a range of 26, a standard deviation of 8.01, and a normalized-gain of 0.39. A boxplot of the pre-test and post-test scores reveals three outliers in the pre-test scores and a positive shift in the mean score from pre-test to post-test (Figure 2). The shift in scores was significant enough that a two-tailed t-test for dependent means was done. The results of the t-test showed a t-value of 7.503 and a p-value of less than 0.00001. At a significance level of 0.05 we reject the null hypothesis of no difference in pre-test to post-test scores.



*Figure 2.* Structure of matter pre-test to post-test boxplot, ( $N=36$ ).

At the mid-point of the intervention period students began the Chemical Reaction Unit. Prior to the beginning the lessons students had a mean score of 15.45 correct responses out of a possible 40 on the Chemical Reaction Test. The median score for the

pre-test was 15, a range of 21, a standard deviation of 4.13 ( $N=34$ ). Two outliers were identified in the pre-test scores. At the conclusion of the Chemical Reactions Unit students had a mean score of 23.75, a median score of 22.5, a range of 26, a standard deviation of 8.01, and a normalized-gain of 0.34. A box-plot of pre-test and post-test scores showed enough variance in the two data sets that a t-test was then done to test for significant gains(Figure 3). A two tailed t-test for dependent means revealed a t-value of 10.84 and a p-value of less 0.00001. At a significance level of 0.05 the null hypothesis of no difference in pre-test to post-test scores is rejected.



*Figure 3.* Chemical reactions pre-test to post-test scores, ( $N=34$ ).

Each of the three sampled sections of eighth grade physical science showed improvement from pre-test to post-test in both units, but two sections showed a greater increase in their understanding of the content (Table 2). Section 1 and Section 3 each had normalized-gains above the normalized-gain for the entire sample population for

both units while the normalized-gain for Section 2 fell below the average gain. Section 2 also had the least change in their mean scores for both units with an increase of 4.9 correct responses on the Structure of Matter Test and an increase of 6.62 correct responses on the Chemical Reactions Test.

Table 2  
*Individual Sections Comparison*

		Pre-Test		Post-Test		
		Mean	Median	Mean	Median	Normalized-gain
Section 1 <i>n</i> =11	Structure of Matter	15.2	15	21.6	23.5	0.43
	Chemical Reactions	17.5	18.5	23.6	27.5	0.39
Section 2 <i>n</i> =14	Structure of Matter	13.9	12.5	18.9	19.5	0.31
	Chemical Reactions	15.07	15	21.69	21	0.27
Section 3 <i>n</i> =14	Structure of Matter	11.1	12	19.1	18	0.42
	Chemical Reactions	14	14	23.82	23	0.38

Note:  $N = 39$

A review of students' journal entries revealed a shift in students' views of their own level of engagement (Table 3). Early in the intervention period one student wrote, "I wasn't that engaged because I didn't really know very much about what we were talking about." In her final journal entry on the final day of intervention period that same student wrote, "Today was really engaging. I really understood the questions on the test." The shift in student engagement was also noted in feedback from the lesson observations. A special education teacher periodically observed lessons throughout the intervention and provided written feedback at three points in the intervention period. The early feedback

stated “students seem engaged for the most part with the exception of a few students.” In the feedback from the middle observations it was noted that “at times during the lesson it appeared that everyone was involved and engaged (hands-on activity), but at other times students drifted in and out.” Feedback from the final observation said, “Students appear much more comfortable with the flow of the lesson than they did on the first day and are more open to being active participants in the lesson.”

Table 3  
*Student Journal Entries-Engagement Responses*

	Beginning	Middle	End
Very Engaged	10	14	19
Neutral	9	16	10
Disengaged	18	7	11

Note: (N=37)

### INTERPRETATION AND CONCLUSION

Students achieved significant gains in their content knowledge for the Structure of Matter Unit and Chemical Reactions Unit while receiving instruction using the 5E Learning Cycle model. While I did not have a comparison group to measure the growth in the 5E Learning Cycle lessons to, based on my prior experiences with these students, I believe the level of understanding achieved in these units was greater than in previous units where more traditional instructional methods were used. Even though many students reported not enjoying the process of going from *a feeling of unknowing*, to *sort of understanding*, and eventually *a feeling of understanding*, they were able to connect their experiences in this process to the content of the lessons. I believe this is true based on my evaluation of the classroom climate and on students’ feedback about this process.

When asked about this shift one student said, “I like having to work through things and figuring it out on my own.” Another student said, “I like starting out with something I know nothing about and by the end knowing tons.” These comments supported the feelings I had about the climate in the classroom as students pushed through their frustration working towards feeling confident with the content.

Allowing students the opportunity to experience a certain level of frustration and uncertainty helped to keep students engaged for longer periods of time. As students became more familiar with the stages of the 5E Learning Cycle their tendency to shut down when they reached a point of frustration lessened. During one observation period a colleague noted, “At the beginning of the session not all students were engaged, some students were engaged in their own conversation and others had their heads down on their desks. As the lesson moved forward everyone in the room became involved and appeared interested in what was going to happen next.” By the end of the intervention period they began to expect that they would reach a point of unknowing and had become comfortable with that feeling as they built their own understanding based on what they were experiencing, which led to many students developing a broader sense of curiosity about the world around them. Towards the end of the intervention period I made a note in a journal entry that said, “Today’s had a good flow. I felt more confident and comfortable with how the lesson progressed. It also felt like the students were eager for the things to move forward so they could piece the concepts together.”

The 5E Learning Cycle model was an effective method for science instruction for this group as a whole. There were several individuals who did not ever reach of a level

of comfort with this approach and would have preferred to have received instruction of the content more directly. One student who felt this way stated, “I do not like not knowing something and I really do not like not being told the answer.” These students enjoyed many aspects of the lessons such as the topics covered and the hands-on activities, but struggled with making the connections between the experiences in the lessons to the explanations of the content. Another student said, “Sometimes I make connections, but usually I don’t think about it and sometimes it is hard because I don’t really have anything to connect to.”

#### VALUE

Prior to this study I felt that I lacked confidence in my ability to teach science. I knew that I capable of building strong relationships with my students and that we valued these relationships, but I did not always feel like my students enjoyed coming to science class. Through this study I have seen a dramatic shift in students’ excitement and eagerness to come into my classroom which has had a significant impact on the ways I view myself as a teacher. I find myself getting excited when I see students get a puzzled look on their face because I know they are going to work through that frustration and that they are going to reach an “ah-ha” moment.

During this study I have also found ways to become a more efficient and effective teacher. Shifting my teaching style to a more student-centered approach and taking on more of a facilitator role in my classroom has allowed to find time to work with students more frequently in a one to one situation and small group setting. Being able to spend more time with students individually and in small groups has allowed to me bring my

instruction to a more individualized level. I have been able to meet students where they are at instead of struggling to meet their individual needs with one general explanation. As I go forward, I would like to focus in on how the 5E Learning Cycle impacts student achieving at different levels in my classroom.

As I have moved through the process involved in this study, I have made a great effort to become more reflective in my teaching practices. The small changes that I have made in how I reflect on what is working and what is not have led to great improvements in my classroom. I have become more open to change and quicker to adapt to meet student needs which has helped me gain confidence that I felt I lacked before I began this study.

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APPENDICES

APPENDIX A

MONTANA STATE UNIVERSITY IRB EXPEMPTION



INSTITUTIONAL REVIEW BOARD  
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**MEMORANDUM**

TO: Kellen Alger and John Graves

FROM: Mark Quinn, Chair *Mark Quinn esj*

DATE: November 25, 2014

RE: "The Impact of the 5E Learning Cycle on Student Achievement and Engagement in a Middle School Science Class" [KA112514-EX]

The above research, described in your submission of November 24, 2014, 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

ALGER PRE-INTERVENTION ATTITUDE SURVEY

## ALGER PRE-INTERVENTION ATTITUDE SURVEY

Please respond to each statement by marking Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree. Use the space below your response to explain if necessary. This is not a graded assignment. I am only interested in what you have to say.

1. "I enjoy science"

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

2. "I find the concepts taught in science to be interesting."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

3. "When I feel confident about something, I also feel more engaged in it."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

4. "I have a sense of curiosity about the world around me."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

5. "I make connections between my own experiences and the concepts taught in science class."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

6. "My personal connections between my experiences and the science concepts help to better understand these concepts."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

7. "I feel more confident in my understanding of the concepts when I am able to connect my personal experiences to the concepts."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

8. "I enjoy the process of going from a feeling of unknowing to sort of understanding, and eventually mastering a concept."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

9. "I find myself more interested in my learning when I am able to work through periods of frustration without being told the answer directly."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

10. "When I am in a period of unknowing, I feel motivated to find a way to move to a period of understanding."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

11. "When I am able to reach a period of understanding through my own experiences I get a feeling of satisfaction."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

12. "When I reach a period of understanding, I feel excited and eager to further explore a concept."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

APPENDIX C

STRUCTURE OF MATTER TEST

## STRUCTURE OF MATTER TEST

Name \_\_\_\_\_

Period \_\_\_\_\_

1. Protons are located in the nucleus of the atom. A proton has
  - a) No charge
  - b) A negative charge
  - c) A positive and a negative charge
  - d) A positive charge
  
2. Neutrons are in the nucleus of the atom. A neutron has
  - a) A positive charge
  - b) No charge
  - c) A negative charge
  - d) Twice as much positive charge as a proton
  
3. An electron is in a region outside the nucleus. An electron
  - a) Is larger than a proton and has no charge
  - b) Has less mass than a proton and has a negative charge
  - c) Is smaller than a proton and has no charge
  - d) Has a positive charge
  
4. A hydrogen atom is made up of one proton and one electron. The proton and electron stay near each other because
  - a) Positive and negative charges repel
  - b) Positive and positive charges repel
  - c) Positive and negative charges attract
  - d) Two negatives make a positive
  
5. The atomic number of an atom is
  - a) The mass of the atom
  - b) The number of protons added to the number of neutrons
  - c) The number of protons
  - d) Negatively charged
  
6. The atoms of the same element can have different isotopes. An isotope of an atom
  - a) Is an atom with a different number of protons
  - b) Is an atom with a different number of neutrons
  - c) Is an atom with a different number of electrons
  - d) Has a different atomic number

7. The atomic mass of an element is
- The average mass of all the isotopes of the element
  - A measure of the density of that element
  - The mass of the most common isotope of that element
  - The number of protons and electrons in the atoms of the element
8. An element and an atom are different but related because
- A particular element is made up of many different types of atoms
  - A molecule is the same as an atom
  - An element is made up of all the same type of atom
  - An element is smaller than an atom
9. The periodic table shows that a carbon atom has six protons. This means that a carbon atom also has
- Six electrons
  - Six neutrons
  - More protons than electrons
  - An atomic mass that equals six
10. The atomic number of nitrogen is 7. The atomic mass is 14.01. This means that
- All nitrogen atoms have exactly 7 neutrons.
  - A small percentage of nitrogen atoms have fewer than 7 neutrons
  - A small percentage of nitrogen atoms have more than 7 neutrons
  - Some nitrogen atoms have fewer than 7 electrons
11. Electrons are in regions around the nucleus called *energy levels*. The first energy level
- Is furthest from the nucleus
  - Is closest to the nucleus
  - Holds the most electrons
  - Needs more than two electrons to fill it up
12. Neon has 10 protons and 10 electrons. The electrons fill the energy levels in Neon like this:
- 2 in the first, 2 in the second, and 6 in the third
  - 4 in the first, 4 in the second, and 2 in the third
  - 2 in the first, 4 in the second, and 4 in the third
  - 2 in the first, and 8 in the second

13. The atoms in a column of the periodic table all have

- a) The same abbreviation
- b) The same number of energy levels
- c) The same number of electrons
- d) The same number of electrons in the outer energy level

14. In the process of covalent bonding, atoms share electrons. This means that

- a) Electrons from *each* atom are attracted to the nucleus of *both* atoms
- b) Protons and neutrons attract
- c) Atoms lose electrons and become ions
- d) Atoms gain electrons and become ions

15. In the process of ionic bonding

- a) Both atoms gain electrons
- b) One atom gains one or more electrons and the other loses the same number
- c) Atoms switch protons
- d) Both atoms lose electrons

16. In the process of ionic bonding, ions come together because

- a) Opposite charges repel
- b) Positive and negative ions attract
- c) Salt is magnetic
- d) Like charges attract each other

17. In a Lewis dot diagram, the electrons shown

- a) Are in the innermost energy level
- b) Always equal the number of protons
- c) Are in the outermost energy level
- d) Always add up to an even number

**True/False and Fill-in-the-blank**

18. *True or false?*

Electrons are found in the nucleus of an atom.

19. *True or false?*

Neutrons and electrons are attracted to one another.

20. The atomic number of an atom is equal to the number of \_\_\_\_\_ in the atom's \_\_\_\_\_.

21. Different atoms of the same element can have a different number of \_\_\_\_\_.

22. The electrons of an atom are located in regions around the nucleus called \_\_\_\_\_.

23. *True or false?*

The first energy level of atom is closest to the nucleus.

24. *True or false?*

In a covalent bond, electrons are shared between two atoms.

25. The electrons on the outermost energy level of an atom are called \_\_\_\_\_ electrons.

26. *True or false?*

In an ionic bond, electrons are shared between two atoms.

27. When an atom loses an electron, it forms a \_\_\_\_\_ ion.

28. When an atom gains an electron, it forms a \_\_\_\_\_ ion.

29. Lewis dot structures are a shorthand way of showing only the valence \_\_\_\_\_ of an atom.

30. *True or false?*

It is possible to have double covalent bond.

APPENDIX D

ALGER CHEMICAL REACTIONS PRE-TEST

## CHEMICAL REACTIONS TEST

Name \_\_\_\_\_ Period \_\_\_\_\_ Score \_\_\_\_\_

**Multiple Choice**

1. A chemical change is different than a physical change because in a chemical change
  - a) Chemicals are used
  - b) Molecules do not physically touch
  - c) A new substance is formed and in a physical change no new substance is formed
  - d) The change can be seen but in a physical change it cannot
  
2. In a chemical reaction
  - a) The atoms of the reactants always stay together to form the products
  - b) The atoms of the reactants un-bond, rearrange, and then re-bond to form the products
  - c) New atoms are formed which combine to make the products
  - d) Some atoms disappear while others multiply to form the products
  
3. In the chemical reaction  $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ , there are reactants on the left of the equation and products on the right. If you count the atoms in the reactants, there are
  - a) 4 carbon atoms, 4 hydrogen atoms, and 2 oxygen atoms
  - b) 1 carbon atom, 4 hydrogen atoms, and 2 oxygen atoms
  - c) 1 carbon atom, 4 hydrogen atoms, and 4 oxygen atoms
  - d) 4 carbon atoms, 4 hydrogen atoms, and 4 oxygen atoms
  
4. In a chemical reaction, mass is conserved. This means that
  - a) The mass of the reactants stays the same during a chemical reaction
  - b) The mass of the products stays the same during a chemical reaction
  - c) The type and number of atoms in the reactants equals the type and number of atoms in the products
  - d) The mass of the products is always twice the mass of the reactants.
  
5. If the reactants on the left side of a chemical equation are  $\text{C}_3\text{H}_8 + 5\text{O}_2$ , the products in a balanced equation could be
  - a)  $4\text{CO}_2 + 3\text{H}_2\text{O}$
  - b)  $3\text{CO}_2 + 4\text{H}_2\text{O}$
  - c)  $2\text{CO}_2 + 3\text{H}_2\text{O}$
  - d)  $3\text{CO} + 4\text{H}_2\text{O}$

6. If more reactants are used in a chemical reaction, more products will be produced. This is because

- a) More reactants cause the reaction to heat up
- b) More reactants take up the same volume
- c) More reactants have more atoms to react to form more products
- d) Too many products can slow down the reaction

7. In a chemical reaction, Substance A reacts with Substance B and forms a new substance AB. The chemical equation for this reaction is  $A + B = AB$  where A and B are the reactants and AB is the product. If you add more and more of only Substance A, there will be

- a) Less and less of product AB
- b) More and more of product AB with no limit to the amount of AB produced
- c) No change in the amount of AB produced
- d) More and more of product AB but limited by the amount of B

8. One clue of a chemical change is the formation of a precipitate. A precipitate is formed when

- a) Two liquids react and a gas is produced
- b) A solid dissolves in a liquid
- c) One liquid dissolves in another
- d) Two liquids react and a solid is formed

9. In a chemical reaction, if the reactants are heated, the reaction usually happens

- a) Faster
- b) Slower
- c) At the same rate
- d) In a smaller volume

10. Some chemical reactions require a substance called a catalyst. The main purpose of a catalyst is

- a) To warm up the reaction
- b) To speed up the reaction
- c) To create more reactants
- d) To stop the reaction

11. One characteristic property of a substance is the way it reacts chemically with another substance. Another way of saying this is that substances react chemically in characteristic ways. This means that

- a) A substance will always react the same way when tested with the same chemical
- b) A substance will always react differently when tested with the same chemical
- c) A substance will react in the same way when tested with two different substances
- d) The characteristic properties of a substance are always changing

12. If two substances react and the temperature of the mixture increases, the reaction is

- a) Endothermic
- b) Not one that produces anything new
- c) One that needs a catalyst
- d) Exothermic

13. If two substances react and the temperature of the mixture decreases, the reaction is

- a) Endothermic
- b) Never going to happen unless it is heated
- c) Exothermic
- d) one that causes atoms to be destroyed

14. If a reaction is exothermic,

- a) It takes more energy to break the bonds of the reactants than is released when the bonds in the products are formed
- b) More energy is released when the bonds in the products are formed than is used to break the bonds in the reactants
- c) The same amount of energy is used to break the bonds of the reactants as is released when the bonds in the products are formed
- d) The temperature goes down

15. If a reaction is endothermic,

- a) The temperature increases
- b) It takes more energy to break the bonds of the reactants than is released when the bonds in the products are formed
- c) More energy is released when the bonds in the products are formed than is used to break the bonds in the reactants
- d) The same amount of energy is used to break the bonds of the reactants as is released when the bonds in the products are formed

16. In any sample of water, there are always some water molecules which have become ions. These ions are produced by transferring a \_\_\_\_\_ from one water molecule to another.

- a) Neutron
- b) Electron
- c) Proton
- d) Molecule

17. In any sample of water, there are always some water molecules which have become ions. These ions are

- a)  $\text{H}_2\text{O}^+$  and  $\text{OH}^-$
- b)  $\text{HO}^+$  and  $\text{H}_2\text{O}^-$
- c)  $\text{H}_3\text{O}^+$  and  $\text{OH}^-$
- d)  $\text{HO}^+$  and  $\text{HO}^-$

18. When the pH of water is neutral, there is

- a) a higher concentration of  $\text{OH}^-$  than  $\text{H}_3\text{O}^+$
- b) an equal concentration of  $\text{OH}^-$  and  $\text{H}_3\text{O}^+$
- c) a higher concentration of  $\text{H}_3\text{O}^+$  than  $\text{OH}^-$
- d) no  $\text{OH}^-$  ions and no  $\text{H}_3\text{O}^+$  ions

19. When the pH of a solution becomes more acidic, the number on the pH scale

- a) Decreases
- b) Increases
- c) Stays the same
- d) Doubles

20. When the pH of a solution becomes more basic, the number on the pH scale

- a) Decreases
- b) Increases
- c) Stays the same
- d) Triples

21. When the pH of a solution becomes more acidic, the concentration of  $\text{H}_3\text{O}^+$  ions

- a) Decreases
- b) Increases
- c) Stays the same
- d) Doubles

22. When the pH of a solution becomes more basic, the concentration of  $\text{H}_3\text{O}^+$  ions

- a) Decreases
- b) Increases
- c) Stays the same
- d) Triples

23. If a solution is acidic, it can be neutralized by adding

- a) A stronger acid
- b) Heat
- c) A base
- d) A weaker acid

24. If a solution is basic, it can be neutralized by adding

- a) An acid
- b) A weaker base
- c) More base
- d) A colder base

25. When carbon dioxide (CO<sub>2</sub>) gas reacts with water

- a) A strong base is produced
- b) The carbon and oxygen atoms disappear
- c) An acid is produced
- d) More carbon and oxygen atoms are produced

#### **True/False and Fill-in-the-blank**

26. *True or false?*

Dissolving salt is a chemical reaction.

27. In a chemical reaction, only the atoms present in the \_\_\_\_\_ can end up in the products.

28. In a chemical reaction, no new atoms are created, and no atoms are \_\_\_\_\_.

29. Increasing the amount of reactants may increase the amount of \_\_\_\_\_.

30. What is the term for a solid that is formed by mixing together two solutions?

31. *True or false?*

A catalyst slows down the rate of reaction to make better products.

32. *True or false?*

Products in a chemical reaction are usually formed more quickly at higher temperatures.

33. A catalyst does not actually become part of the \_\_\_\_\_ of a chemical reaction.

34. *True or false?*

Because substances react chemically in characteristic ways, you can use the way they react to identify an unknown.

35. It takes \_\_\_\_\_ to break bonds, and \_\_\_\_\_ is released when bonds are formed.

36. If it takes more energy to break the bonds of the reactants than is released when the bonds of the products are formed, the reaction is \_\_\_\_\_.

37. If a reaction is \_\_\_\_\_, more energy is released when the bonds of the products are formed than it takes to break the bonds of the reactants.

38. *True or false?*

Two molecules are more likely to react if they have more energy when they collide.

39. The \_\_\_\_\_ and \_\_\_\_\_ of atoms are the same on both sides of a chemical equation.

40. *True or false?*

In a combustion reaction, matter is destroyed.

APPENDIX E

ALGER STUDENT INTEREST INTERVIEWS

## ALGER STUDENT INTEREST INTERVIEW

1. How confident do you feel in your understanding of the science content we cover in class?
2. What about science do you find most engaging?
3. Why do you think that is engaging for you?
4. What about science do you find most challenging?
5. Why do you think it is challenging for you?
6. Do you find science more engaging on some days compared to others?
7. Why do you think those days are more engaging than other days?
8. When we start a new topic in class do you feel like you can relate the material to an experience you have had in your life or something else you already knew about?
9. Do you think making these connections help you better understand new material?
10. Can you give me an example of this?
11. Do you prefer to work independently, in a small group, or as a whole class?
12. What about your choice is appealing to you?
13. Is there anything else you would like me to know?

APPENDIX F

ALGER STUDENT REFLECTIVE JOURNALS

Structure of Matter Pre-Test
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Day 1
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

Protons, Neutron, Electrons
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Day 2
-------

How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

The Periodic Table	Day 3
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

The Periodic Table and Energy Level Models	Day 4
--	-------

How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

Energy Levels, Electrons, and Covalent Bonding	Day 5
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

Energy Levels, Electrons, and Ionic Bonding	Day 6
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

Represent Bonding with Lewis Dot Diagrams	Day 7
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

Structure of Matter Post-Test	Day 8
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

Chemical Reactions Pre-Test
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Day 9
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

What is a Chemical Reaction?
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Day 10
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

Controlling the Amount of Products in a Chemical Reaction	Day 11
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

Forming a Precipitate	Day 12
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

pH and Color Change
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Day 17
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

Neutralizing Acids and Bases
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Day 18
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

Carbon Dioxide can Make a Solution Acidic
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Day 19
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

Chemical Reactions Post-Test
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Day 20
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How Engaging was Today?

One-minute Summary of Today's Content:

Muddiest Point:

APPENDIX G

ALGER COLLEAGUE OBSERVATION RUBRIC

Name \_\_\_\_\_

Date \_\_\_\_\_

Lesson Observed \_\_\_\_\_

Please respond to each of the following statements based on your observations during this instructional session.

Students were actively engaged in the lesson				
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Comments:				

Students' understanding of the content appeared to increasing				
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Comments:				

Instruction was student centered.				
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Comments:				

Teacher involvement, interventions, and guidance was appropriate.				
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Comments:				

Additional Feedback: