Improving Chemistry Instruction via the 5-E Learning Model: Inventing, Adapting and Incorporating the First “E”

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Improving chemistry Instruction via the 5-E Learning Model: Inventing, adapting, and incorporating the first “E”

Cecilia Christopher
Fall 2013
Advisor: Dr. Peter Veronesi
IMPROVING CHEMISTRY INSTRUCTION VIA THE 5-E LEARNING MODEL:
INVENTING, ADAPTING AND INCORPORATING THE FIRST “E”

by
Cecilia Christopher

Chapter One: Introduction

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**Chapter One: Introduction**
In the past 20 years many aspects of society have changed. Some argue these changes have been good and others think back fondly on “the good old days.” Adults think back on their teenage years with fondness or horror. In general, school wasn’t a “fun” place for students because they sat in classrooms listening to their teachers drone on about something that would never impact them. Most adults remember the fun they had outside of the classroom. A few might remember that one teacher that made a difference. It isn’t the teacher who lectured the most; it is usually the one who CARED the most about their students. Care could be shown by talking with students, by making the material relevant, by being “tough” but understanding and there to help students. These qualities in teachers transcend time. Students today still like teachers who care about them as a person and ask about their lives, not just homework.

One development that has been consistent across these 20 years in science education research is the fact that lectures are an ineffective way to teach students science concepts. Although the idea that lectures are ineffective has been prevalent in the research, lecture remains the main method of instruction in high school and undergraduate institutions across the US. What has been found is that inquiry instruction and engaging students in content can be effective teaching methods when done correctly. Students learn more when they are interested, curious and motivated to learn.

One of the most critical aspects of a lesson is the first five minutes. Engagement can come in many forms and seen in students in even more forms. The 5E learning cycle is based on constructivist theories of learning that provide support and guidance to increase student inquiry (Wilson et. al., 2010, p. 280). The 5E cycle is based on historical research by people like John Dewey, Heiss, Obourn, Hoffman, Hebart, Atkin and Karplus (Bybee et al., 2006). These authors all developed a type of learning cycle that has been integrated into or is the basis of the 5E cycle in the current model. In fact, Karplus was the “founding father” of the 5E cycle which he rooted in constructivist theories (Liu, Peng, Wu, & Lin, 2009). There is a staircase of guided inquiry that allows students to follow guidelines to generate their own knowledge (Liu, Peng, Wu, & Lin, 2009). Studies have shown that student must be involved in the learning process because learning is an active process and requires students to process the information (Bybee et al., 2006). Engaging students in content increases their ability to learn as well as drawing out
their misconceptions (Bybee et al., 2006). The first phase of the 5E model is “engage”. Students engage in the topic, get motivated to learn, and excited about what they are going to learn, usually by using some type of prior knowledge. Engaging students can be done with almost anything that will focus students’ attention on a particular topic helping them to create links between prior knowledge and new facts. The “hook” keeps students excited and motivated to learn for the remainder of class. Students might volunteer to participate in demonstration, ask questions related to the content, shift in their seats, actively participate in classroom discussions, and be excited to come to class or work harder than usual to complete an assessment or task in class (Milne & Otieno, 2007). Engaging students can require anything from a simple question to a complex open ended task. Developing these engaging pieces is essential for student learning as students are constantly bombarded by media pictures, videos and statements. Students need something to engage them in the classroom so they aren’t worrying what their friend is tweeting down the hall, but what is going on in their classroom or how they can figure out a problem given to them. Current research is directed towards inventing, adapting, and incorporating engage pieces into a high school chemistry classroom.

Chapter Two: Review of Literature

Reasons for change: Teacher use of Inquiry

Despite the importance of inquiry and engagement that has been shown to increase student achievement and understanding, most teachers find a reason to avoid teaching using inquiry methods. The methods like inquiry, project based learning, context based learning and so many others have been studied for over 20 years, but are still considered alternative methods. In addition to the US, in places like Thailand where education research and countrywide reforms were instituted to increase student engagement, most places still teach using lecture style and only implement inquiry for lab (Chairam, Somsook, & Coll, 2009). Chairam, Somsook, and Coll found a study where 364 teachers were interviewed, less than 2% used inquiry in their classrooms and another study using a survey found that only 12% of the teachers felt they had implemented national science standards with only 4% of those 12% confident that they could explain the standards to colleagues (Wilson, 2010). Some teachers have tried
inquiry only to realize they do not like giving up the power in their classrooms or found that it went poorly. Others avoid inquiry at all costs because it is new and from what they know, and sounds like it would take a lot of time to plan and time away from preparing students for standardized tests (Breslyn & McGinnis). Even still others cite the lack of materials and absent professional development on the topic of inquiry as reasons why it is not used more (Breslyn & McGinnis). Barriers from implementing inquiry also range from political, cultural, and technological dilemmas, to cultural myths, pedagogical constraints, as well as the belief that standardized tests constrain curriculum leaving no time for inquiry (Wilson et al., 2010, p. 277). King (2012) encourages readers to participate in professional development that offers suggestions and structures as to how to implement the alternative approaches. At these professional development sessions, King suggests that offering samples is not an effective way to help teachers learn the new methods. Teachers must work with the material within their content and place it in a framework of inquiry themselves so they understand how it works and how it can be effective.

One piece of inquiry requires students to ask their own questions and drive their learning. Many teachers have a difficult time in a classroom where they are not the central figure. These teachers expect to arrive at work and ask all of the questions to their students and have prompt correct answers within their classroom. When a student breaks the routine cycle by asking an inquiry question, the teacher most likely skips over the question or says we’ll talk about that later to maintain classroom control (Rop, 2003). Inflexibility can take away from deeper understanding for students when they have thought provoking questions, but the teacher refuses to answer them.

Breslyn and McGinnis (2012) state that none of the reasons given for avoiding inquiry are adequate reasons for the scarce use of inquiry. These authors, analyzing forty-eight National Board Certified Science teachers, analyzed the style of inquiry implemented in the classroom. It was an in depth analysis that found different disciplines in the sciences implement inquiry very differently. For example, chemistry teachers have a central objective for students to learn content knowledge through inquiry experiences while biology teachers had the central goal of students learning to investigate a problem. With this being said, it was the discipline and expectations within the teachers’ particular field
of science that lend to inquiry usage type. The work of Breslyn and McGinnis (2012) also helps support that inquiry can be used in any classroom and can be a best practice if NBCST are using inquiry.

**Reasons for change: Increasing student interest in science**

Social constructivism points to the idea that knowledge can’t be transferred to others, but students must construct their knowledge. Teachers must work to create situations so that students can construct their own knowledge and work with others to socially construct their knowledge together. Past experiences also play into the knowledge that can be constructed by individuals and groups of students. Knowledge must be constructed through the use of language and communication between learners according to Vygotsky (Chairam, Somsook, & Coll, 2009).

**Strategies for improving Science Instruction**

Teachers have been trained for years on how to correctly teach students, assess, engage, and motivate students in their preparation programs. Lesson plans and objectives are central to these types of programs. Some preparation programs provide different types of training, but since most teachers in the field still teach using lecture, students in these programs do not learn to implement any of the “alternative” methods because they aren’t in action. These new teachers are the catalyst of change and must be for the country. Students can learn content and be excited about the material in a science classroom in so many different ways that are different than lecture. One way to improve science instruction can be to determine and address misconceptions with students directly (Ozmen, 2007), use inquiry methods based on Piaget and Vygotsky, motivate students, and engage them in the material through a variety of mediums.

**Addressing Misconceptions**

Research from Aydeniz and Kotowski (2012) looks at different misconceptions in chemistry that most people obtain from their life experiences. Many students and adults hold on to these misconceptions
regardless of what they are taught in a class. Aydeniz and Kotowski (2012) conducted a study with 41 high school students in a general and honor’s chemistry with the same teacher and 46 middle school students also participating in the study who had the same teacher. The teachers used direct instruction as their main method of teaching. The teachers required students to write down notes, look at Power Points and complete homework on worksheets that had practice problems. Neither teacher used a pre-assessment to gauge where students began their knowledge and was a research flaw as a pre-assessment could have increased the validity of the study and decreased the number of questions associated with this research. After a semester of instruction, students were given the Particulate Nature of Matter Assessment (PARNOMA) misconception test directly related to chemistry. It was immediately analyzed and found that most students had major misconceptions related to one or all of the following topics. Students didn’t understand the influence of phase changes on chemical compositions of matter with many thinking phase changes resulted in a chemical change (Aydeniz & Kotowski, 2012, p. 61). Students also believed that matter could be lost and were confused on how the law of conservation of matter applied to phase changes (Aydeniz & Kotowski, 2012, p. 61). The last major misconception was how atoms behaved during phases changes and how they do or do not change size (Aydeniz & Kotowski, 2012, p. 61).

Aydeniz and Kotowski (2012) questioned why are there still all of these misconceptions when we have highly qualified teachers teaching students and research that shows how to positively affect change in understanding? Aydeniz and Kotowski (2012) imply that teachers are missing the pedagogical content knowledge needed to successfully teach about the particulate nature of matter (p. 63). What Aydeniz and Kotowski (2012) are describing is that the highly qualified teachers don’t know how to use analogies, illustrations, explanations, demonstrations and examples to represent the subject they are teaching in a way that students can understand and internalize the ideas (p. 63-64). Aydeniz and Kotowski (2012) imply that teachers must have student possible misconceptions in their minds when planning units and lessons related to the particle nature of matter. Without explicitly addressing the misconceptions and helping students understand particles, major misconceptions will be present. Teachers need to facilitate
how students learn about chemistry by using instructional strategies that help students understand chemical processes on a macroscopic, but more importantly, a microscopic level (Aydeniz & Kotowski, 2012, p. 64). What students see can create a misconception which is why the microscopic level must be addressed related to matter, phase change, physical changes, and how intermolecular forces are weakened, not bonds, when a sample changes from a liquid to a gas. Aydeniz and Kotowski (2012) suggest that to combat the misconceptions, programs on computers can be used to show students how particles behave. Aydeniz and Kotowski (2012) caution that these programs must be used correctly in conjunction with teacher direction to coordinate proper use and understanding of the model. It is also suggested that teachers can use metaconceptual questions to help address misconceptions. These types of questions help students reflect on their learning and enhance their thought processes while learning.

Research by Ozmen looks at misconceptions that high school students have related to chemical equilibrium. A 20 question multiple choice test was created to use as both a pre-assessment and post assessment to determine student changes in misunderstandings. The control group received traditional methods of teaching and the experimental group, in addition to traditional methods, was given conceptual change texts that specifically addressed alternative conceptions related to equilibrium. The major aim of the study was to determine what the effect on misconceptions would be based on conceptual change texts used in instruction based on the results from the pre and post tests (Ozmen, 2007, p. 415). Ozmen found that the conceptual change texts had significantly more impact in changing students alternative conceptions compared to traditional teaching styles. The traditional style teaching, or control group, also had some decrease in misconception, but not significant compared to the experimental groups change in understanding. It should also be noted that both groups held almost the same alternative conceptions before instruction on this topic.

Ozmen found that some of the misconceptions were not able to go away completely in the case of the experimental group. It is suggested that some misconceptions are difficult to change because they have been taught to students previously and their misconceptions are deeply rooted in what they think is correct science (Ozmen, 2007, p. 419). Overall Ozmen was pleased that the conceptual change texts were
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able to help change students alternative conceptions for scientifically accepted ones as this is what he had hoped for (Ozmen, 2007, p. 421). So much research has shown that traditional methods of teaching are not adequate in helping students understand information, but that students are sometimes able to regurgitate the information on an exam and then forget their knowledge. Other studies have shown that many teachers do not know what the alternative conceptions are of students and therefore cannot address the concerns while teaching. Ozmen suggests that more research must be done regarding misconceptions to determine what else can be done because just the conceptual change in texts was not enough to remedy all of the misconceptions that were present for students. Other studies, some discussed here, have had some success with decreasing student misconceptions. Ozmen suggests that other studies regarding altering misconceptions should be combined with the current one by Ozmen to have conceptual change texts coupled with other tools such as models, analogies, demonstrations and computer animations to help remedy the alternative conceptions that students have associated with equilibrium (Ozmen, 2007).

Numerous studies have been done in the chemistry field related to misconceptions surrounding chemical bonding. Unal, Calik, Ayas and Coll analyzed many studies addressing the needs, aims, methods of exploring students’ conceptions, general knowledge claims and students’ alternative conceptions in articles related to chemical bonding (2006). The analysis looks at level of education, understanding of covalent, ionic, and metallic bonding as well as understanding of intermolecular forces, energies and theories of bonding, how analogies and anthropomorphic language as well as student generated mental models can enhance students’ conceptual understanding. Unal et al. (2006) point out that many chemistry concepts, specifically bonding, are abstract and difficult to visualize making alternative conceptions a real area of interest for researchers. Numerous articles were reviewed and analyzed and were then broken down into individual components.

What Unal et al. found was that about half of the studies look only at high school level students, what topics students held alternative conceptions, how teachers are not addressing the instructional needs of their students and how teachers can change methods to determine alternative conceptions and address those conceptions. The other set of studies were cross-age studies that ranged from high school to college
with aims to see where gaps in knowledge were created. Overall it was found that many college
professors blame learning gaps on previous teachers and that many students hold on to misconceptions
through their college years as the misconceptions aren’t addressed. The methods of exploring student
misconceptions varied from interviews, which provide deep thought and a unique understanding of
student misconceptions, to paper and pencil tests which can prove positive due to the quick administration
of the test and the alternative conceptions that can be determined by using the test. Two tiered tests can
help researchers and teachers to more fully understand the REASONS behind an alternative conception
with a simple statement followed by an explanation. Unal et al. suggest this as one of the more highly
developed and beneficial research methods. Another method that studies that were analyzed used was to
have students draw their understandings of chemical bonding with pictures.

What was found through the analysis of chemical bonding research was the nature of teaching
high school through college doesn’t help students understand difficult concepts like chemical bonding due
to the highly conceptual nature of the topic (Unal, Calik, Ayas, Coll, 2006, p.155). There have been
studies specific to covalent, ionic and metallic bonding that have found both students and teachers
oversimplify concepts which can lead to alternative conceptions. Through modeling these students have
started to think that ionic compounds are molecules. Many undergrad and graduate chemistry students
believe that in metallic bonding, covalent bonds are present. Another area looked at was students’
understandings of intermolecular forces. Unal et al. found in their analysis that many students confuse
bonding (referred to as intra-molecular forces) with intermolecular forces (2006). One reason that is
given for a possible source of this misconception is that hydrogen bonds are overemphasized as strong
intermolecular force, but the name “bond” confuses many students.

Through analysis, Unal, Calik, Ayas, and Coll found that there is a huge misunderstanding about
polarity of bonds and molecules and how electronegativity versus the number of valence electrons is
applied to the problem. In looking at anthropomorphic language use and analogies, the studies found that
when students are given a new and difficult concept, they will try to relate it to what they know and what
they have experienced in the past (Unal, Calik, Ayas, Coll, 2006, p.15). With regard to how students
create mental models, chemistry students appear to hold onto and make simple models. Simple models explain phenomenon and don’t challenge content. It was found that even with doctoral candidates held onto simple models because they helped explain a given phenomenon they had learned years prior. The last major finding or category from Unal et al, enhancing students’ conceptual understanding, suggests using mental modeling and analogies to explicitly teach student about modeling, the limits of models and analogies and how they can be beneficial. The more ways that students are asked to engage with the content, the better understanding they will develop.

Unal et al. suggests that students aren’t taught about the different levels of chemistry (symbolic, macroscopic and microscopic worlds) and therefore can’t understand the relationships that are vital to the understanding of chemistry. Teachers must stress the link between these different levels to help students improve their mental modeling. Unal et al.’s review finds that a key component to help remedy misconceptions is for the teacher to be aware of misconceptions through a diagnostic test. After being made aware of the misconceptions, the teacher can’t simply state they are incorrect as students do not internalize words. Students must be given an experience to help them see the “true” concept versus the alternative conception according to constructivist theories. Much of the research also says that analogies can serve to benefit chemistry students and decreasing their alternative conceptions if used in the correct fashion. Teachers should suggest the limits of the analogy, according to Unal et al., so that students don’t believe that the analogy directly explain all areas of the chemical bonding concept. The review also finds that chemistry teachers should use modeling of concepts, but not models that are extremely complex which can cause more confusion and frustrations with learning a new concept. Like analogies, teachers should explain the limitations of the mental models and given students a frame of reference to help them learn with the model. The last finding indicates that teachers should use chemistry content specific examples when working with students to help them understand chemical bonding (Unal, Calik, Ayas, Coll, 2006, p. 167).

**Motivation: How teacher actions can positively or negatively affect Motivation**
Motivation can come to students in many forms. A student may be inspired to learn from their teacher, internally be motivated to achieve success or know that a certain class will help them in their future career. Lang, Wong, and Fraser conducted a study in Singapore where educational reforms started in 1984 specifically for gifted and talented students (2005). The program is for students age 10-16 and is devised to increase the rigor within the classroom and getting students ready for challenges they will face in the future (Lang, Wong, & Fraser, 2005, p. 18). Teacher’s beliefs and perceptions have been analyzed in the past to see if they can influence how students enjoy a particular topic. Lang, Wong, and Fraser (2006) seek to look specifically at a chemistry classrooms and how the teachers nurture or do not nurture students within the gifted and talented program. Research has been done suggesting that assessing the learning environment can give information related to the classroom environment. Classroom environment can have a large affect on how much students learn about the content and their enjoyment of the topic as well as teachers perceptions of their own classrooms (Lang, Wong, & Fraser, 2005, p. 18). A model has been adapted to look at the interpersonal relationship between the teacher and students for the study by Lang, Wong and Fraser (2005). Student motivation and interactions with other students has been analyzed, but this is the first study of its kind to look at the relationship between teacher interactions and gifted students and how those interactions affect the actions and beliefs of students. Studies have been done where the teacher’s positive attitude has a positive effect on students’ attitudes towards the class as well as the opposite. Other studies have shown that directive and authoritative teachers who have a controlled, well structured environment saw the greatest cognitive gains for their students compared to uncertain and aggressive teachers. Numerous other studies from both Japan and Singapore show that girls have a much more favorable perception of their teachers when the teacher had positive leadership with a friendly and helpful behavior (Lang, Wong, & Fraser, 2005, p. 20).

Lang, Wong, and Fraser (2005) found gifted students had a favorable perception of their teacher if the teacher showed leadership qualities, was helpful and friendly and was understanding. If the teacher was demeaning, unsatisfied and strict, more students disliked the teacher (Lang, Wong, & Fraser, 2005, p. 23). Another finding is that the girls in an all girls’ school perceived their young (30-35 years old)
teachers more favorably because they perceive they have increased freedom and more responsibility when they are with these teachers (Lang, Wong, & Fraser, 2005, p. 25). Boys, on the other hand, had more negative perceptions of their all female teachers and stay distant from their female chemistry teachers (Lang, Wong, & Fraser, 2005, p. 25). Since cultural and environmental factors weren’t studied here, no conclusions can be made regarding these findings although it does indicate that the girls may have increased motivation to do well when in female chemistry teachers’ classrooms.

When analyzing student perceptions of teacher behavior, enjoyment of chemistry lessons was positively correlated with leadership, understanding and helping/friendly scales of student perceptions of teachers. Enjoying chemistry was negatively associated with teachers who were uncertain, dissatisfied and strict (Lang, Wong, and Fraser, 2005). One implication, that is essential to any teacher, is that teacher-student interactions can promote enjoyment of chemistry or destroy the love of science. Positive enjoyment is associated with teachers being helping and friendly. In this way, when teachers reflect on their lessons, they shouldn’t just look at learning outcomes, but attitudes, statements and openness to students’ feelings and perceptions. If more teachers were aware of how their small comments, statements, favoritism was affecting students then the educational system could be more effective.

In Rop (2003) five different categories of research were reviewed. The first category, teacher questions in science classrooms, focuses on the idea that most teacher student interactions are through simple fact based questions addressed to the whole class or one student. When a student breaks the routine cycle by asking an inquiry question, the teacher will most likely skip over the question or say we’ll talk about that later to maintain classroom control. The next category is student questions in science classrooms. Research that Rop found, states that most questions are related to procedural information or content for the next test. Questions were rarely because a student was genuinely interested in learning or understanding a topic, but when they were formatted for this reason, it was likely an indicator of the students’ interest, conceptual engagement and change occurring within the student (Rop, 2003, p. 14). It is suggested that teachers who listen to these types of questions help students and themselves because
they are looking to improve their practice and increase understanding, rather than simply teaching to the test.

The third category of research Rop analyzed was related to the motivation for student questions. Some student questions are related to the motivation to learn, others use them as a “think aloud process” that isn’t intended to disrupt class time. Some questions are to gain autonomy in the classroom or may come from self-motivated learners who really want to know the answer to their questions so aren’t afraid to shout out the questions. Some research points to the idea that inquiry and questioning can result in social pressures from peers and the teacher who many times redirects questions to focus on the content to be “covered” that day. The next set of research analyzed is about student perspectives which have rarely been done in high schools because it takes so much time to look at why and what students think. One researcher was able to come to the conclusion that he could change the culture of the classroom by allowing flexibility and the ability of students to ask questions freely to engage in the material (Rop, 2003, p.16). “The need for student perspectives on their questioning behavior” in the classroom has limited research which is why the present study is conducted- to learn about why students question and why they act the way they do in classrooms (Rop, 2003, p.16).

Rop (2003) has two major sets of findings related to the questions: why do students ask spontaneous inquiry questions (SIQ) and what the responses of other students’ are when SIQ’s are asked. The first major finding was that students ask questions for one of two reasons. If a student is bored in class and they are trying to engage, they may ask a question related to the topic, but at a higher level of thinking so they can be intellectually challenged (Rop, 2003, p. 21). All of the motivated students in the study expressed that learning facts for a grade isn’t enough of a reason to be complacent in the classroom. These students want to learn more to be ready for the workforce truly engage and work with the material. Students also felt that the same ideas were repeated multiple times and this was boring. To alleviate the boredom, the students worked to expand their knowledge by asking challenging questions. Reviewing or “drilling” of the same concept is boring and pointless for students who understood the topic the first time. In this way, students who are in this category are often the ones who ask the challenging
questions. Some lower performing students also love to ask questions that appear to be “off task”, but are related “real world” chemistry.

The second reason given for why students ask SIQs is that they want to “fill an intellectual hunger to understand [the] subject matter better” (Rop, 2003, p. 21). One student describes teachers drive for student success on tests that only require completion of homework, memorizing facts and not really understanding of concepts. Most of the students interviewed are looking for more from their classes. The students want lifelong lessons and answers to questions. One student describes his thought process of knowing that he has all of the information to do well on a test, but the question “why does that work” runs through his head related to a concept (Rop, 2003, p. 23). Sometimes a student will share this type of question and other times they are afraid to share. The students express frustration when the answer to quandaries about how chemistry concepts work is just that won’t work (Rop, 2003, p. 23).

Rop’s next major finding in this study is that there is significant pressure from both the teacher and other students to NOT ask SIQ. The teacher is concerned about time or being too complex and may shut down questions on a regular basis. The other students, concerned about grades and doing well, shut down SIQ’s because they want to be sure their teacher has taught them what they need to know before the next test. Students in the study who were highly motivated describe other students rolling their eyes at them and getting looks from other students. These negative reinforcements cause the students to feel no pride, or curiosity related to the subject. To many of the students, school should be a place to ask questions, discover and learn a concept thoroughly so they get frustrated with the idea that they are confined to learning the curriculum (Rop, 2003, p. 27). The students understand that the teacher doesn’t have much choice in curriculum and is preparing them for the future so they understand why their questions are shushed and they aren’t called on, but at the same time wish it was different (Rop, 2003). Teachers subconsciously control their classrooms by the questions they allow and the types of questions that are answer or not answered. Rop supports the idea that inquiry, which requires student questioning, is essential in high school classrooms and that it IS possible to do without content suffering on the part of these highly motivated students.
Rop (2003) suggests that teachers need to find a way to balance the fine line between standardized testing and helping students to become developed individuals learning and wanting to ask questions and go deeper into the content. There is a “time pressure” that comes from trying to cover the national curriculum and little time for class discussions to help students gain a deeper understanding of a particular topic (Rop, 2003, p. 28). Rop states that the only way to solve this problem is to change the rules for success by restructuring the educational system and increasing the incentive for students to learn (Rop, 2003, p. 30). While it would be wonderful to be on the horizon of this change, educators have known about inquiry and engagement for over 20 years and traditional lecture classrooms are still the norm. Change will likely not happen until time, thought and effort are focused on science education and policy makers understand why it is important to have questioning and inquiry in the classroom. Rop suggests that the first way teachers can start to make a change is to look at how classroom time is spent, slow down and allow for students to ask thought provoking questions related to the chemistry topics. Rop issues a challenge that there needs to be a dialogue about the curriculum K-16 to help increase the questioning and inquiry basis of science. The curriculum at a college level could change and pre-service science teachers could engage in necessary authentic science inquiry so they know how it feels, what it’s like and the benefits that come with inquiry. The teachers who have experienced inquiry need to take a front seat to educating other science teachers about the benefits. In addition to teachers needing to slow down, they need support from administration and parents to help them slow down their curriculum so students can ask questions and come to a deeper understanding of real science and will take time. Rop also suggests that more research should be done to look at the social implications for students who ask deeper level questions. The last statement Rop makes summarizes the implications for science educators: “A central role of instruction in high schools should be to teach students to ask better questions and to create an environment where it is socially and academically rewarding to do so” (Rop, 2003, p. 32).

Inquiry Learning

With all of the barriers that appears to exist for implementing inquiry in classrooms, Wilson et al. (2010) look to examine the evidence that exists in research for inquiry based teaching. There have been
numerous studies published about the negative consequences of inquiry based teaching that are based on open inquiry where frustration is overwhelming, or when students generate incorrect ideas. Wilson et al. suggest that there needs to be guidance and scaffolding, and points of direct instruction to avoid frustration with ideas and concepts. Two papers reviewed by Wilson et al. provide support for inquiry learning showing that students who were immersed in inquiry education did better than those not exposed to inquiry education on standardized tests (2010). Another study reviewed found the same results in terms of inquiry: regardless of diversity factors, student outperformed peers who hadn’t been exposed to inquiry education (Wilson et al., 2010, p. 278). Inquiry education provides long term learning benefits to students involved. Even other studies reviewed by Wilson et al. suggest that a combined inquiry and direct instruction approach provides the best learning opportunity for students and another study found that the ability of students to work through a problem who had participated in inquiry that is based on the learning cycles and open inquiry had significant gains in their reasoning abilities (Wilson et al., 2010, p. 279).

Wilson et al. found that the experimental inquiry group had made significantly more gains than the traditional teaching method control group. Regarding gender, there was no difference in gains achieved in the inquiry group versus the commonplace group. Pre-test scored showed no differences between races for both groups. Post-test scores were higher for whites in the commonplace group compared to non-white, while in the inquiry experimental group, this difference wasn’t seen. These findings imply that inquiry can break racial barriers, but sadly, the difference wasn’t statistically significant due to the small number of students, especially non-white students, who were involved in this study. Overall it was found that the inquiry participants made medium normalized gains, while the commonplace control group made low to medium normalized gains. Little difference was found in terms of gender and more research must be done looking at race related to free and reduced lunch and their gains with regard to inquiry. With regard to the interviews, students who participated in the inquiry segment had higher scores related to stating claims with evidence and reasoning than those students who were in the commonplace grouping.
Wilson et al. were thrilled with the results because they continue to support the idea that inquiry education can improve long term understanding and learning. Educational reform, curriculum documents and advocacy for inquiry education can all be strengthened by this research. Wilson et al. conclude that inquiry is effective meaning a major implication should be that curriculum materials related to 5E and inquiry need to be available to teachers. The 5E model will be discussed later in this literature review. Many teachers lack the knowledge of how to generate inquiry lessons and avoid using inquiry methods because they don’t know the research behind their effectiveness. If more curriculum materials were made readily available for teachers to use and modify to their classrooms, more inquiry would likely be seen in science classrooms. Information needs to be disseminated with regard to inquiry because there are still so many teachers who refuse to even look at inquiry because they will “lose instructional time” and the students won’t understand the material. Using a rationale like losing instructional time and students will not understand is a myth. Parents need to be educated with regard to inquiry so that when they hear their child is frustrated in class, they don’t go to the teacher with a complaint, but can support the learning because frustration must be a part of learning and engaging in content.

Bridle and Yezierski in 2012 conducted a study regarding inquiry. In Bridle and Yezierski’s literature review it was found that students have alternative conceptions, as discussed in the misconceptions portion of this literature review, that can be addressed using inquiry methods. A better conceptual understanding as well and decreased number of misconceptions has been found to be a large benefit of inquiry instruction. When paired with particulate level instruction, there is an even greater effect. Due to this information being found in the literature, Bridle & Yezierski (2012) thought that a more in depth look at these two methods coupled together should be studied. Since the particulate nature of matter, the material Bridle & Yezierski (2012) were assessing, is more abstract than other science concepts, it is essential that students discover the ideas and create their own understandings.

Bridle & Yezierski administered a pre-test and post test measuring students’ understandings of particulate nature of matter. The pre-test was administered within the first few days of school and then students were given five and a half instructional periods (60 minutes for each period) with material
related to particulate nature. The pre and post tests were “Particulate Nature of Matter or ParNoMA” which looks specifically at concepts related to physical and chemical change related to the particulate matter. The post-test was administered 4 weeks after the end of content delivery to ensure any bias of memory was eliminated and true understanding was being measured. In addition, interviews were conducted 3 months after students completed the post-test. The length of time was to erase undue bias and have students come with their long term knowledge. The other reason for interviews was to determine what students were thinking related to particulate matter and why, or why not, their test scores improved from pre to post-test.

Bridle and Yezierski (2010) found that one of the two classes made significant improvements from the pre-test to the post-test and those students who had scored well on the pre-test also scored well on the post-test indicating that the curriculum with inquiry and particulate matter had a positive effect on student learning and understanding. Through the interview process, it was concluded that the participants were able to identify particulate changes in matter and identify physical versus chemical change.

Students lack the ability to distinguish between breaking of chemical bonds (H\textsubscript{2}O\textsubscript{(l)} becoming H\textsubscript{2} & O\textsubscript{2}) versus intermolecular forces (H\textsubscript{2}O\textsubscript{(l)} becoming H\textsubscript{2}O\textsubscript{(g)}). Bridle and Yezierski conclude that the curriculum is a good basis for particulate matter and inquiry education, but that it needs to be studied more and the results and data should not be extrapolated out to other populations. The data collected by Bridle and Yezierski leads to a need to explore broader contexts of the application of the particulate nature of matter tools developed for this study.

While the research here point to benefits of inquiry, many teachers and researchers are still conducting studies that find inquiry to be frustrating, unmanageable and pointless in a classroom. Criswell (2012) has analyzed and found five essential components to help teachers “frame” inquiry so that it will be beneficial to both students and teachers.

Criswell found creating a context for inquiry was the first major finding discussed in the article by Criswell (2012). Criswell gives examples of students who weren’t given an “anchor” or focus for why they were doing an activity or lesson. Students were confused about the purpose of the activity if this
component was missing. When given context related to prior knowledge in the course and to the real
world, students felt as if they understood the material better with much less confusion. The second major
frame was goal setting for the lessons. The goals must be explicit and evident to students. Goals should
be presented in a way that engage students and encourages them to use higher level thinking skills.
Actions as the third component were found to sometimes be given too often and other times not enough to
students. Those teachers who provide too much information on how to complete the activity did so often
by using cookbook labs that required little thought from students involved in the experiment. On the
other hand, there are teachers who do not provide enough information for students to be able to determine
the process necessary to solve the problem. Limiting information can occur with open inquiry where
teachers don’t want to give too much information resulting in frustration with the problem for students
and overall misunderstandings. Students often are unable to perform activities.

In addition to goals, context and actions, tools are a necessary portion of inquiry. Criswell (2012)
suggested that teachers needed to point out tools that may be of use during an inquiry activity so that
students are “oriented” towards resources that help them to solve the problem. The example given is with
a demonstration inquiry activity where some students were oriented to the periodic table and were able to
correctly predict the result while those who weren’t oriented to the periodic table were not able to make a
correct prediction. The last major finding indicated that the interactions from student to teacher and
student to student are essential so that students are engaged in true scientific inquiry to learn and build
knowledge (Criswell, 2012, p. 202). The implications Criswell gives are mainly for teachers. Criswell
suggests that teachers will not be able to address every aspect discussed for successful inquiry in every
inquiry lesson they plan. The five aspects are all reflection pieces teachers while planning, but do not
need to be addressed in every inquiry experience given to students. The frame provides teachers with a
base set of materials that are helpful to plan a successful inquiry lesson.

**Practical applications of inquiry concepts**

While inquiry concepts are wonderful to hear about, there are many practical applications of
inquiry that can be found in the research. Chairam, Somsook, and Coll found that the main aim of labs in
higher education is to learn the basic skills for lab, a way to demonstrate how concepts described in lab are related to the real world and to provide students complete true scientific experiences (Chairam, Somsook, & Coll, 2009, p. 98). Other researchers reviewed by Chairam, Somsook, and Coll have found that the laboratory work is not always beneficial to students as they are following procedures. In order to make laboratory work more beneficial, real science with practical application need to be a part of the lab work according to Chairam, Somsook, and Coll (2009). In addition to not working well when there isn’t a practical application, cookbook labs do not work well and are ineffective at helping students to learn concepts. Chairam, Somsook, and Coll suggest opposite to cookbook style labs, inquiry style labs help students to understand the nature of science by engaging and trying to figure out scientific concepts and procedures.

Chairam, Somsook, and Coll (2009) chose 419 students who were 18 and 19 year old first year undergraduate students in their first year chemistry laboratory. All of the students were also in a lecture session that met and usually covered concepts prior to the lab experiment. Groups of four to five students were used because that is what was recommended in the literature for inquiry based experiments. All of the students had also participated in a POE style model of laboratory work prior to the study (predict, observe, explain). Since the study was conducted in Thailand, most experiments were written in Thai to decrease error. Chairam, Somsook, and Coll (2009) looked at the group learning aspect to this inquiry lab. Most students felt positive about the group work and stated that working in a group “stimulated” their thinking (Chairam, Somsook, & Coll, 2009, p. 110). In addition, the eggshells added a component of “real life” to the experiment instead of simply having the chemical (calcium carbonate) on hand, the eggshells made the experiment related to their lives in a better fashion.

The major findings are grouped into three categories: “student laboratory activities; student conceptual understanding of chemical kinetics; and the role of the teacher” (Chairam, Somsook, & Coll, 2009, p. 103). Overall Chairam, Somsook, and Coll (2009) found that students understood the topic of chemical kinetics after completing the inquiry POE activity and lab activities. The students enjoyed the different approach to lab learning (instead of cookie cutter labs) as they were engaged in scientific
thinking. Students were truly engaged in the process and learned more about kinetics than they probably would have with a lecture or formal lab following teacher instruction. Chairam, Somsook, and Coll indicate that a key component to the success of the experiment was the use of POE strategies and small and whole group discussions. Chairam, Somsook, and Coll (2009) suggest that due to the success of the experiment, the engagement of students in the process and the ease at which student conceptions were altered, this would be a good experiment to implement in the classroom. Students saw “real life” materials (eggs) and were able to make the connection to make the pieces smaller to have the reaction proceed faster. Students, while working had to talk with each other or the experiment wouldn’t have worked and they would not have learned about kinetics. The students enjoyed the process. What this means is that educators in science need to find ways to incorporate inquiry that is nonhazardous to engage students easily into content related to their lives. The researchers looked at the teacher role because in this study serving as a facilitator is a large contrast to what the “norm” is in Thailand. The students thought that teachers were friendly and that they attempted to help the students when they were having difficulties (Chairam, Somsook, & Coll, 2009, p. 109). Lastly, Chairam, Somsook, and Coll asked students if they enjoyed the predict observe explain (POE) technique. Overall, students said that they enjoyed the technique and they were able to carry out an experiment like a “real scientist.”

**What engages students in the material?**

In a study conducted by King in 2012, numerous papers were reviewed that have looked at the change that has occurred within the science and teaching community. King analyzed articles that related to a variety of approaches: “science teaching and technology, problem based learning and project-based science” (King, 2012, p. 52). The review focused on the learning outcomes of these types of courses comparing them to traditional chemistry approaches by looking at the outcomes: student’s interest in the material, attitude toward learning and motivation for learning chemistry (King, 2012, p. 52). After analyzing numerous articles from the past 20 years, King provides a new theoretical framework to help teachers make connections for students from science concepts to real world ideas. King chose five studies to analyze from numerous different countries that over the years have implemented new context-
based curriculums. The curriculums were aimed at increasing the relevance of chemistry, increasing the student’s interest, attitudes and motivation and lastly a deeper understanding of chemistry concept. Each of the studies has been reviewed prior to this one and was of interest to King who was trying to relate real world concepts to students. King also looked at inquiry, collaboration and how this can benefit students.

One major finding from King in 2012 was that if teachers were properly trained with professional development to teach context related chemistry by learning pedagogical teaching styles, students were more successful. Also, the context that chemistry was placed in helped students to see the relevance of the material to their lives better with properly trained teachers and proper materials. With more relevance, students are more engaged. King also noted that when the subject (physics or chemistry) was taught in the context of the “real world,” students were able to apply their learning to reality and were more aware of the social implications and responsibilities as future citizens (King, 2012, p. 60).

King then reveals that students truly have a higher interest in the subject when they are engaged in real world problems. Some students were frustrated with the context based education due to the disconnect they felt between test questions and class work. Another issue that arose from a few of the studies was that the instructors were not invested in the context based chemistry. The teachers were sometimes lacking knowledge and explanations or they simply weren’t enthusiastic about the new approach. Students definitely “picked up on” the lack of enthusiasm and didn’t perceive their learning to be as meaningful because they weren’t learning the facts. With that being said, there was a study that completed a pre and post-test of the control and experimental groups. At the beginning both groups were excited about chemistry and had the same base knowledge. By the end, the content knowledge was about the same for both groups, but the group that had used context based instruction had a much higher motivational level related to science.

King’s next set of findings are related to the deeper understandings that students can have when exposed to context based education. It was found that when students are exposed to a context based curriculum, the students will understand the material in a more complete manner to have a deeper understanding. Several studies analyzed by King found that there were no significant differences in the
outcomes on tests. King (2012) suggests this means that while there may not be a significant academic benefit, the context based education isn’t doing students any harm. In addition traditional tests are usually modeled after memorizing facts and trying to understand specific examples, yet context based education addresses larger ideas that can apply to reality so giving a traditional test isn’t a fair assessment of what students know. King mentions another study conducted at a university that found no difference between the control and experimental group that was participating in context based education with regard to testing, but did find that the people who had taken part in context based education were more likely to go on to the second year of college chemistry. King found yet another study that indicates that because context based education doesn’t necessarily focus on one concrete idea, but multiple ideas and revisits them, students in the context based course are able to see topics more and understand them more in depth. King refers to this as a “drip feed” which allows students to develop a deeper understanding of a particular topic over a period of time (King, 2012, p. 65). One very interesting fact is that students, regardless of context or non-context based teaching, had difficulty with bonding versus intermolecular forces and the different types of bonding. King found that context based courses do not compromise student understanding.

Next King found that in places where regional or “state” testing is mandated, the exams that are administered to students must change to fit the curriculum. Change takes times, initial trials, revisions and retesting to ensure the test is fair and without bias. In places where there isn’t regional testing or assessments, there was no consistency in what the students were learning in their context based class nor were they learning enough of the same key ideas for a regional test to be appropriate.

King also reviewed new science initiatives and how they relate to context based education. He started by reviewing STS which is science-technology-society. STS is designed to look at how science is related to society which is directly linked to context based education as it relates to students lives and how they can connect chemistry to student’s real lives (King, 2012, p. 70). Another version of initiatives is project based learning and problem based learning. These make students think about and work with science concepts through the lens of a problem or assignment from a company. King suggests that both
of these approaches, because they usually involve an element of inquiry and thinking outside of factual knowledge, are context based science and a benefit to students. A study is mentioned by King that looked at students test scores who had been in a project based curriculum compared to a traditional one. There was little difference between the two sets of scores, but those who had project or problem based curriculum were able to easier answer the part two free response questions. The last science teaching initiative reviewed is called society based teaching in context. Society based teaching involves having students out in the community experiences and relating science in their world to science in the classroom.

King reviews Vygotsky’s theories about learning and suggests that the nature of context based curriculum is beneficial to students. Vygotsky says that knowledge must be created, not transferred. All the science initiatives described here require student to investigate concepts, work with them to develop understandings. Not be told what happens. The author looks at agency structure which often requires stronger students to stand up and question to change the dynamic of the classroom. The idea of agency structure paired with agency passive (listening and drawing from old information) can work very well in a context based classroom.

The last finding from King states that fluid transitions are important to help students understand the chemistry behind the context based education. King found research that shows high achievers have a much easier time with transitioning between “real world” scenarios and content than students with lower level abilities. Therefore, lower level students need to be supported in their transitioning of concepts and understanding of ideas if a context based curriculum is going to work. Regardless of how a student may or may not perform on a test, context and engaging science has benefits that are equal to or greater than those associated with traditional methods of teaching. Another implication of context based implementation is we would see students more engaged and excited about science!

**The 5E cycle**

The 5E cycle is based on constructivist theories of learning that provide support and guidance to increase student inquiry (Wilson et. al., 2010, p. 280). The 5E model has 5 phases with each “E” representing an experience related to constructivism starting with an “e:” engage, explore, explain,
elaborate, and evaluate. The 5E model has been described as serving as a tool for teachers to assess their inquiry lessons. Orgill and Thomas (2007) suggest that analogies can support each of the phases of inquiry in the 5E model to help students develop a better understanding of concepts. Analogies have two parts—the analog which is the common familiar concept and the target which is the concept that students are trying to learn. With analogies, a difficult concept can become a very easily understood concept for students. Analogies have been cited as constructivist learning supports because students have to formulate ideas around the analogy so they can associate them with the content concept. Orgill and Thomas (2007) cite the importance and emphasis on constructivist learning styles that has been researched. The idea that when students learn, that knowledge must be integrated with the information they already know is an essential component of constructivism as well as the key to a successful analogy. With the relation between constructivism evident through research, Orgill and Thomas (2007) strive to integrate and support teachers trying to use analogies in constructivist 5E classrooms by offering suggestions as to how the analogies can be integrated.

The first phase of the 5E model is “engage”. Students engage in the topic, get motivated to learn and excited about what they are going to learn usually by using some type of prior knowledge. It can be done with almost anything that will focus students’ attention on a particular topic helping them to create links between prior knowledge and new facts (Orgill & Thomas, 2007, p. 41). These activities many times bring out alternative conceptions which can help teachers. These engage activities also are perfect for the use of analogies because a student is more likely to pay attention to something familiar than something with many different scientific concepts they’ve never heard before. Orgill and Thomas (2007) found that most analogies in the engage phase are provided by the teacher as students don’t have enough prior knowledge to generate an analogy at this point in the cycle.

In the “explore” phase, Orgill and Thomas (2007) describe how teachers usually create a scenario for students to become actively involved in. The explore phase works perfectly with analogies, Orgill and Thomas describe, as it requires students to look at both parts of an analogy and defend or debate how it is or isn’t a good analogy. Students are required to find support in order to support their “claims” about the
analogy (Orgill & Thomas, 2007, p. 41). The “explore” portion of the 5E model can come in many different forms, from experiments to research related to the topic. Orgill and Thomas suggest that this is an essential component for students so they can create solid understandings about the concept to be learned and shared in the classroom as a common frame of reference during the 5E cycle (Orgill & Thomas, 2007, p. 42). The next portion of the 5E cycle, “explain”, is usually associated with lecturing students to help them come to a better understanding of how the analogy works. These ideas are usually harder for students to determine on their own and with a lecture; a clear link between the analogy and the concept that must be learned is established. Orgill and Thomas also found that the use of visual aids is more effective when explaining analogies. When a visual aide isn’t possible, more students can come to think of a concept incorrectly based on the analogy and therefore must be aided by clear instruction from the teacher (Orgill & Thomas, 2007, p. 43). Towards the end of this phase, teachers should assess students to see if their understanding of the analogy is correct. The “elaborate” phase is described as a time for students to take the information they have already learned through the model and apply it to a new concept to increase their understanding (Orgill & Thomas, 2007, p. 44). The “elaborate” phase is designed to help students and teachers determine how well the new concept is being understood. Students can ask questions and grapple with the concept so they can learn the idea more completely. The last phase, “evaluate”, should occur within every phase of the 5E cycle, but is listed last as a summative assessment, but can be conducted at the end of the learning cycle. It can occur as a simple question from teacher to student, or as a project that is a result of the “elaboration” stage. Evaluate is meant to be an all encompassing formative and summative assessment strategy that requires all participants to be looking to gain knowledge through the entire 5E learning cycle process.

Orgill and Thomas (2007) cite that an analogy in the “engage” phase should be a novel concept. Teachers need to engage students with something out of the ordinary whether it be a song, poem, story, demonstration or visual aide, it should be related to their lives. With this being said, teachers need to be given materials, time and resources to develop these engaging activities so that students are able to learn productively. One implication for students regarding the explore phase is students become better at
defending their beliefs, increase the consistency of their research and by looking into the analogy, they are more confident in their understanding of how the analogy relates to the new science concept they are learning. In terms of implications for the explain phase, teachers must be aware that alternative conceptions are present and may have been supported by the analogy. Teachers must be prepared with how to answer questions related and surrounding the analogy that has been used the first two stages. Students are starting to develop concrete ideas and therefore the teacher must clarify and check through some type of assessment what students are learning in the classroom through the third step of the 5E model. In the elaborate phase, it is important that teachers look to see what students are doing because this can be the “make it or break it stage” for understanding. Teachers and students can have a clear understanding at this point whether a concept is understood or not understood. The idea that assessment must always occur is an extremely important implication for teachers, students, administrators and parents to understand. One grade in the grade book does not equal student learning. While not always a product of the 5E cycle, grades are a part of school and being able to measure at different points within the learning cycle is essential to student learning success and a teacher’s ability to teach. Overall the 5E cycle has huge implications for student learning, engagement and enjoyment of science. Teachers need to work to create lessons together for the benefit of students to help them engage with the content and not simply absorb it through an “explain” lecture all class.

**Demonstrations related to engagement and the 5E cycle**

Related to the 5E cycle, the first component of engagement is essential to keeping students engaged. There has been much research completed on what types of “engage” activities are useful and what engagement looks like in students. The following articles relate the 5E cycle to one of the most common engagement techniques in a chemistry classroom: demonstrations.
Milne and Otieno (2007) first reviewed research on understanding engagement and found that engagement can come in many forms. These include behavioral emotional and cognitive engagement, and can be derived from many different factors including interaction with peers, and willingness to participate in outside classroom activities which is why demonstrations were looked at in relation to engagement. Milne and Otieno (2007) believe that positive emotion which comes from cognitive and emotional engagement is required for learning to take place. Milne and Otieno then reviewed engagement, interactions and conversations surrounding science, context of discussions and the sequence they occur. Students and teachers must participate in a conversation to provide students with some sort of background and sequence to the topic being discussed. Research found by Milne and Otieno cites that conversations are different from “institutional” conversations within a classroom for a particular group of individuals because at least one person has an end goal in mind (usually the teacher), there are limits to what can be discussed, and the talking must relate to the ideas at hand (Milne, Otieno, 2007, p. 525-526). Research by Collins regarding interactions and engagement show that motivations and simply entering into the conversation can signify engagement (Milne, Otieno, 2007, p. 526). Regarding understanding engagement and emotion, Milne and Otieno find that teachers must constantly be assessing and renewing the conversation and interactions related to the demonstration to make sure it meets instructional and interpersonal goals and if the needs of students aren’t being met, change the dynamic or questioning strategies (Milne, Otieno, 2007, p. 528). Regarding science demonstrations and learning, there have been limited papers of how demonstrations are used within the classroom related to assessment and the engagement of students so these authors are looking to fill the gap by looking at student interactions during demonstrations. Prior research found by Milne and Otieno has found many demonstrations to be confusing to students and not worthwhile instructionally due to their complexity. When demonstrations are planned as interactions, special relationships between people, questions asked and interaction with the observers is used, the demonstrations are more successful with helping students be engaged.

Milne and Otieno conducted their ethnographic study in one urban classroom and were intending to simply study interactions. When video and transcripts were recorded, though, Milne and Otieno
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decided to look more specifically at the demonstration interaction component. One finding was that developing a mutual focus for the class during and after a demonstration is a huge benefit as the level of engagement and interaction of students was greatly increased compared to other days of class without demonstrations. The energy, interactions, dependence on each other and questions that are asked created a greater sense of belonging for students in the class. When there was little gap between teacher speaking and student speaking, this was an indicator that the students were engaged in the topic. Another engagement indicator is student’s body orientation towards the demonstration and openness to communicate with others. Another finding by Milne and Otieno is that student engagement is higher when students and teachers collaborate together to make the demonstration successful. There must be an order to the demonstration and when students start to understand the “chain of events” they become more engaged making predictions and suggesting modifications to the experiment. These are all indicators of student engagement. Milne and Otieno found that more demonstrations can continue to increase the “emotional energy” due to the successful completion of the demonstration leading into excitement about the second (2007, p. 544). Milne and Otieno also suggest that when teachers and students are equally represented in demonstrations the students do better. What this means is that the teacher shouldn’t have more power—both the students and teacher should have “positive emotional energy” on the same level to produce the best benefits for students. Another finding was that in terms of engagement, most of the students were similarly engaged, but showed it in different ways. For example, the African American students were more vocal while the Caucasian and Asian Americans were quieter, but showed engagement through “eye gaze [or] raising of hands to signify their vote” (Milne, Otieno, 2007, p. 545).

Milne and Otieno also found that demonstrations are shared experiences by the whole class including the teacher. After a discussion, all parties present will have the same idea about a particular concept within a phenomenon which leads to a better understanding and more community. The shared ability of theses demonstrations also has both teachers and students using more language and symbols to represent what they are seeing and talking about with each other. The more questions and discussions that occur create a better classroom community where it is appropriate to ask questions, try answering
questions and make suggestions for modifications and further tests within the demonstration to determine an explanation for the phenomenon (Milne, Otieno, 2007, p. 546). Students in this study felt a “sense of control” over the experiments, resources, and observations which leads to more conversation between students, positive emotional energy and student engagement (Milne, Otieno, 2007, p. 548). The interactions of the students and comfort of students also may have to do with the fact that in the demonstration, there was a role for the students and the materials used were familiar to students. These items served a positive role in that students felt comfortable, but when the actual demonstration was occurring, the unexpected results and behavior of the phenomenon contributed to the continued engagement of student with the demonstration. Milne and Otieno suggest that the interactions or “establishing [of] rituals” with students, and having familiar materials suggest a role for demonstrations as “a shared experience for all students and provides a basis for ongoing science conversation” (2007, p. 548). Milne and Otieno also suggests that “successful interactions” between students and teachers are necessary to develop the basis for any demonstration with initial conditions, focus and establishing the emotional energy necessary to keep students engaged through the process of demonstrations. Milne and Otieno also show that an assessment component to the demonstrations can serve to reinforce student learning of the concepts and the interactions that are present during the demonstration. The assessment administered by Milne and Otieno also asked students for feedback on the demonstration and questioning process giving students a feeling of control over their classroom and their teacher good feedback regarding how the demonstrations affected each of her students.

Milne and Otieno find that demonstrations are helpful in providing teachers an activity that is “central to student engagement” that also gives students structure and flexibility in terms of questioning and their own level of their involvement. Students in school are generally looking for “fun” things to do— Milne and Otieno show that demonstrations can fill that gap for students while also fulfilling an instructional goal for teachers. The engagement and “successful interactions” with new concepts allow teachers a window into student’s thoughts. The window helps teachers to understand any misconceptions and clarify questions that would normally go unanswered in a traditional classroom due to the limited
interactions that occur in this type of classroom. The comfort that students have with their teachers and peers can be essential for helping students have success. Another important implication is that if students are talking more, they are likely using more scientific terms developing a familiarity with them. The comfort with the terms will likely increase engagement in a concept for the next class or next set of demonstrations. These interactions can cause a change in interest for students inspiring others to learn science and take higher level science courses.

Another implication that is possible is that if students are talking more in science classrooms about science, they are going to be more motivated to stay on task while learning about the phenomenon related to the demonstration. Students who are engaged and focused within the classroom usually ask good thought provoking questions inspiring more engagement from their peers. When students are engaged, they are more on task and focused and more willing to learn than if they are simply taking notes. Teachers who use demonstrations as a springboard for discussion are creating engaged students who are able to talk about being more engaged in the science classroom to others. Sparking interest in others and spreading the “fun” part of science can have a positive impact on the community and parents of students. It has been found through much research that students learn better and more when they are engaged. These demonstrations, then, will create better learning environments and more learning for all of the students involved.

Specifically regarding demonstrations, Pierce and Pierce conducted a study in 2007 looking at the effective use of demonstration assessments in the classroom relative to laboratory topics. Pierce and Pierce started by looking at research that has been done on simple demonstration activities. It was found that a demonstration must engage students in a concept, not simply be there for the entertainment value and then forgotten about—performed. Students can be highly engaged using demonstrations, but there are a few factors that must be present for engagement and learning to occur. Research that Pierce and Pierce found also showed that students, while observing or helping take part in the demonstration, must ALSO be asked challenged and pushed by their teacher to try and create a chemical reason to explain what they are seeing (Pierce, Pierce, 2007, p. 1150). Teachers must frame the demonstration with
concrete ideas and help students to work through their alternative conceptions and “inevitable cognitive conflicts” that are caused or challenged by the demonstration so students can explain what they have witnessed in the demonstration.

Research that Pierce and Pierce have found has been done looking at how assessment can be tied into demonstrations to increase the rigor of the demonstration and the focus of the students during the demonstration. There have been a variety of models for assessment of demonstrations, one of which has students record their observation after observing the demonstration and then discussing their findings after they’ve turned in their assessment. It has been shown that this type of assessment can increase student scores on standardized test questions that emphasize conceptual understanding (Pierce, Pierce, 2007, p. 1150). Although assessment can be a motivator, this process doesn’t following the learning cycle because it doesn’t engage students and give them time to explore by asking questions and manipulating the materials. With this step lacking, it requires large amounts of inductive reasoning. Students would be better off, according to the learning cycle, if they were given the demonstration, given time to ask questions interact with the teacher and other students, then given an explanation, time to expand their knowledge with another similar idea and then assessed on the concept.

Pierce and Pierce then conducted a study with 2 large introductory chemistry courses at a large university. These two similar classes were chosen because the researchers wanted to see the difference between groups that used demonstration assessments coupled with laboratory work compared to a groups that just did lab work. Pierce and Pierce were able to control variables such as class size, instructor gender and similar teaching style, pace of the course, text book, and assessments which was another reason this population was used. Students were given a pre-assessment after they had been in lecture for a few weeks, taken one test and done 3 labs (both groups same lab and test). Treatment was then started and the demonstrations coupled with assessments began and the other group continued without the demonstrations. A post assessment was given at the end of the semester to assess changes in student attitudes and any differences between the two groups of students. All students took the same exams
which included multiple choice and free response questions that were mainly used to check the effects of demonstration assessments and were the main comparison between the two groups.

First, Pierce and Pierce found in their study that the two groups were similar in terms of scores on their first exam and in terms of their attitudes towards chemistry. Students in the treatment group had slightly lower ratings related to their attitude towards chemistry. For the treatment group, as the demonstration assessments progressed from the first to last assessment, students became more cognizant of the requirements meeting expectations of the rubric more fully. These findings indicate that demonstration assessment can be used with a wide variety of levels and the cooperation required for the activity to be successful “stimulates inductive reasoning” of these students (Pierce, Pierce, 2007, p. 1153). One surprising finding is that about one quarter of the students couldn’t explain the demo using the correct vocabulary or symbolism. Half of these students couldn’t use the new terminology correctly and the other half couldn’t link concrete visuals from the demonstration to abstract concepts.

Both the treatment and control groups had similar percent of questions correct related to the lab exercises. Since the demonstrations were designed to couple with the laboratory work, it was determined that the demonstration assessments had no real measurable effect on learning when they were coupled with a lab. When the topic wasn’t covered in lab, but in a demonstration, the treatment group did much better. Since there were only four demonstration assessments, the affect wasn’t large enough to have any effect on exam scores for the two groups. It was also found that there was not a significant change or difference in attitude between the two groups after treatment. Since Pierce and Pierce found little affect for demonstrations that correspond to lab activities and the assessments that are coupled with demonstrations are lengthy to create, they suggest that demonstration assessments should only be used when lab activities are not used for the same topic. Since the control and experimental groups performed similarly on test questions related to demonstrations, it is implied that instructors should take care to determine when a demonstration is educationally necessary for students and that it isn’t something that is easily extrapolated from content knowledge as the control group was able to do here. Since demonstrations can be difficult to create and coordinate, videos may be used to show a concept, but needs
to be looked at more closely with additional studies as a video may not hold as much “wow” factor as a live demonstration. There could be loss in terms of engagement and the question for researchers is does the value of seeing a demonstration and completing an assessment to engage offset the idea that the demonstration isn’t live? Pierce and Pierce suggest that another study should be conducted with demonstrations applied to the learning cycle to see if that more positively affects student learning outcomes compared to a control group.

In terms of implications for teachers, demonstrations should NOT be used for the same idea that is supported in a lab. Demonstrations should be used to engage students in content and may possibly be used after a concept in taught to see if students can apply given microscopic knowledge to the demonstration in front of them. When students say “blow something up,” a teacher needs to have educational need to complete that demonstration or to serve as a hook for a lesson or unit where an explosion might occur. When asked about quality assessments from an administration, this type of assessment would be one that could be brought up. It engages students in content and checks their understanding after and during the demonstration.

Meyer, Schmidt, Nozawa, and Panee (2003) next look at chemistry through the eyes of students today compared to the chemistry of “real chemists” who have made significant discoveries. Students in science classrooms today see chemistry as boring and mundane due to cookbook labs, lectures all with expected outcomes many times given by their teachers. The students are likely seeing the chemists who made great discoveries as boring old people who worked in labs as social outcasts and chemistry as a “subject for nerds.” Trying to help students understand that scientists had to use trial and error, question everything, and work hard to then make a surprise discovery is part of engaging students in science. Meyer et. al look to examine ways that teachers can engage students in chemistry by using demonstrations and the nature of science. The goal is for the review of the literature by Meyer et al. is to help teachers gain more knowledge to help students to be more engaged in science concepts which can be done through demonstrations.
Meyer et al. address some of the reasons that educators give for not using demonstrations. For example, teachers can be pressed for planning time and therefore lack adequate time to complete all of the research necessary to understand and plan a demonstration effectively. Also, teachers who weren’t exposed to demonstrations in their education may not be aware of the educational benefits associated with them and may uncomfortable completing them for their classes (Meyer, Schmidt, Nozawa, Panee, 2003, p. 431). Meyer et al. then go on to show some positive reasons to complete demonstrations. The engagement factor of a demonstration is one of the most important benefits cited by Meyer et al. In addition, a demonstration versus a lab allows students to see more experiments and experience more chemistry compared to the “mundane” classrooms they learn in. Demonstrations versus labs also save equipment and disposal cost as the teacher only has one thing to set up and dispose, not 10 different lab stations. The authors also cite the missing link between chemistry and real world concepts as an important reason to complete chemistry demonstrations. Demonstrations encourage students to ask questions, create links between prior knowledge and new learning and increase “the personal relevancy of new learning” (Meyer, Schmidt, Nozawa, Panee, 2003, p. 432). Demonstrations can also be done at the very beginning of class to conserve time and to engage students in the process of wondering what the teacher is doing or what they will do within the demonstration (Meyer, Schmidt, Nozawa, Panee, 2003, p. 432). In addition to engaging students, these demonstrations can help to address many of the different learning styles that are present in a classroom at the same time as building a sense of community that can be essential for student learning success within a given setting. Meyer et al. cite that modeling is starting to reemerge in education as an important part of learning. Demonstrations can serve as a time for teachers to model thinking and questioning cognitive processes to students. Modeling helps students to understand that not all questions can have an absolute and immediate answer. Discovery—this is what science is about. Helping students to see that is part of a teacher’s job. The students, in addition to understanding more of science, will be required to use higher level thinking skills than are usually required by standardized tests to EXPLAIN why or give a reason as to what was occurring. Another important finding is that demonstrations can help students to develop real world problem solving skills.
and see that chemistry isn’t an isolated subject, but all around them. Students are encouraged to ask questions and work together to try and solve problems instead of being expected to take textbook reasoning as law. Students can come to understand concepts and have those ideas supported by the textbook instead of no support or understanding of “why” a fact written in the textbook is correct.

Due to the fact that demonstrations can create all of these benefits, teachers must know how to properly plan them. First, the teacher must decide if the demonstration is purely for entertainment or if it serves a learning purpose. If it serves a learning purpose, the teacher should be sure to select a demonstration that is appropriate for the age group of students and seek other teacher’s opinion on the reliability, effectiveness and positive ways the demonstration can be used. Also requiring that teachers plan how to link the demo to previous knowledge, question students during the demonstration and practice the demonstration through at least one whole time to provide maximum benefit to students. One reason given for teachers not completing demos by Meyer et al. is the uncertainty of how the demo will progress. Uncertainty can be alleviated by practicing the demonstration at least once. Students will see the demonstration as a scientist if the teacher is comfortable with the presentation, questions and process required for the demonstration to go smoothly compared to students who observe a teacher struggling to complete the demonstration. Students will leave feeling like scientists discovering what happens during the demonstration. Practice also allows the teacher to play up their understanding or ignorance related to what is going on in the demonstration which encourages students to ask question, have high energy, and being sure that students are focused on the academic purpose. When students are more involved, they remember concepts better and score higher on tests. Another implication for a demonstration is that engaged students are more involved in science and when they are actively involved in discussions that serve to clarify chemistry principles, students remember a particular concept more concretely. In order for this to work, teachers must clarify any vocabulary or language that is new to students so as not to confuse with jargon and language that makes the concept out of reach for students. One main purpose of a demonstration is to engage students. Common language and explaining new vocabulary is essential to keep students engaged with the topic as to not take the demonstration from exciting to incomprehensible
explanations. With more engagement in chemistry, society will hopefully see more chemists determined to learn about the world around them.

Summary

Engaging students in chemistry concepts can occur in so many ways including demonstrations, videos, mini-lab activities, questioning, POGIL, problem based learning, and so many others. With all of these resources, it is hopeful that soon in the future lecturing students for 80 minute blocks will become something of the past. In order for students to enjoy science
topics, chemistry more specifically, it is essential that lecture style instruction decreases so that students can engage with the material instead of being a passive observer. Although it has been known for over 20 years that lecture style instruction does not benefit students learning, it is still commonplace teaching practices. Numerous “alternative” methods have been described here in the literature review. These alternative methods range from conceptual change text, to project and problem based learning as well as inquiry learning, and being willing to let students ask questions and answer them. Using these “alternative” methods has been shown to significantly decrease misconceptions and increase deeper understanding of students participating. These methods are able to increase student learning by engaging them in the material, making it relevant and more than simple facts to memorize. Students appreciate the honesty and efforts of teachers who allow them to explore a concept and relate a difficult chemistry concept to their lives. All of the “alternative methods” allow teachers to do this. The 5E cycle suggests that students MUST engage with the material before they can start to learn about a concept. The 5E learning cycle is deeply rooted in Piaget, Vygotsky and constructivist principles. While the cycle suggests engagement for every concept, this is not seen in many classrooms across the country. There are drawbacks that many teachers see to these “alternative methods” which is why lecture is still the main more of instruction. There have been a few studies published that show the drawbacks to inquiry education. These studies usually focus around open inquiry and where the students aren’t given enough support to be able to successfully complete the task. Other teachers have heard of these “alternative methods,” but don’t know where to find information, how to implement them in their classrooms and are afraid to take away from the limited instructional time. The last factor, limited instructional time, is what most teachers fear about using alternative methods. Teachers must prepare students to take a test that affects both the students and teacher. What these teachers do not know is that the “alternative” methods result in a better
understanding of concepts initially requiring less review. When students are engaged in the material, they will learn better. With this being said, materials must be developed to help teachers engage students in their lessons. All of these reasons are why the current project of improving chemistry instruction is underway to invent, adapt and incorporate engagement pieces is being conducted. These pieces are essential for students to “engage” with the material, be excited to come to chemistry class, ask thoughtful questions and learn more fully when in class to determine how the demonstration or activity relates to the topic at hand. The project underway to invent, incorporate and adapt engagement pieces has three goals to improve chemistry instruction: 1) Use the Regents Chemistry curriculum and prior years lesson plans to determine the lessons that start new topics and units that require engage pieces 2) Invent and adapt the first “E” in the 5E learning cycle to fit into a Regents Chemistry high school classroom 3) Implement the engage activities within my classroom and disseminate the information to other chemistry teachers for their use.

Chapter Three: Final Project with 30 Engage Activities

Narrative: Significance of Project

There are many instances where a compilation of engage activities will prove useful to science teachers. Students are always saying “can you blow something up?” While a valid plan, there has to be some planning by the teacher to “blow something up.” This compilation will provide teachers a resource to engage students through a variety of modes including demonstrations to increase student engagement and therefore learning.
Students in any classroom have an innate ability to “zone out.” With an engage activity at the beginning of the block or when starting a new concept causes those students to wonder, ask questions, observe and obtain motivation to learn. The “wow” factor and time to wonder helps to engage student in the chemistry content they are about to be taught. Students who are more aware are more likely to learn a concept, ask questions and pay attention to what is going on in the classroom and therefore learn more about the concept. Giving students an opportunity to wonder about a concept before they are taught how it works can benefit students. They can talk with their peers and develop a sense of community. The goal of this project is to motivate students within my classroom to want to learn, be excited to come to class, engage in discussion surrounding concepts and feel comfortable asking questions. Providing engage activities has been shown to help with all of these factors. Engage activities can also serve to provide students with the opportunity to see and experience activities that would otherwise be too expensive or dangerous. It also can help students to see the real world connection between chemistry and the “real world.”

Improving chemistry Instruction via the 5-E Learning Model: Inventing, adapting, and incorporating the first “E”

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**Title:** What is this stuff? Cornstarch & YouTube  
*For use in the beginning of the year to create community and engage students in chemistry!*

**Source/website:** Created by C. Christopher 8/26/13  
YouTube clip found at: [http://www.youtube.com/watch?v=f2XQ97XHjVw](http://www.youtube.com/watch?v=f2XQ97XHjVw)

**Research Support**  
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<th>NYS Chemistry Standard:</th>
<th>Key Ideas:</th>
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<td>3.1jj The structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure.</td>
<td>3.1kk The three phases of matter (solids, liquids, and gases) have different properties.</td>
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These standards are addressed in a limited manner as students have no background knowledge. By the end of the engage portion, students are expected to ask questions like “how does this work?”, “Is it a solid or liquid?”, “What makes it do that?”

| Supplies | A story told to the students to gain and focus their attention as well as a computer with either internet access or a file stored on flash drive of the video found at: [http://www.youtube.com/watch?v=f2XQ97XHjVw](http://www.youtube.com/watch?v=f2XQ97XHjVw) |

| Key Questions | To be asked after the completion of the video and through the follow up activity. Tell me about what you saw? (Think pair share probably necessary with a new group). So I said this was related to chemistry- in what ways do you think it is? (think, pair share→ share out) ask follow up questions to how this is related to chemistry. What do you think this substance is? What do you notice about it that makes you think that? If I took a handful of this substance, what would you expect to happen to it? What kinds of things might you do to it to change its behavior? What other experiments do you want to conduct using this material? Besides the “cool” factor, where might this substance be useful in society? |

| Summary of Engage: | Students will enter into a motivating and relevant engage piece on the first day of school. This engage segment will be closely linked to their lives and will pose a challenge to them to learn more about a topic. The teacher will start with a story: “A few years ago, I was looking for something chemistry related on the internet (because that’s the kind of nerd I am), but I got distracted on my e-mail and started watching videos [NOW- where on the internet do we all find ridiculous and unrealistic videos?]” Class should respond: YOUTUBE! “Yes, so I was on YouTube and I was watching videos of cats playing with water (quite hysterical as my own cat hates water) –which lead me to a marshmallow experiment. Which lead me to this penguin video about team work- it was rather funny (there was a shark approaching about to eat them & they tipped the ice berg they were on to have the shark crash)...(pause for laughing). Ok so I went through a few other videos (that I won’t bore you with the details), before I found something that IS actually true and it happens to be chemistry related take a look” The video found at [http://www.youtube.com/watch?v=f2XQ97XHjVw](http://www.youtube.com/watch?v=f2XQ97XHjVw) titled “A pool filled with non-Newtonian fluid” will be shown. At this point, students are expected to be “hooked” and excited about chemistry. They should have questions in their mind about what is the substance, can I do that, and why are we watching this fun ridiculousness in chemistry class? Students will be given time to discuss as they are asked to begin their follow up explore activity. Students will be able to work with cornstarch and water will be to help students dive deeper into the content. |

| Rationale: | On the first day of school, many students are nervous about the difficulty of |
chemistry. This story should help students to see that the teacher is indeed a real person, not a scary chemistry teacher. The nature of this *engage* piece should peak student interest as well. The video should help students to see that there is a “real world” connection to what is learned in chemistry class. It is also possible that students have seen cornstarch and water before and will feel more comfortable as they make connections to prior learning experiences. This will help with the classroom community aspect of teaching.

### Possible Misconceptions:
Showing students the video of cornstarch and water in this *engage* activity may lead to students thinking that solids when mixed with water can become “non-newtonian” fluid. According to Papageorgiou, Stamvolasis and Johnson (2010), a major misconception is that solids, liquids and gases all contain different “types” of matter. This same issue could arise with the *engage* activity presented here. The idea with this activity is to explore the properties of solids and liquids using prior knowledge. To avoid this misconception noted by Papageorgiou et al (2010), the teacher should listen to student conversations and discuss what is going on during the video.

According to Unal et. al, students are taught about the different levels of chemistry and how particles relate to the macroscopic world (2006). To address this with students is an essential to link it to chemistry and can be done using particle diagrams. An example can be seen to the right of a non-Newtonian fluid under applied pressure and how it changes to solid particles under pressure and is liquid state without pressure (Slowik, 2012). These discussions should take place during the *explain* phase of the 5E model. There is also the risk that they will want to “try this at home.” Students need to be aware that there are few things that act like this (including quicksand) and this is not a common behavior for what we see in class. Also, this is NOT safe to do at home unless it’s in a small handheld container (of which they will be able to work with in class for the explore activity).

### Recommendations:
The story told for the *engage* activity is a teacher-centered activity followed by a video. Teacher should gain students attention before starting the story and be EXTREMELY animated while telling it or students won’t pay attention. It is recommended that the teacher walk around the room & not read from a script while telling the story. The clip from YouTube should already be cued up on the screen ready when the teacher finishes the story. This *engage* should take about 7 minutes total including the video and occur within the classroom.
| Title: | Thinking like a scientist- *What's on the Paper*  
*For use in the beginning of the year to engage students in the scientific method while being in awe of chemistry.* |
|---|---|
| Source/website: | Modified from S. Julien “Thinking like a scientist” Fall 2009  
Used and modified by C. Christopher 2010-2013 school years |
| NYS Chemistry Standard: | STANDARD 1—Analysis, Inquiry, and Design  
Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.  
S2.1 Devise ways of making observations to test proposed explanations.  
• design and/or carry  
S2.3 Develop and present proposals including formal hypotheses to test explanations, i.e.; they predict what should be observed under specific conditions if their explanation is true.  
• develop research proposals in the form of “if X is true and a particular test Y is done, then prediction Z will occur”  
S2.4 Carry out a research plan for testing explanations, including selecting and developing techniques, acquiring and building apparatus, and recording observations as necessary.  
• determine safety procedures to accompany a research plan  

These standards are essential to helping students understand the nature of science. Students are asked to create procedures, test hypotheses and predict what is going to happen. Students will see how the scientific process works while engaging with common household materials. |
| Supplies | Small colorful spray bottles with Windex (can be labeled mystery liquid or left without a label). Cardstock that has been “written on” with phenolphthalein and dried by the teacher (with a q-tip). Messages like “chemistry is cool” or “wear goggles” or “I love chem. class” are the types of messages suggested. Students also need the handout titled “Thinking like a scientist” (appendix A). |
| Key Questions | To be asked while students are completing the “Thinking like a scientist” engage activity with a partner. **Tell me about what you’re seeing** (note: this phrasing can change based on where the students are in the activity). What do you think this substance is? What do you notice about it that makes you think that? We are completing this activity in chemistry class, why do you think we might be doing this? How is it related to chemistry? What other ways can you observe these substances? (What senses are you using)? What questions do you have based on what your saw? How would you test what you are seeing in an experiment? Why do you think these substances are doing this? When do you think this would occur? Where do you notice a change and why do you think you notice this change? What could you have done differently? |
| Summary of Engage: | After looking at the different types of chemistry, students will be presented with the *engage* activity *thinking like a scientist*. Students will be presented with a piece of white paper (cardstock) and a small bottle full of a liquid. The teacher will say “These are your supplies to help you think like a scientist. Use the guidelines presented to you on your paper, your worldly knowledge and your lab safety skills. Get with your partner, obtain materials and get started *thinking like a scientist*. This *engage* segment will be cause for students to wonder why they are given paper and a bottle. A challenge is posed to them to be a scientist and therefore engages students to wonder “why did my teacher given me paper and a bottle?” |
Students must complete observations, think about how the two objects can be used together to determine that the bottle can be SPRAYED onto the paper. When it is sprayed, writing appears. Past experience has shown that students are excited, wondering what is the material, how did it work, what is going on. This is a great *engage* to capture the attention of students. Student then get to explore a bit more with the activity making predictions, hypothesizing and asking questions. Students will be given time to discuss with other groups as they finish the *explore*. This activity will allow students to think about the scientific method while still being in awe of the chemistry behind what was going on.

| Rationale: | During the first few days of school, students are still trying to adjust to being back to school. This activity uses household products which have been found to engage students helping them learn more and perceive their teachers in a positive light due to the relevancy to students (Chairam, Somsook, & Coll, 2009). In addition, teachers who ask students to collaborate through the learning process tend to have better results and a better classroom community. The nature of this *engage* piece should peak student interest as well. The results when students to see the paper “turn colors” makes them excited to learn in chemistry class. All of this combined will help with the classroom community aspect of teaching. |
| Possible Misconceptions: | This *engage* activity may lead to students thinking that everything in science is predetermined. The teacher will know what is written on the pages and how it works. Not everything in science is this way. Students come to think this way also with cookbook labs that always have the same ending. Although this could be an issue, students are interacting with materials that are familiar to them to explore the nature of science. Students generate their own ideas and reflect to create methods uniquely their own. The presentation connected to creativity and scientific thought processes helps students understand the material better with less confusion (Criswell, 2012). To address the ideas that experiments are predetermined should be an ongoing process with the students and teacher through the school year. A discussions should take place during the explain phase of the 5E model not just about what happened, but the process and the method by which student discovered what happened. |
| Recommendations: | After handing out the paper and bottle, the questioning and using the supplies should be a student-centered activity. Teacher should gain students attention simply by holding up the paper and bottle with goggles on. Simply holding these up should have students wondering. It is recommended that the teacher walk around the room while students are completing the *engage* activity with their partner and ask the key questions. To extend this activity, the teacher should ask questions based on the nature of science derived from Michael Clough: “in what sense is scientific knowledge tentative,” “how are observations different from inferences,” “in what sense is scientific knowledge the product of human inference, imagination and creativity,” and “how does the notion of a scientific method distort how science actually works”? (“The Nature of Science,” 2013). These questions are important to helping students understand that science isn’t predetermined, it is creative, we can make observations and many times those observations lead into inferences without realizing and those same observations can lead to human interaction with facts creating a really wonderful understanding of the natural world. After the activity is
done and students have been able to both *engage* and *explore* with their peers, a discussion for the *explain* should begin. Holding up the paper followed by student exploration with the supplies should take about 20 minutes total and occur within the classroom.

| Title:               | Name that change—and defend yourself  
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<tbody>
<tr>
<td></td>
<td><em>For use to engage students in the difference between chemical and physical changes. The use of mini demos and questioning leads to a fun exciting learning centered atmosphere.</em></td>
</tr>
</tbody>
</table>
| **Source/website:**  | Created by C. Christopher 9/2/13  
NYS Chemistry Standard:

Key Ideas:

Major Understandings:
3.2a A physical change results in the rearrangement of existing particles in a substance. A chemical change results in the formation of different substances with changed properties.

*Standard 3.2a above is an extremely important standard and is addressed in a variety of different manners through the curriculum. Identifying physical versus chemical change in the activity below will provide a base set of knowledge for the topics that build upon matter changes.*

### Supplies

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Hot plate</td>
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<tr>
<td>Beaker (3x 250mL recommended)</td>
<td>Water</td>
</tr>
<tr>
<td>Matches</td>
<td>Salt</td>
</tr>
<tr>
<td>Sodium carbonate (baking soda)</td>
<td>Piece of paper</td>
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<tr>
<td>Erlenmeyer flask</td>
<td>Acetic Acid (vinegar- in small bottle)</td>
</tr>
<tr>
<td>~1 M Hydrochloric acid</td>
<td>Magnesium (ribbon or mossy)</td>
</tr>
<tr>
<td>Pennies</td>
<td>Small test tube</td>
</tr>
<tr>
<td>Volumetric flask</td>
<td>Nitric acid</td>
</tr>
<tr>
<td></td>
<td>Wet paper towels or fume hood</td>
</tr>
</tbody>
</table>

### Key Questions

To be asked through the *engage* activity as demonstrations are performed. *Tell me about what you are seeing using all of your senses.* (This can be changed slightly depending on the portion of the activity occurring). *What might happen if I combine these two substances? What can I do with these supplies that would produce some type of change (whether physical or chemical)? What type of change do you think it is? (think pair share → share out) What do you notice about it that makes you think that? Can you elaborate? Call on a different student Listening to this explanation, is it correct for what is happening in this situation and explain why or why not. What kinds of things might you do to it to change its classification?*

### Summary of Engage:

Students will enter into a challenging and “highly controversial” *engage* piece. The *engage* segment will be closely linked to many common actions they’ve seen before. It will pose a challenge to the class to learn more about a topic. The teacher will start with explaining the activity:

“In the next few minutes, I am going to show you some changes that you may or may not have seen before. It is your job as a class to come to a consensus on whether the change is a physical or chemical change. We’ve look at different types of properties, but not changes. I am not going to lead the discussion, but everyone in the class MUST agree. If there is even one person who thinks the change is different than the rest of the class, each side will have to present an argument before coming to a conclusion as a class. I wish you all luck. Turn to the person you’re sitting next to and explain what you’re doing for 1 minute. (wait) Do you have any questions?”

The teacher should start with the “easy” changes and work up to the hard ones. After performing each change, the teacher should wait for students to discuss and come to a conclusion. If necessary, the teacher can help the conversation along with key questions.

A hot plate with water in a beaker should be on and pointed out when it boils.

The teacher should start by holding up a piece of paper and tearing it in half.
The teacher should then take one of the pieces of paper, light a match and burn the paper. The paper should be extinguished within 10 seconds of lighting in a sink combined with blowing it out.

A beaker should be filled about ¾ full of water and the teacher should dump salt into the water.

The teacher should have a small, what appears to be water, in an unmarked bottle with vinegar in it and a small cup of baking soda. The two should be combined into a beaker or Erlenmeyer flask. In addition to the key questions, the students should be asked “What do you think these materials are and what leads you to that conclusion? What is your evidence?”

Magnesium ribbon or mossy should then be added to a test tube containing ~1M hydrochloric acid.

5-6 pre 1982 pennies should be added to the volumetric flask, a paper towel should be obtained and rinsed in the sink to make wet and ~5 drops of concentrated nitric acid should be added to the flask and immediately covered with the paper towel to prevent poisonous gas from escaping into the room. The alternative is to complete this in the fume hood.

The beaker on the hot plate (boiling) should be pointed out. The teacher will have to do the most guiding on this to help students obtain the proper change.

During all of these demonstrations, the key questions should be asked and students should be discussing whether the change is physical or chemical.

At this point, students are expected to be “hooked” and excited about chemistry. They should have questions in their mind about what is the definition of physical and chemical changes. The teacher should then have students develop definitions for physical and chemical changes based on what they described and saw. Students will be given time to discuss.

**Rationale:** Many teachers simply given notes regarding what physical and chemical changes are only to follow the lecture with a lab or demonstration. The order is changed so students are actively engaged with each other and the presentation of “cool” chemistry demos to create a definition at the end. Some students may be frustrated with the lack of direction, but the purpose of this activity is to have students working with each other. The nature of this engage piece should peak student interest as well. It is also possible that students have seen these changes before and will feel more comfortable as they make connections to prior learning experiences. The familiarity with concepts will help with the classroom community aspect of teaching.

In addition to having students generate conversation and the teacher asking questions, Milne and Otieno (2007) have found that demonstrations can help students to participate in classroom discussions, be excited to come to class or work harder than usual to complete an assessment or task in class. It was also found that after a demonstration, there is a mutual focus within the classroom which results in a greater feeling of belonging for students in the classroom (Milne and Otieno, 2007). After these sets of mini-demonstrations, the class has worked together to solve a problem and challenge that the teacher has presented.

**Possible Misconceptions:** Looking at physical versus chemical changes in this engage activity does not address the particulate nature of the chemical and physical changes that are being presented to students. According to Aydeniz and Kotowski, many students do not understand
how processes work on a microscopic level even when they’ve seen the macroscopic level. The teacher must use particulate drawings to explain physical and chemical changes. Doing this after the activity has been completed or during the explore or elaborate might be a good idea. Teachers could draw two different molecules in a box all spaced out. Then students should be asked to work with a partner and try and develop a picture for physical change and one for chemical change. The initial drawing could look similar to the one created below:

![Physical change](image1)
![Chemical change](image2)

This activity would allow the teacher to see how students are thinking about the changes and help students to solidify definitions and what they are thinking. Completing this follow up activity explicitly addresses the particulate nature of matter misconceptions, which, according to Ozmen (2007), should help decrease students misconceptions.

**Recommendations:**
Completing the demonstrations is a teacher-centered demonstration followed by student-lead discussion to determine the type of change. The teacher should gain the attention of all of the students before starting and help to create “controversy” by playing devil’s advocate if necessary to generate classroom discussion related to the types of changes. The purpose is for students to get excited enough and passionate enough to defend their position and rally the class together. The discussion and demonstrations should take about 20 minutes total. The follow-up to aide with dispersion of misconceptions and development of definitions will add 10 minutes and occur within the classroom.

**Title:**
States of People

For use before drawing particle diagrams of solids liquids and gases to create community, refresh students memory and engage students in chemistry!

**Source/website:**
Modified by C. Christopher 9/14/13 from P. Brennan from fall 2010.

**Research Support**


Ozmen, H. (2007). The effectiveness of conceptual change texts in remediating high school students' alternative conceptions concerning chemical equilibrium. Asia
<table>
<thead>
<tr>
<th>NYS Chemistry Standard:</th>
<th>Key Ideas:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1jj The structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure.</td>
<td></td>
</tr>
<tr>
<td>3.1kk The three phases of matter (solids, liquids, and gases) have different properties</td>
<td></td>
</tr>
</tbody>
</table>

Standards 3.1jj and 3.1kk are addressed directly as students have solid background knowledge on what a solid, liquid and gas do. The clarifying point in this activity is through questioning what the particles do, their interactions and their arrangement.

<table>
<thead>
<tr>
<th>Supplies</th>
<th>A verbal or printed title to the activity (States of people) and a challenge given to students to gain and focus their attention</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Key Questions</th>
<th>To be asked during the states of matter making. Tell me about how you are arranged? What indicates that you are a (solid, liquid gas)? Students should be directed towards talking about distance and spacing, as well as movement (how much and where), and speed, collisions and fluidity. What can you tell me specifically about your movement as a solid? (This is addressed as a specific question because of the misconception that solid particles do not move at all). Why did you arrange yourselves like this? Gas phase only as you are moving quickly, show me what might happen if you collide with something (NOT SOMEONE!). What kinds of things might you do to it to change from one state to another?</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Summary of Engage:</th>
<th>Students will enter into a motivating and relevant engage piece on a topic that they are already familiar with. A challenge is posed to them to work as a class to model the states of matter. The teacher will start by saying “We are going to do an activity called (dun dun dun) STATES OF PEOPLE!!! Your goal as a class is to make the 3 states of matter with yourselves! Let’s start with a solid.” If students don’t get up, the teacher should instruct students to move and arrange themselves like a solid. The teacher should then ask the key questions related to solids. After asking the questions the teacher should ask for the other states of matter and follow each with the same key questions, but modified for the correct state of matter. During the gas phase, be sure to ask the gas specific question (student should bump into objects and fly off). The teacher may have to demonstrate this. When all of the states have been modeled the teacher should ask the last key question and have students return to their seats to discuss this as a class. At this point, students are expected to be “hooked” and excited to see how the states of matter apply to chemistry.</th>
</tr>
</thead>
</table>

| Rationale: | The state of matter concept is familiar to students, but having student act them out takes an “old topic” and puts a fun kinesthetic spin on it. Students know what a solid, liquid and gas are as well as some properties, but chemistry adds the particle diagrams. Using themselves as particles in this activity gets to the root of the particulate nature of what is going on in the states of matter. According to Aydeniz and Kotowski (2012), teachers must know and explicitly address misconceptions in lessons related to particles. They should address them not just by describing, but by looking at the microscopic interactions between particles; this is exactly what the “states of people” activity does. The nature of this engage piece should get students talking with one another to create the best solid, liquid and gas. A leader usually steps up and directs what should be |
happening. The interactions required to make the states of matter will help with the classroom community aspect of teaching.

**Possible Misconceptions:**

Students have the misconception about solid particles that they do not move. This is addressed throughout the key question that asks “What can you tell me specifically about your movement as a solid?” According to Ozmen (2007), students were able to alter their particulate nature misconceptions more thoroughly when presented with alternative methods of teaching, not lecture. The movement in this activity is certainly an alternative method.

![Solid, Liquid, Gas diagram](http://www.scienceedemo.co.il/en/gallery_image.asp?return_parent=0&gallery_id=714)

The figure to the left is what the students represent through movement of their bodies. Figure from: (American Chemical Society, 2013)

**Recommendations:**

Creating the states of matter with their bodies is a student-centered activity with teacher questions for prompting. Teachers should be EXTREMELY excited when explaining the activity. It is recommended that the teacher be a particle of the states of matter with the students. This *engage* should take about 10 minutes and occur within the classroom or a smaller controlled space.

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**Title:**

What did you do? Endothermic demonstration  
*For use in the beginning of the topic of energy when talking about heat transfer to engage students in chemistry!*

**Source/website:**

Modified by C. Christopher 9/14/13 from A. McGrath during fall 2010. You tube clip of this demonstration found at:  [http://www.youtube.com/watch?v=GQkJI-Nq3Os](http://www.youtube.com/watch?v=GQkJI-Nq3Os)

**Research Support**


**Key Ideas:**
2.4 Compare predictions to actual observations, using test models.
4.1b Chemical and physical changes can be exothermic or endothermic.

*Standard 2.4 addresses the importance of using observations which is an essential component to the following demonstration. Standard 4.1b is addressed in a limited manner as students have little background knowledge. By the end of the engage portion, students are expected to ask questions like “how does this work?”, “What makes it do that?”*

**Supplies**
Barium hydroxide octahydrate \( \text{Ba(OH)}_2 \bullet 8\text{H}_2\text{O} \), ammonium chloride (\( \text{NH}_4\text{Cl} \)) or ammonium thiocyanate, Erlenmeyer flask, piece of wood to set the flask on and goggles, water. A story told to the students while the reaction is taking place.

**Key Questions**
To be asked during the demonstration and after. *What state of matter do these two substances seem to be as we start? Let’s predict: what will happen if I mix these two together? Tell me about what you are seeing? What has started happening to the two substances? As I am stirring these two substances I am noticing a distinct odor, what can you tell me about the reaction?* (lead to the idea that reactants are different than products) *What do you think this substance is that we smell? What do you notice about it that makes you think that? When I lift the flask, what are we noticing? How did that happen or what may I have done to help this?* While walking around with the flask ask students to touch the flask and ask *what are some observations about the flask you can tell me?* The picture seen to the left is what should happen when the flask is raised ("Endothermic Reaction 1060-06," n.d.).

**Summary of Engage:**
The teacher must set up the demonstration by obtaining 32 g of barium hydroxide octahydrate and 17 g ammonium thiocyanate in two separate containers. The teacher also needs to obtain a block that is “pre-watered” so the students do not see it happening.

When students enter into the classroom, a demonstration is exciting to them. The teacher should start with the key questions of describing the solids and predicting what will happen. The teacher should put the two solids together and place them on the wooden block, stir the contents and continue asking the key questions. The teacher might start to say (after the liquid is formed) “I’m not sure this is going to work- it doesn’t seem to be doing much- any thoughts on what I can do to make this work?” Students might wonder why the teacher is stumped and should question what is happening. They should start giving suggestions. The teacher can follow the suggestions OR the teacher can pick of the flask and have the wooden block come with it. This should elicit a reaction from students of excitement, awe and hopefully more questions. The teacher should entertain the questions and describe what was going on in the demonstration. The endothermic, freezing and chemical change pieces should be specifically discussed.

**Rationale:**
The mixing of the two solids is extremely exciting for students as they “don’t know what’s coming.” The idea of endothermic reactions is extremely difficult for students to understand and this helps to provide a concrete example and build understanding before the topic is discussed in class. Although a chemistry teacher may not find this topic boring, many students do. By adding a demonstration, student interest should be peaked. The block sticking to the flask is the “hook” that provides help to keep students interested in the class instead of worrying about who is texting or tweeting (Milne & Otieno, 2007). In addition to questioning, having the class work together to come to a common
prediction and working with the teacher as an equal to “determine what else to do” when
the demonstration “isn’t working” is helpful according to Milne and Otieno (2007). The
equality helps to create a “positive emotional energy” within the room and provides huge
benefits to students (Milne and Otieno, 2007).

### Possible Misconceptions:

When students feel the flask and how cold it is, the common misconception is that the
students hand is “taking away the cold.” While correct in some respects, the main idea
that the reaction is endothermic or absorbing heat from the surroundings is contradictory
to what students believe. It must be pointed out that the flask feels cold because the
reaction is absorbing heat or bringing heat INTO the reaction. This causes it to feel cold
when touched because the chemical reaction is taking away the heat- your hand isn’t
“giving heat away.” According to Aydeniz & Kotowski, teachers must know what the
misconceptions are for a particular topic and explicitly address these misconceptions
(2012). It is also suggested that teachers address these misconceptions directly on both
the macroscopic and microscopic level especially when related to changes associated
with matter (Aydeniz & Kotowski, p.64, 2012).

### Recommendations:

The demonstration is a teacher-centered activity mixed with student questions to lead to
student-centered discussion. The teacher should make sure the wooden block is wet
before any students are in the room OR pretend to get it dirty and have to wash it off in
the sink. A worksheet could be paired with this activity for a “Before During After”
prediction. The author of this engage activity does not use a BDA activity. As a teacher,
be prepared and ready to sell the idea that the demonstration is “going wrong” so that you
can get as many student ideas as possible. As a teacher, the question “what is supposed
to happen” should not be answered by you. Asking questions, mixing the solids, getting
it to stick to the block followed by the questions should take about 7 minutes total and
occur within the classroom.

| Title: | Who is Rutherford and what did he discover?  
*For use to introduce Rutherford’s gold foil experiment to students. This gives students a chance to “do” the same experiment.* |
| Source/website: | Modified by C. Christopher 9/21/13 from E. Muller 2003  
http://www.exo.net/~emuller/activities/Rutherford%20Roller.pdf#search=%22Rutherford%20experiment%20with%20marbles%22 |
doi:10.1080/02635140802658933  
### NYS Chemistry Standard:

3.1a The modern model of the atom has evolved over a long period of time through the work of many scientists.

3.1b Each atom has a nucleus, with an overall positive charge, surrounded by negatively charged electrons.

*Standards 3.1a and 3.1b are addressed in a limited manner in this particular engage. Students have already made a timeline of the history of the atom. Students are asked to go more in depth with the work of Earnest Rutherford who discovered the nucleus and that the atom was mostly empty space. Students should come to the same conclusion as they work through this engage. By the end of the engage portion, students are expected to ask questions like “how do you figure this out?”, “Determining the size and shape of the nucleus was difficult with our supplies, how was this even possible with an atom?”, “What makes the marble do that?”*

### Supplies

Cardboard with a small piece of wood or a smaller piece of cardboard (shaped like a square, triangle, rectangle or trapezoid shape) hot glue gunned or taped to the bottom. One marble per group, butcher paper, marker or colored pencil. A story told to the students about Rutherford and directions given to students for their task.

### Key Questions

Note: Questions related to the story are included in the summary. These questions are to be asked after the engage during the explore activity and after with the whole class.

*Tell me about what you saw (are seeing)? What do you notice about your lines on the paper? What do you think this substance is? What do you notice about it that makes you think that? What other tests would you like to conduct for more information?*

### Summary of Engage:

Students will enter into an experimentally driven engage piece with kinesthetic learning being used to learn one of the most important experiments conducted in the development of the history of the atom. The teacher will start with a story:

“A few years ago, approximately 103, in a land far far away (Manchester England) there was a man- Earnest Rutherford. Now Rutherford had studied as far away as New Zealand and Canada, but had returned to his home country as a professor at Manchester. He started working with JJ Thomson and radioactive materials. Now Rutherford did many different experiments and helped to find the atomic numbers of the elements using something called emission spectra. One more fascinating piece of information about Rutherford is that in 1914 he was knighted for all of his hard work. So that was a bit more information about him, but today- yes today- we are going to complete a simulation of his most famous experiment. Rutherford’s job (working with JJ Thomson) was to conduct an experiment to prove that the plum pudding model was correct using radioactive material. Sadly (or not so sadly) we will not be using radioactive material. The radioactive material that Rutherford used was shot at a piece of gold foil. Again-sadly, no gold foil. We are going to use a marble as our simulation for the radioactive materials (alpha particles to be specific) and an “atom” which I have constructed. It is going to be your task together with your colleagues (classmates) to come to some conclusions using these materials. Rutherford shot the alpha particles at the gold foil to come to 2 conclusions. What do you think you’re going to do with the marble and “atom”? (Try and get the marble “through the atom”)

YES! I have also provided you with butcher paper. What might this be useful for?
(we could track where the marble goes so we can make conclusions at the end)

BRILLIANT! Now, while it took Rutherford a few years to complete his project (and in the end obtain a Nobel prize), I am giving you 5 minutes with your partners to track your marble’s location within the atom. One MAJOR rule- you may not flip over the atom. Just as Rutherford couldn’t see what was in the atom, you can’t either. As a class we will come together at the end of 5 minutes to discuss what we’ve found. Turn to your partner for 1 minute, discuss your implementation plan and see if you have any questions.” Wait 1 minute for discussion and ask for any further questions. Have students go to an “atom” located around the room on the floor on butcher paper, obtain a marble and marker.

At this point, students are expected to be “hooked” and excited to complete the explore activity described in the story above. They should have questions in their mind about what is the substance, how can we do that, and why won’t the teacher just tell us the conclusions? Students will be given time to discuss as they are asked to begin their follow up explore activity. Students will complete the activity described.

| Rationale: | Rutherford’s experiment is one of the most important concepts within the history of the atom. Students are often given picture representations or have it verbally explained to them. Students get to “experience” what Rutherford did to discover the nucleus by using a marble aimed at the atom in this engage portion. Students should be excited for an activity that allows them to model a major experiment in the history of the atom. Learning by doing, instead of being told, is an essential component to constructivism, inquiry and Vygotsky’s theories (King, 2010 and Chairam, Somsook, & Coll, 2009). Students are set up for constructing their own knowledge through doing an experiment like a “real scientist” (Chairam, Somsook, & Coll, 2009). This isn’t a predetermined step by step procedure, it asks students to figure out a problem. With a bit of background and history on Rutherford, students should be excited to engage in the real experiment that he conducted. |
| Possible Misconceptions: | Students may think that both the nucleus and alpha particles are much bigger than they really are due to the nature of the simulation. Note- the teacher should address with students the size of the nucleus (compare to marble inside a football stadium). When discussing the explore activity after it is complete, teacher should prompt students to aide in drawing what an atom looks like. Another possible fault in this engage is that students may think they need to memorize the story told. Ensure students before telling the story that this is a fun, but true story—not something they are required to know. |
| Recommendations: | The telling of the story is teacher-centered followed by an explore activity described in the Summary of engage section. Teacher should gain students attention before starting the story and be EXTREMELY animated while telling it or students won’t pay attention. It is recommended that the teacher walk around the room & not read from a script while telling the story. The story and explaining of the explore activity should take about 7 minutes total, occur within the classroom. The explore activity can begin. The picture to the left is what may result from the explore activity leading students to come to similar conclusions as Rutherford (‘Rutherford
<table>
<thead>
<tr>
<th>Title:</th>
<th>Atomic Nucleus- Motivational Song</th>
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<tbody>
<tr>
<td></td>
<td><em>For use in the beginning of the “atom” unit to create community through humor and engage students in chemistry!</em></td>
</tr>
<tr>
<td>Source/website:</td>
<td>Modified by C. Christopher 9/8/13 to use with: <a href="http://www.youtube.com/watch?v=TCUK93s1jUY">http://www.youtube.com/watch?v=TCUK93s1jUY</a></td>
</tr>
<tr>
<td>NYS Chemistry Standard:</td>
<td>Key Ideas:</td>
</tr>
<tr>
<td></td>
<td>3.1b Each atom has a nucleus, with an overall positive charge, surrounded by negatively charged electrons.</td>
</tr>
<tr>
<td></td>
<td>3.1c Subatomic particles contained in the nucleus include protons and neutrons</td>
</tr>
<tr>
<td></td>
<td>3.1d The proton is positively charged, and the neutron has no charge. The electron is negatively charged.</td>
</tr>
</tbody>
</table>
3.1e Protons and electrons have equal but opposite charges. The number of protons equals the number of electrons in an atom.

Standards 3.1c and 3.1d are addressed directly in the song. Both 3.1b and 3.1e are addressed in a limited manner as they have no background knowledge. By the end of the engage portion, students are expected to have a basic understanding of these standards.

<table>
<thead>
<tr>
<th>Supplies</th>
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<tbody>
<tr>
<td>Directions told to the students to gain and focus their attention on the video as well as a computer with either internet access or a file stored on flash drive of the video found at: <a href="http://www.youtube.com/watch?v=TCUK93s1jUY">http://www.youtube.com/watch?v=TCUK93s1jUY</a></td>
</tr>
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<table>
<thead>
<tr>
<th>Key Questions</th>
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<tbody>
<tr>
<td>To be asked after the completion of the video and through the follow up activity. So I said this was a funny video, in what ways is it related to chemistry? Tell me about what you saw? (THINK, pair, share probably necessary with the nature of video). What sort of information can we obtain from this segment? What do you think this song is referring to? What do you notice or what evidence is there to make you think that?</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Summary of Engage:</th>
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<tbody>
<tr>
<td>Students will enter into an engaging and culturally relevant piece. A “silly song” will be used to engage students and pose the challenge to students to learn more about a topic. The teacher will say “This is the BEST video I’ve found relating to chemistry and the atom. It has the best song EVER and will help you significantly as we continue learning chemistry. Pay attention as I will be looking for your help to make a list of what we’ve learned.” The video found at <a href="http://www.youtube.com/watch?v=TCUK93s1jUY">http://www.youtube.com/watch?v=TCUK93s1jUY</a> titled “Atomic Nucleus- Motivational Song” will be shown. Following the song, laughter and awe will likely follow. The teacher should then engage students with the key questions. At this point, students are expected to be “hooked” and excited about chemistry. They should have questions in their mind about why are we watching this fun ridiculousness in chemistry class? Students will be given time to discuss as they are asked to begin their follow up explore activity. Students will be able to work with groups to analyze an article to explore concepts related to the atom.</td>
</tr>
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<table>
<thead>
<tr>
<th>Rationale:</th>
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<tbody>
<tr>
<td>The video with the atomic nucleus song engages student by sparking interest in an extremely important topic for chemistry. With the enthusiasm of the teacher combined with the “silliness” of the video, students should see that the teacher is indeed a real person and bring the class together around this video. It is also possible that students have heard of the nucleus before and will feel more comfortable as they make connections to prior learning experiences. Connections to prior learning and the funny video will together help with the classroom community aspect of teaching. By using the video and engaging students in the material before going into lecture, this activity changes the way classroom time is spent. According to Rop (2003) spending more time and allowing students to think, ask questions and engaging students is the first step to creating an inquiry classroom where students are engaged in the material.</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Possible Misconceptions:</th>
</tr>
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<tbody>
<tr>
<td>The video engage activity may lead to students thinking that protons, neutrons and electrons are all the same size and mass. All of the singing subatomic particles are the same size. That being said, the mass and size of these particles is directly addressed in the explore and explain segments that will follow this activity.</td>
</tr>
<tr>
<td>Recommendations:</td>
</tr>
<tr>
<td>---</td>
</tr>
</tbody>
</table>
| Title: | Isotopes are cool? A new tool for Crime fighters  
*For use in the beginning of the topic of isotopes to generate discussion and interest in an otherwise “boring” topic.* |
| Source/website: | Created by C. Christopher 9/14/13 modified article from:  
format for questions from Mike Breed: Chenango Valley HS Science Dept. dropbox:  
[https://www.dropbox.com/sh/j36inl6xcm0mv0w/eG23CtmExE](https://www.dropbox.com/sh/j36inl6xcm0mv0w/eG23CtmExE) |
### Research Support:

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Title</th>
<th>Journal</th>
<th>Volume</th>
<th>Issue</th>
<th>Pages</th>
<th>DOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rop, C. J.</td>
<td>Spontaneous inquiry questions in high school chemistry classrooms: Perceptions of a group of motivated learners.</td>
<td>International Journal of Science Education</td>
<td>25</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### NYS Chemistry Standard:

- **3.1g** The number of protons in an atom (atomic number) identifies the element. The sum of the protons and neutrons in an atom (mass number) identifies an isotope. Common notations that represent isotopes include: $^{14}$C, $^{12}$C, carbon-14, C-14.
- **3.1m** Atoms of an element that contain the same number of protons but a different number of neutrons are called isotopes of that element.
- **3.1n** The average atomic mass of an element is the weighted average of the masses of its naturally occurring isotopes.
- **3.1o** Stability of an isotope is based on the ratio of neutrons and protons in its nucleus. Although most nuclei are stable, some are unstable and spontaneously decay, emitting radiation.

*The above standards are addressed in a limited manner as students have no background knowledge. By the end of the engage portion, students are expected to ask questions like “how does this work?”, “What makes it do that?”, “How do we get different isotopes?”*

### Supplies


### Key Questions

To be asked after the completion of the reading to start the conversation and if necessary to aide in the discussion. *Tell me about what you read. In what ways is this related to chemistry? What societal implications might this have? What other kinds of things might this be helpful for? Are there any negatives to this discovery- if yes what are they and why are they bad- if no, why not?*

### Summary of Engage:

Students will enter into a motivating and relevant *engage* piece on the first day of isotopes. Using a story to *engage* students will be closely linked to their lives and will pose a challenge to them to learn more about a topic. The teacher will start with an introduction: “Before we learn about isotopes in class, I would like you to have some ‘real world’ background knowledge related to isotopes. This is an article that I found fascinating and I’m 99% certain you will also enjoy it. The title is: *A New Tool for Crime Fighters*. Your goal is to read the article, find a few interesting pieces of information, learn some new vocabulary and talk about the implications. We will come together when everyone has completed the reading and discuss our findings. We will have a discussion about the implications and each person must make at least
one contribution to the discussion. This is an exciting challenge and it is my expectation that you will take it seriously.”

When all students have completed the reading the teacher will ask the class to arrange their desks so that they’re in a “u” or circle (depending on arrangement of the classroom). The teacher should start with the key question “tell me about what you read.” The teacher should serve as facilitator for the discussion, not the center of the discussion. If necessary, the teacher can continue with the key questions.

At the end of the discussion, students are expected to be “hooked” and excited about isotopes. Students will be able to work with model isotopes (m&m’s) to help dive deeper into the content.

| Rationale: | The reading serves as a “real world” connection for students between the classroom and their lives. Many of the students in chemistry classes are interested in forensics and medicine and this connects to those topics as well. In addition to serving as a connection, it helps to peak student interest in an otherwise “boring” topic. The discussion at the end of the engage activity serves to create social awareness and community when students are engaging in discussion constructing their own knowledge. According to Vygotsky, knowledge must be constructed through the use of language and communication between learners (Chairam, Somsook, & Coll, 2009). The discussion surrounding the article should lead to student questioning which has been studied by Lang, Wong, and Fraser (2005) related to student perceptions and therefore learning. It has also been studied by Rop (2003) who looks at the different types of questions that are asked by students. The current activity allows for all types of questioning supported by the teacher looking for deeper answers and questions which, according to Lang, Wong and Fraser, should lead to a more conducive learning environment. King (2012) also revealed that students have a higher interest in the subject when they are engaged in real world problems and situations. |
| Possible Misconceptions: | Students think that it is easy to measure ratios of isotopes based on the reading. With the proper equipment, it is not difficult, but in a high school chemistry lab, it is. The reading about isotopes actually helps dispel many common misunderstandings. This addresses that there are many different isotopes around the world and that each oxygen doesn’t have a mass of 15.9994g/mol nor does each hydrogen have a mass of 1.0079g/mol, but that this is a weighted average that can be determined from the ratios of isotopes found around the world. In this case, in different cities. |
| Recommendations: | The discussion following the reading should be a student-centered activity with minimal teacher input. The teacher should monitor student progress through the article and questions to ensure timeliness as well as depth in answering questions. The entire engage activity should take about 45 minutes total including reading (which can be done in class or at home) followed by the discussion. |
| Title: | Why Fireworks? Relating fireworks to the chemistry of electrons For use before flame tests to engage students in the safety and enjoyment of chemistry! |
| Source/website: | Created by C. Christopher 10/6/13 Researched on http://scifun.chem.wisc.edu/chemweek/fireworks/fireworks.htm Image taken from Chemistry Listserv from P. Iacovella: Washingtonville HS |
| Research Support | King, D. (2012). New perspectives on context-based chemistry education: Using a... |
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<table>
<thead>
<tr>
<th>NYS Chemistry Standard:</th>
<th>Key Ideas:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.1i Each electron in an atom has its own distinct amount of energy.</td>
</tr>
<tr>
<td></td>
<td>3.1j When an electron in an atom gains a specific amount of energy, the electron is at a higher energy state (excited state).</td>
</tr>
<tr>
<td></td>
<td>3.1k When an electron returns from a higher energy state to a lower energy state, a specific amount of energy is emitted. This emitted energy can be used to identify an element.</td>
</tr>
</tbody>
</table>

*Students have addressed these standards in a limited manner. Both excited and ground states have been discussed, but color emission has not. By the end of the engage portion, students are expected to ask questions like “how does this work?”, “What elements have which colors” “What rules must be followed to stay safe?”*  

| Supplies | A story told to the students to gain and focus students attention on the topic and the chemistry of fireworks image Appendix A. |

| Key Questions | To be asked during the story. *What can you tell me about fireworks? Who can tell me why we might be talking about fireworks today?* (because we’re going to make them? (no), they’re related to chemistry! (yes)). In what ways are they related to chemistry? (made of chemicals, explode, combust, make color) All great things, I want to zero in on who said “make color.” Based on what we’ve learned so far, is there any indication as to what might CAUSE the fireworks to “make” color in the sky? (share with a group). Any groups think they have a piece of the puzzle as to how fireworks create color? In what ways will our experiment be different than that of fireworks? In terms of safety what should we do when we are conducting our flame tests? How is this similar to fireworks? |

| Summary of Engage: | Students will enter into a motivating and relevant *engage* piece on “flame test” day. This *engage* segment will be closely linked to their lives and will pose a challenge to them to learn more about a topic. The teacher will start with a story: “Before we get started with our flame tests today, I thought we should talk a little about FIREWORKS! What can you tell me about fireworks? (color, sound, pollute, explosive, dangerous, illegal in NYS to buy). Who can tell me why we might be talking about fireworks today (because we’re going to make them? (no), they’re related to chemistry! (yes)). This is when the image seen in appendix A should be shown. In what ways are they related to chemistry? (made of chemicals, explode, combust, make color) All great things, I want to zero in on who said “make color.” Based on what we’ve learned so far, is there any indication as to what might CAUSE the fireworks to “make” color in the sky? (share with a group). Any groups think they have a piece of the puzzle as to how fireworks create color? (let all groups share, commenting and asking questions as they go). In what ways will our experiment be different than that of fireworks? In terms of safety what should we do when we are conducting our flame tests? How is this similar to fireworks? |

At this point, students are expected to be “hooked” and excited about how the
different salt compounds emit light after they’ve been excited. Students now know “how fireworks work.” Students will be given time to discuss as they are asked to begin their follow up *explore* activity. Students will be able to work with salts of the different compounds in the lab setting to determine color.

<table>
<thead>
<tr>
<th>Rationale:</th>
<th>Flame tests are always and exciting experiment for students, but they don’t always make the connection to the real world. According to Orgill and Thomas (2007) the more a concept can be related to the real world, the more student interest in class. According to King (2012) science technology society based education can be extremely useful for students. Societal based education requires that the concepts be linked to real world activities. Fireworks are something the most students have experiences seeing and hearing and even if they haven’t they’ve heard of fireworks before. The familiarity with the topic will help with the classroom community aspect of teaching and students excited to learn.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible Misconceptions:</td>
<td>Talking about fireworks before flame tests may lead to students thinking that elements lighting on fire is what causes the colors. The light causing the fire can be addressed immediately if the teacher refers to the image and explains that the “elements” are in a compound- a salt more specifically. During the <em>explore</em> portion where students are completing flame tests, they see that it is not the metal form they are putting into the flame, but a salt.</td>
</tr>
<tr>
<td>Recommendations:</td>
<td>Talking about fireworks is a teacher centered activity with student questioning and input to increase engagement. Teacher should gain students attention before starting the story and be excited and EXTREMELY animated while asking questions. It is recommended that the teacher walk around the room &amp; not read from a script while telling the story. The discussion about fireworks and showing of the pictures as the <em>engage</em> activity should take about 5 minutes total including the student discussion and occur within the classroom.</td>
</tr>
</tbody>
</table>

### Title:

Are the elements cool? YouTube

*For use in the beginning of the periodic table unit to engage students in chemistry!*

### Source/website:

Created by C. Christopher 9/16/13

You tube clip found at: [http://www.youtube.com/watch?v=DYW50F42ss8](http://www.youtube.com/watch?v=DYW50F42ss8)

### Research Support

| NYS Chemistry Standard: | Key Ideas:  
2.1 Revise a model to create a more complete or improved representation of the system.  
• show how models are revised in response to experimental evidence, e.g., atomic theory, Periodic Table  
3.1u Elements are substances that are composed of atoms that have the same atomic number. Elements cannot be broken down by chemical change.  
3.1v Elements can be classified by their properties and located on the Periodic Table as metals, nonmetals, metalloids (B, Si, Ge, As, Sb, Te), and noble gases.  
3.1w Elements can be differentiated by physical properties. Physical properties of substances, such as density, conductivity, malleability, solubility, and hardness, differ among elements.  
3.1x Elements can also be differentiated by chemical properties. Chemical properties describe how an element behaves during a chemical reaction.  
3.1y The placement or location of an element on the Periodic Table gives an indication of the physical and chemical properties of that element. The elements on the Periodic Table are arranged in order of increasing atomic number.  

Standards 3.1v and 3.1y are addressed in a limited manner as students have no background knowledge regarding the periodic table. The other standards are prior knowledge and should be discussed between students and teachers before the video during questioning. |
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Supplies</td>
<td>A story told to the students to gain and focus their attention as well as a computer with either internet access or a file stored on flash drive of the video found at: <a href="http://www.youtube.com/watch?v=DYW50F42ss8">http://www.youtube.com/watch?v= DYW50F42ss8</a></td>
</tr>
<tr>
<td>Key Questions</td>
<td>To be asked before the video (also seen in summary section): What can you tell me about the periodic table that we know so far? After the completion of the video and through the follow up activity. Tell me about what you saw? In what ways do you think this video is related to chemistry? What types of questions do you have about the video or ideas in it? If I looked at the periodic table 100 years ago, how would it have been different? What kinds of things might have caused this change?</td>
</tr>
</tbody>
</table>
| Summary of Engage: | Students will enter into a motivating and relevant engage piece on the first day of the periodic table unit. Up to this point, the teacher should have been talking about really how wonderful the periodic table is based on the location of the elements in the table. Prefacing all interactions with this idea will have students excited to start the unit. The video and fast paced nature of the engage segment will be closely linked to fast pace of their lives and will pose a challenge to them to learn to become excited about the topic. The teacher will start with a story: 
“Today we start on a new adventure- the adventure of exploring the periodic table! We want to make sure we take on the challenge before its Argon (pause for laughter or explanation of joke). Ok- so really the periodic table is wonderful. What can you tell me about the periodic table that we know so far? (ask questions to talk about elements, metals, gases, solids, different specific heats and densities). With over 100 elements on the periodic table, I find it fascinating all of their names- for example: Rutherfordium (what do we know about him?), Plutonium (what does this
The video found at [http://www.youtube.com/watch?v=DYW50F42ss8](http://www.youtube.com/watch?v=DYW50F42ss8) titled “Tom Lehrer CHEMISTRY element song”

At this point, students are expected to be “hooked” and excited about the periodic table or in absolute amazement. They should have questions in their mind about what the different elements do, why certain pictures appeared for each element and how they are arranged on the periodic table. Students will be given time to discuss as they are asked to begin their follow up explore activity. Students will be able to work with 20 random objects and asked to arrange them into columns and rows (like the periodic table).

**Rationale:**
While a chemistry teacher may find the periodic table extremely intriguing, teenage chemistry students do not usually agree. The “elements video” serves to ignite their interest in what they might consider a “boring topic.” It should spark interest; create a positive feeling in the room related to the topic of the day. When student to teacher interactions are rated as positive, it has been found that positive student to teacher relationships are essential (Lang, Wong, and Fraser, 2005). The questioning method that is done by the teacher prior to the video is essential to the success of the activity. Teachers should reflect on the type of questions they ask as well as their own openness to student questions, attitudes and statements as these all can affect enjoyment of the subject (positively or negatively). The questioning allows students to activate prior knowledge and be present mentally when the video starts and will help with the classroom community aspect of teaching.

**Possible Misconceptions:**
The story followed by the video for this engage activity may lead to students thinking that chemistry is just memorizing facts. The teacher can discuss this misconception by explaining that this video was for fun to get the class excited about the periodic table.

**Recommendations:**
A teacher-centered story followed by a video is what makes up this engage. Teacher should gain students attention before starting the story and be EXTREMELY animated while telling it or students won’t pay attention. The clip from YouTube should already be cued up on the screen ready when the teacher finishes the story. The story followed by the song should take about 5 minutes total and occur within the classroom.

The picture to the left is of Tom Lehrer performing the elements song.

**Title:**
Going to a school Dance- using models

*For use before teaching types of reactions to help student engage with the concepts.*

**Source/website:**
Created by C. Christopher 10/11/13 concept modified from POGIL types of reactions

**Research Support**
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<table>
<thead>
<tr>
<th>NYS Chemistry Standard:</th>
<th>Key Ideas:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.2b Types of chemical reactions include synthesis, decomposition, single replacement, and double replacement.</td>
</tr>
<tr>
<td></td>
<td>Standard 3.2b is indirectly addressed using this engage activity. Students have no background knowledge and their teacher will use a story to engage in a “dance” that describes all four of these types of reactions. By the end of the engage portion, students are expected to ask questions like “why is she asking us questions about middle school dances?” “does this have to work always?”, “what makes it do that?” and “how is a middle school dance related to chemistry?”</td>
</tr>
</tbody>
</table>

| Supplies | A story told to the students to gain and focus their attention as well as a smart board or white board to draw on. |

| Key Questions | To be asked during and after the engage activity. Who remembers a middle school dance? What can you tell me about a middle school dance? Tell me what you would see, hear, possibly be feeling. How does a middle school dance relate to chemistry class?” If students are able to talk about reactions, ask: What do you notice about it that makes you think that? How can we depict this reaction/dance using chemistry particle diagrams (think pair share)? What kinds of things might you do to it to change the behaviors of molecule creation? |

| Summary of Engage: | Students will enter into a motivating and relevant engage piece on the day they start looking at types of reactions. Students will need to uses memories closely linked to their “past” lives to actively participate in the questioning of the teacher. The involvement and answers will help to give an analogy with which to compare types of reactions. The teacher will start with questions: “I have some questions to ask- By the end of class today, your goal is to determine how the topic might relate to chemistry. A long time ago in a land far far away- or really close, depending on where you grew up- who remembers a middle school dance? What can you tell me about a middle school dance? Tell me what you would see, hear, possibly be feeling. We are going to be respectful in our explaining. Where might the dance be (gym, cafeteria)? Turn to the person you’re sitting next to and try and come up with at least 3 descriptors about the dance. When you have 3, one partner go write ONE up on the board- NO REPEATS!” (this gets students engaged in thinking, a little bit of competition and working together.) The teacher should walk around and keep track of who has written examples on the board. It is hoped that things like “boys on one side, girls on the other”, “awkward” “little dancing” “couples fighting” “whispers” “nervous asking to dance” be written on the board. If these do not appear the teacher should guide students to some of these statements. At this point the engage is over and students should be asked the question “How does a middle school dance relate to chemistry class?” Students should discuss with each other and present a few ideas to the class. |
At this point, students are expected to be “hooked” and excited about chemistry because it has been related to a dance. They should have questions in their mind. Students will be given time to discuss as they are asked to begin their follow up *explore* activity. Students will be able to work with a POGIL (process oriented guided inquiry learning) to dive deeper into the content.

**Rationale:** Types of reactions are not difficult topic, but many students get confused and need a memory tool. The question of how this relates to chemistry should “plague” them and help them to enjoy the *explore* activity more. The nature of this *engage* piece should peak student interest as well. Analogies should help students to see that there is a “real world” connection to what is learned in chemistry class. It has been found that if students have a connection to the material, they are more likely to remember, be interested in and have a deeper understanding of the concepts (King, 2012). According to Unal, Calik, Ayas, Coll (2006) students would try to create the analogy on their own if presented with a new concept. This *engage* presents students with an analogy and the teacher can help to support and to question the analogy to strengthen student understanding.

**Possible Misconceptions:** It has been found that analogies can create many misconceptions. While this *engage* activity does not go into the specifics of the reactions, the analogies created from it may lead to students thinking that all reactions are a simple one process that “always works.” The misconception that all reactions occur in a simple process should be addressed by the teacher after the POGIL (explore phase) during the *explain*. The teacher should questions students as to the simplicity of the feelings involved at the dance. If Aand B are together, but one has to use the restroom, the split, but eventually come back together. The alteration from the model should be addressed by the teacher. Ozmen (2007) suggests that analogies can help to dispel misconceptions. With this being said, the original analogy (dance) can be expanded upon by having students discuss the weak points of the analogy (two girls decide they want to dance to a slow song together or an individual decides to join a pair dancing).

Below are all of the “scenarios” that the teacher should discuss with students.

\[
\begin{align*}
A + B & \rightarrow AB \quad \text{or} \quad CD \rightarrow C + D \\
AB + E & \rightarrow EB + A \quad \text{or} \quad AB + EF \rightarrow AF + EB
\end{align*}
\]

**Recommendations:** The beginning of the engage is a teacher-question-centered activity. Teacher should gain students attention before starting the story and be EXTREMELY animated while asking questions to get students involved won’t pay attention. If students are not excited, the teacher can start acting some of the scenarios out. Acting out the scenarios is recommended to engage more students. Having students brainstorm, sharing the middle school stories and discussing how the scenarios relate to reaction types should take about 10 minutes total and occur within the classroom.

**Title:** Why do you have Duct Tape?  
*For use in the beginning of the topic of bonding when talking about energy required to break bonds and to engage students in chemistry!*

**Source/website:** Created by C. Christopher 10/13/13

**NYS Chemistry Standard:**

<table>
<thead>
<tr>
<th>Key Ideas</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2i When a bond is broken, energy is absorbed. When a bond is formed, energy is released.</td>
</tr>
</tbody>
</table>

*Standard 5.2i is addressed in a limited manner as students have little background knowledge. By the end of the engage portion, students are expected to ask questions like “how are duct tape and air mattresses related to chemistry class? And why do bonds form so easily, but take so much energy to break?”* 

**Supplies**

- Duct Tape and a story told to the students to engage them in the content.

**Key Questions**

To be asked during the story and after.

*What can you tell me about duct tape?*

*Besides being sticky, tell me about my arm and the tape. Tell me about the initial process of the duct tape getting stuck. What do you notice about it that makes you think that? How did it get stuck and what may I have done to help this?* Note: Key questions associated with the explore portion are written in the summary of engage section found below.

**Summary of Engage:**

When students enter into the classroom, a story followed by “doing” is exciting to them. The teacher should start with the key questions of what can you do with duct tape? The teacher should listen to student input and then begin the story- well since we now know a little bit about duct tape, I’m going to tell you a story. Duct tape is wonderful; we’ve seen it can help fix electrical cords and a temporary tent fix when you’ve got nothing else. That being said, I was trying to fix a hole in an air mattress so I could have some guests and decided duct tape would be the temporary solution. I cut a few pieces, and put them in the temporary location of my arm so they’d be readily accessible. I put the first piece on the air mattress and tried inflating- it appeared that it had worked! So I lay on the mattress and didn’t hear air rushing out… No more leak in the air mattress!!! I was so excited. Through my fixing and excitement, I had failed to take into account the extra pieces of duct tape. They had gotten stuck to my skin. Besides being sticky, tell me about my arm and the tape (let me say simply that I have no pain tolerance). Let students discuss- “OW- how did you get it off- just do it all at once- have someone else do it, put your arm in warm water, it will make the removal easier.” Once students have discussed for a few minutes, the teacher should bring students back together and say “tell me about the initial process of the duct tape getting stuck” This should evoke terms like “easy, you didn’t know you’d done it, fast.” The teacher should then hand out 2 pieces of duct tape to partners. NOTE: THIS IS THE EXPLORE PORTION OF THE ACTIVITY: I want you to create a scenario LIKE the one I discussed, but where it is NOT stuck to you or your partner. You must use both pieces of tape. (students’ should stick the two pieces together). “Can you describe what you did and the difficulty” WONDERFUL! “Now- I need you to “remove” them from each other just as I took the duct tape off of my arm.” Students should struggle for a few minutes and start saying- it’s not possible- why did you make us stick them together.” The teacher should confirm no one got them apart (if a group did they can be the “model”) Teacher should ask the question “in terms of removal, what did you
notice?” Impossible, not enough energy, they are too well stuck together! Now that we’ve looked at duct tape and I’ve gotten you thoroughly frustrated, why did I have you do this? How is duct tape sticking related to chemistry? (Give students time to think and discuss with other groups)

At this point students are expected to be “hooked” and excited and wanting to explore more of the duct tape analogy and how it relates to chemistry.

**Rationale:**
The story detailed above is used as an *engage* because it is something “out of the ordinary” for chemistry class and shows the students a “real” side to the teacher fixing an air mattress with a leak. The story does not seem to relate at all to chemistry. The topic of bond breaking and forming is important, but most students have extreme amounts of trouble remembering and understanding the energy behind bond formation and breaking. The author of this *engage* remembers not truly understanding this concept in high school and going through a series of analogies that didn’t work for her. The story combined with manipulatives serves as a “hook” to keep students interested in the class instead of worrying about who is texting or tweeting (Milne & Otieno, 2007). In addition to questioning, having the class work together to solve the problem of how to get the duct tape off of the teacher with low pain tolerance helps to build community. The *explore* activity described also helps students to work cooperatively with common objects related to chemistry.

**Possible Misconceptions:**
The idea that bond formation is “easy” and requires no energy in isolated situations works, but could cause misconceptions when looking at thermodynamic equations with $\Delta H$ values given in the reference tables. Teacher should address this with students explaining that when removed from specific situations into simple contexts, this analogy holds true. Aydeniz & Kotowski suggests that teachers must know what the misconceptions are for a particular topic and explicitly address these misconceptions (2012). The author has seen the misconception detailed here confusing students later in the year and knows that it must be addressed as soon as possible with students.

**Recommendations:**
The duct tape story is teacher-centered which is mixed with student questions to lead to student-centered discussion. The teacher should sell the story as their own by acting (or modify based on experience) As a teacher, be prepared to guide students to the understanding of bond formation. Writing with symbols on the board to show ideas or modeling with duct tape after students have explored and discussed might be necessary. The *engage* described above should take about 7 minutes total and occur within the classroom.

\[ H_{(g)} + H_{(g)} \rightarrow H_{2(g)} \]  

The example to the left can be used as student should know that hydrogen is a diatomic element and unstable alone as $H_{(g)}$. When it “sticks” together it is more stable and lower in energy, just like the duct tape. It gives off energy and is extremely difficult to break the bond once formed.

**Title:**
What do I round my answer to?!?!

*For use in the beginning of the year to engage students in the importance of significant figures and why they matter!*

**Source/website:**
Created by C. Christopher 9/29/13

**Research Support**
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<table>
<thead>
<tr>
<th>NYS Chemistry Standard:</th>
<th>Key Idea 1: Abstraction and symbolic representation are used to communicate mathematically. M1.1 – use appropriate equations and significant digits – show uncertainty in measurement by the use of significant figures. Standard M1.1 above is addressed in a limited manner as students have no background knowledge. By the end of the engage portion, students are expected to be able to answer the questions “what do I round to?”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplies</td>
<td>Ancillary “quiz” found in appendix A.</td>
</tr>
<tr>
<td>Key Questions</td>
<td>To be asked after the “quiz” is completed. Tell me about what you are thinking? (Think pair share probably necessary with a new group). What would have made this an easier quiz? In what ways do you think this activity is related to chemistry? What might we learn about next based on this activity?</td>
</tr>
<tr>
<td>Summary of Engage:</td>
<td>Students will enter into a “quiz” environment where they will be asked to answer 5 questions. They will be able to use a calculator, but may NOT ask the teacher any questions. All of the questions are math problems (+, -, x, or ÷) where there are many digits that will be in the answer. This initial activity is to spark a little bit of frustration in students who want to be right, but can’t ask “what do I round my answer to.” This discomfort will help to engage students into significant figures because they can now have a motivating reason to learn. After the students have been given 4 minutes to complete the questions the teacher should ask the question “who thinks they got a 100%?” It is possible that some will say yes, but the majority will express some frustration with the lack of direction. The teacher should say “tell me about what you are thinking” and students should discuss any frustrations they felt. The teacher should continue and ask, what would have made this an easier quiz? (suggestions like “where to round to” and how many numbers you wanted in our answer” are likely to be suggested). This is when the teacher should say that this is not really a graded quiz, but something to show students why knowing significant figures and rules for calculations are important. At this point, students are expected to be “hooked” and ready to learn the rules for significant figures so they can be successful the rest of the year as they complete calculations.</td>
</tr>
<tr>
<td>Rationale:</td>
<td>The mini “quiz” activity is being completed to spark student interest in a topic that students find pointless in Regents Chemistry. It helps to show why significant figures are important. It also helps to create a community of learners through being frustrated and developing a common understanding of why significant figures are important. According to Milne and Otieno (2007) this mutual focus can help the class create more of a community or “greater sense of belonging” for students.</td>
</tr>
<tr>
<td>Possible Misconceptions:</td>
<td>According to Lang, Wong, and Fraser (2005), the quiz portion of the engage activity may lead students to thinking that their teacher is a mean, strict person who does not want them to succeed based simply on the directions and inability of students to ask questions. Since this activity is positioned late in the year, students should know these things are not true about their teacher so this shouldn’t be a problem.</td>
</tr>
</tbody>
</table>

**Recommendations:** This is a student-centered activity followed by a mini-discussion. Teacher should set clear expectations that no questions may be asked of the teacher and the quiz is an “on your own” assignment. It is recommended that the teacher walk around the room, but not answer questions for the 4 minutes and wait for students to be done. Start the key questions after collecting the “quiz.” If the teacher notices that students are distraught regarding the quiz, it should be stated as quickly as possible that the “correct” answers do not matter and the quiz was not really a quiz. In total, the quiz and mini discussion should take about 10 minutes and occur within the classroom.

| **Title:** | Metric Mishap- why are units important?  
*For use in the beginning of unit conversion discussions to help students understand why labeling units and using the correct units is essential.* |
|**Source/website:** | Created by C. Christopher 9/27/13  
Article found at: [http://www.cnn.com/TECH/space/9909/30/mars.metric.02/](http://www.cnn.com/TECH/space/9909/30/mars.metric.02/) |


**NYS Chemistry Standard:**

“Systems of Units: International System (SI) units are used in this core curriculum. SI units that are required for the chemistry core are listed in the Reference Tables. SI units are a logical extension of the metric system. The SI system begins with seven basic units, with all other units being derived from them (see Reference Tables). While some of the basic and derived units of the SI system are commonly used in chemistry (mole, Kelvin, kilogram, meter, joule, volt), there are other units that are used in chemistry that are exceptions. Thus, in addition to the SI units, you will find liters used in volume measurements, atmospheres and torr used as pressure units, and Celsius as a temperature indicator.”

*The statement above is found in the introduction to the NYS chemistry standards. This activity also addresses NYS Common Core ELA Learning standards shift number 2.*  
*The importance of using a standardized system to talk about numbers will be addressed. By the end of the engage portion, students are expected to ask questions like “Why do we have different units” or “why didn’t they ask questions?”*

**Supplies**

The handout titled “Metric mishap caused loss of NASA orbiter” found in Appendix A.

**Key Questions**

To be asked after the completion of the reading to start the conversation and if necessary to aide in the discussion. *Tell me about what you read. In what ways is this related to chemistry? What societal implications did this have seeing as it was in 1999? What do you think SHOULD have happened as a result of this? What are some key points and why are they important. What questions can we ask NASA? How do you think they would answer? Is there anything you wish you could do related to this article?*

**Summary of Engage:**

Students will enter into a motivating and relevant engage piece on the first day of dimensional analysis and “math” chemistry units. The reading for the engage segment will be closely linked to their lives and will pose a challenge to them to learn more about a topic. The teacher will start with an introduction: “Before we start our next topic, I would like you to have some “real world” background knowledge as to why we need to learn this next topic. This is an article that I found fascinating and I’m 99% certain you will also enjoy it. The article is titled Metric mishap caused loss of NASA orbiter. Your goal is to read the article, find a few interesting pieces of information, create a summary, ask some questions and be prepared to talk about the implications. We will come together when everyone has completed the reading and discuss our findings. We will have a discussion about the implications. I have issued you an exciting challenge and it is my expectation that
When all students have completed the reading the teacher will ask the class to arrange their desks so that they’re in a “u” or circle (depending on arrangement of the classroom). The teacher should start with the key question “tell me about what you read.” The teacher should serve as facilitator for the discussion, not the center of the discussion. If necessary, the teacher can continue with the key questions.

At the end of the discussion, students are expected to be “hooked” and excited to know that they will be able to avoid mistakes that NASA couldn’t. Students will be able to work with unit conversions in a POGIL (Process oriented guided inquiry learning) activity to help dive deeper into the content.

| Rationale:     | The NASA reading serves as a great “real world” connection for students between the classroom and their lives. Many of the students in chemistry classes find the topic of unit conversions pointless. It serves as a connection; it helps to peak student interest in an otherwise “boring” topic. The discussion at the end of the engage activity serves to engage students in a “boring” topic through a fascinating mistake made by one of the best known science organizations in the US, NASA. Many students find this “funny” that they are learning how to complete unit conversions and not have “naked numbers” when NASA and a large company couldn’t do the same. The topic elicits much discussion from students which helps students to construct knowledge, have a more positive outlook on classroom activities and engage with the concepts on a deeper level (Chairam, Somsook, & Coll, 2009; Lang, Wong, and Fraser, 2005; Rop, 2003; King 2012). |
| Possible Misconceptions: | The engage story and discussion may lead to students thinking that “since NASA didn’t have their units correct, neither do I” although this is the minority of students. For most students this article helps dispel the idea that labeling with units is pointless since the “teacher knows what the units should be.” |
| Recommendations: | A student-centered reading and activity with minimal teacher input is how the above activity should run. The teacher should monitor student progress through the article and questions to ensure timeliness as well as depth and completeness in answering questions. This engage should take about 25 minutes total including reading (which can be done in class or at home) followed by the discussion. |

Title: A Mole is a Unit (or have you heard)? YouTube  
For use in the beginning of the math of formulas and equations to engage students in moles related to chemistry! 

Source/website: Created by C. Christopher 10/4/13  
You tube clip found at: : [http://www.youtube.com/watch?v=PvT51M0ek5c](http://www.youtube.com/watch?v=PvT51M0ek5c) 

**NYS Chemistry Standard:**

| Key Ideas: | 3.3c A balanced chemical equation represents conservation of atoms. The coefficients in a balanced chemical equation can be used to determine mole ratios in the reaction.  
3.3e The formula mass of a substance is the sum of the atomic masses of its atoms. The molar mass (gram-formula mass) of a substance equals one mole of that substance. |

*The standards above are addressed in a limited manner as students have no background knowledge. By the end of the engage portion, students are expected to ask questions like “how does this work?” “Why is the number so big, yet so small?” Can we use this for all substances?” “What makes it do that?”*

**Supplies**

| A story told to the students to gain and focus their attention as well as a computer with either internet access or a file stored on flash drive of the video found at: [http://www.youtube.com/watch?v=PvT51M0ek5c](http://www.youtube.com/watch?v=PvT51M0ek5c) |

**Key Questions**

| To be asked after the completion of the video and through the follow up activity. So I said this was a funny video, in what ways is it related to chemistry? Tell me about what you saw? (THINK, pair, share probably necessary with the nature of video). What sort of information can we obtain from this segment? What surprising facts did you learn about a mole? How is a mole different from other units of measure? What do you notice or what evidence is there to make you think that? |

**Summary of Engage:**

| Students will enter into an engaging and culturally relevant piece. This engage piece will use a “silly song” to engage students and pose the challenge to students to learn more about a topic. The teacher will say “I will be playing a WONDERFUL video to help explain chemistry related to the mole. It has a nice catchy tune and this is your warning- be prepared to have it stuck in your head all day. Pay attention as I will be looking for your help to make a list of what we’ve learned. The video found at [http://www.youtube.com/watch?v=PvT51M0ek5c](http://www.youtube.com/watch?v=PvT51M0ek5c) titled “A Mole is a Unit!” will be shown. Following the song, laughter and awe will likely follow. The teacher should then engage students with the key questions. At this point, students are expected to be “hooked” and excited about chemistry. They should have questions in their mind about why are we watching this fun ridiculousness in chemistry class? Students will be given time to discuss as they are asked to begin their follow up explore activity. Students will be able to work with samples of elements to determine how much of a mole they have. |

**Rationale:**

| The video engage activity serves the purpose of sparking interest in an extremely important topic for chemistry. The “mole” is an essential component that can frustrate students with the math involved. With the enthusiasm of the teacher combined with the “silliness” of the video, some of the barriers and resistance to the mole should be broken down. Students should see that the teacher is indeed a real person and bring the class together around this video. The mole song takes the word “mole” which many students have heard of as an animal or a “spot on your chin that you gotta shave around” according to the song. In this way, it pulls in some prior knowledge making the topic more relevant to students also helping with the classroom community aspect of teaching. By using the video and engaging students in the material before going into lecture, this activity changes the way classroom
time is spent. According to Rop (2003) spending more time and allowing students to think, ask questions and engaging students is the first step to creating an inquiry classroom where students are engaged in the material.

**Possible Misconceptions:** Since this *engage* activity starts with large real life style amounts, students may think the mole is always too much. By the end of the video, it does show that a mole of sugar can fit into your hand. One misconception related to this is that a mole of many elements fits in your hand, but the mass varies. Since this is an EXTREMELY important concept, teachers should have on hand a “mole” of multiple substances (perhaps water, copper, iron, aluminum, sugar, and salt). These samples will help students to see that a mole is many different “looking” amounts and that a mole can have MANY different masses. Teachers should listen to student conversations during the pair share to see if any other misconceptions arise.

**Recommendations:** The engage described above is a video centered activity followed by a brief discussion, laughter and questions. Teacher should gain students attention before starting by completing the directions in an EXTREMELY animated way. It is recommended that the teacher walk around the room while the video is playing and sing along at some points. The students laugh and are more engaged when they see their teacher excited. The clip from YouTube should already be cued up on the screen ready when the teacher finishes the story. The story followed by the video for this *engage* should take about 7 minutes total and occur within the classroom.

| **Title:** | What do we need for a Ham Sandwich?  
*For use to introduce the idea of mole ratios and balancing equations. Students are given a chance to “create” moles and balanced equations.* |
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td><strong>Source/website:</strong></td>
<td>Modified by C. Christopher 10/13/13 from <a href="http://books.google.com/books?id=K33lkZQ2_woC&amp;pg=PA139&amp;lpg=PA139&amp;dq=chemical+reactions+dance+analogy&amp;source=bl&amp;ots=fwifAHDacx&amp;sig=cFMGadnZ8UD1dyWthhHv_ar572U&amp;hl=en&amp;sa=X&amp;ei=tKVZUsDiHdG4kQe1woHACw&amp;ved=0CFkQ6AEwBg#v">http://books.google.com/books?id=K33lkZQ2_woC&amp;pg=PA139&amp;lpg=PA139&amp;dq=chemical+reactions+dance+analogy&amp;source=bl&amp;ots=fwifAHDacx&amp;sig=cFMGadnZ8UD1dyWthhHv_ar572U&amp;hl=en&amp;sa=X&amp;ei=tKVZUsDiHdG4kQe1woHACw&amp;ved=0CFkQ6AEwBg#v</a></td>
</tr>
</tbody>
</table>
### Research Support


### NYS Chemistry Standard:

Key Ideas:

3.3c A balanced chemical equation represents conservation of atoms. The coefficients in a balanced chemical equation can be used to determine mole ratios in the reaction.

*Standard 3.3c is addressed directly using “ham sandwiches” as an analogy to chemical reactions. This engage asks students to “make sandwiches” given the “recipe” of 2 pieces of bread, one piece of ham for a ham sandwich. By the end of the engage portion, students are expected to ask questions like “how do you figure this out?”, “this was easy with these supplies, how can this be related to chemistry”, “in what way could I write this related to chemistry?”*

### Supplies

Enough “bread” so that each group can have 6 pieces (can be real bread or cardboard with “B” written on it size of a pieces of bread), enough “ham” so each group can have between 1 and 5 pieces (can be real ham or red construction paper with “H” written on it. Board to write on and a story with directions given to students for their task.

### Key Questions

Note: Questions related to the story are included in the summary. These questions are to be asked after the *engage* during the *explore* activity and after with the whole class.

- *Tell me about your model? What are you seeing?*
- *What do you notice about the amount you had when you started to when you ended? What could the bread and/or ham represent in chemistry (more specifically chemical reactions)? What do you think the sandwich might represent? What substance is it? What do you notice about it that makes you think that? What other tests would you like to do with these materials for more information? Why does the amount of bread and ham matter when we are making sandwiches? How is this related to chemistry? “If I have 3 slices of ham, how much bread is needed to make complete sandwiches? (taken from book cited above)” If I have 20 pieces of bread and 13 slices of ham, how many sandwiches can I make?*

### Summary of Engage:

Students will enter into an experimentally driven *engage* piece with kinesthetic learning being used to look at balancing equations and mole ratios. The teacher will start with a story:

- “What can you tell me about a sandwich and how it might relate to chemistry? Ok, let’s get a little more specific; if I wanted to make a ham sandwich what MUST I have to make it?” (Let students respond). Should determine need bread and ham.
- “Ok so I’m going to make a sandwich (use B and H manipulative). What should I
start with?” Students should indicate 2 pieces of bread and there is likely a bit of discussion about pieces of ham. With the discussion, the teacher should say “although some of you may be rather hungry, my favorite snack is one slice of ham on bread- so this is what I’m going to make. Your task for the next few minutes is to take a baggie with bread and ham and make AS MANY sandwiches as you can. In terms of rules, you MAY NOT change the 2 bread to 1 ham ratio. At the end, your goal is to create some explanation of how this is related to chemistry. You should use all of your chemistry knowledge to create a model or statement describing what you’ve made. We’ll see which group can determine the best chemistry explanation. For those of you dying to get started, make sure you are thinking about how this is related to chemistry as you are moving along. You have 5 minutes to complete your task and we will take 30 seconds per group to present our chemistry model. Get your partner, bread, ham and paper to write down your model and get started.” The teacher should wander around the classroom helping students who seem stuck asking questions like “what do we use in chemistry to show the final product? What could we use to represent the bread or ham? In what ways is this related to chemistry?” After students have had time to create their model, the teacher should bring the students back together and discuss the models through presentation asking questions as they go (in key questions section).

At this point (after students have completed their models and presented, students are expected to be “hooked” and excited to complete the explore activity as a class to determining the entire number of sandwiches given the formulas they determined in the engage. Students will be given time to discuss as they are asked to begin their follow up explore activity.

| Rationale: | Balancing reactions is an essential component in chemistry and many students question why they have to bother learning something that is unrelated to their lives. The use of manipulatives related to their lives shows students immediately (even before they learn how to balance equations), that ratios and knowing what you have and what you can end with is important. The ham sandwich analogy can be taken further by asking students to create analogies of their own related to ratios in their lives (making cars, number of workers required at the holiday to avoid long lines). Students’ interest will be activated by using food, learning by doing, instead of being told, and working with manipulatives (King, 2010 and Chairam, Somsook, & Coll, 2009). Students are set up for constructing their own knowledge through doing an experiment like a “real scientist” (Chairam, Somsook, & Coll, 2009). Students aren’t given a predetermined step by step procedure, but asked to figure out a problem. Students should have a deeper engagement and rationale for what is going on in ratios. Students should be able to answer the question of “WHY” related to balancing reactions. |
| Possible Misconceptions: | The ham sandwich analogy helps students to think about simple ratios that seem complex when balancing. The misconception of “leftovers” may confuse students especially since limiting reactant is not a topic discussed in Regents chemistry. The teacher should point out that “extra supplies” do not make sandwiches and can be “ignored.” The teacher should show students the “chemical reaction” if students are not able to determine on their own “2B + H ⇌ 2BH.” The ham sandwich analogy could also lead to students thinking that only small ratios are possible or starting with |
the “correct number of one will always occur. The manipulatives in this *engage* should help to dispel some of these misconceptions compared to the teacher lecturing about balancing and ratios.

**Recommendations:** The analogy simulation is teacher-centered with questioning followed by students exploration and discussion. Teacher should gain students attention before starting the story and talk excitedly about making ham sandwiches. The teacher should also be asking questions during student work time to EVERY group to make sure the students understand the task and the concept. According to Unal et. al, the teacher should suggest the limits of the analogy and ask for student input as to the flaws and benefits of the analogy (2006). The explanation by the teacher followed by student creation of sandwiches should take between 10 and 20 minutes total, and occur within the classroom.

<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>What are we doing with an Aluminum can? <em>For use in the beginning of the year to create community and engage students in chemistry!</em></th>
</tr>
</thead>
</table>
| **Source/website:** | Modified from “Collapsing Can” [http://scifun.chem.wisc.edu/homeexpts/COLLAPSE.html](http://scifun.chem.wisc.edu/homeexpts/COLLAPSE.html)  
Modified by C. Christopher 10/2010 |
<table>
<thead>
<tr>
<th>NYS Chemistry Standard</th>
<th>Key Ideas:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1xxii</td>
<td>Use a simple particle model to differentiate among properties of a solid, a liquid, and a gas</td>
</tr>
<tr>
<td>3.1jj</td>
<td>The structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure.</td>
</tr>
<tr>
<td>3.1kk</td>
<td>The three phases of matter (solids, liquids, and gases) have different properties</td>
</tr>
<tr>
<td>3.4b</td>
<td>Kinetic molecular theory (KMT) for an ideal gas states that all gas particles:</td>
</tr>
<tr>
<td></td>
<td>• are in random, constant, straight-line motion.</td>
</tr>
<tr>
<td></td>
<td>• are separated by great distances relative to their size; the volume of the gas particles is considered negligible.</td>
</tr>
<tr>
<td></td>
<td>• have no attractive forces between them.</td>
</tr>
<tr>
<td></td>
<td>• have collisions that may result in a transfer of energy between gas particles, but the total energy of the system remains constant.</td>
</tr>
</tbody>
</table>

The standards above are addressed in a limited manner as they have no background knowledge. By the end of the engage portion, students are expected to ask questions like “how does this work?”, “What makes it do that?”

**Supplies**

- A hair tie for demonstrator with long hair, goggles (for demonstrator and all students), beaker (to fit aluminum can) almost full of water, beaker tongs (without plastic), pop can with ~5mL of water, flint or matches, Bunsen burner hose and gas accessibility (or hot plate), pen/ pencil, ancillary document in appendix A.

**Key Questions**

To be asked during and after the completion of the demo activity before looking at the explanation. *Tell me about what you predicted? What leads you to think that way? What did you see? What are you hearing? How does this change your prediction?* (The phrasing of this question can change based on where in the engage it is asked. *So this is related to chemistry- in what ways do you think it is?* (pair share→ share out) ask follow up questions to how this is related to chemistry. *What do you think caused this to occur? What did you notice about it that makes you think that? What could we have done differently to change its behavior? What would you expect to happen to the can?*

**Summary of Engage:**

Students will be presented with a motivating and relevant engage piece. This engage segment will have a pop can and will pose a challenge to students asking them to predict and learn about what can be done in chemistry with a pop can.

The teacher should show the students all of the materials after passing out the ancillary page. Students will write down all of the materials required. The teacher will then state their challenge “*With these materials I will be doing SOMETHING. Take 3 minutes on your own and come up with a prediction for what I will do. You can’t be wrong, but you must have a prediction written on your page before I begin.*” Teacher should then walk around the room while students complete their predictions.
The teacher will then have all students obtain goggles from the goggle cabinet and gather around the demonstration desk with their papers and pencils. Remind students to be quiet so they can complete the “during” section of their paper. The teacher should light the Bunsen burner, pick up the pop can with the beaker tongs and hold it above the flame. The teacher should remind students to listen and ask what they hear. Once students have heard the water boiling inside the can, the teacher should ask all students to look up at the demonstration (if they are writing), and invert the can into the beaker of water. The can will immediately collapse and make a loud popping sound.

At this point, students are expected be “hooked” and excited to learn why this happened and how this demonstration relates to what they are learning about in chemistry class. They should have questions in their mind about why did this happen, can it be done at home to show family? Students will be given time to complete their ancillary document and discuss what happened. They are then asked to describe the experiment and given a mini explanation as to what occurred during the demonstration.

**Rationale:**

The concept of solids liquids and gases has already been learned by students and the idea of vapor pressure related to gases is a small topic in the chemistry curriculum. The demonstration followed with discussion and explanation allows for teachers to engage students this topic while not spending too much time. It also serves as a connection to the “real world” as students have seen pop cans and have crushed them with their hands. The added “coolness” of this activity helps to engage students in the unit following the demonstration. Since the class is in awe, the demonstration also serves to help create more of a classroom community.

Inquiry is used to hook students. As suggested by Criswell (2012), the activity is set to give students materials and “frame” the activity to help students orient themselves to the purpose of the activity. Students know that something is likely going to be done with the aluminum can, given the title of the engage. By giving students these frames, their “cognitive load” is decreased and allows each student to engage more deeply in the engage experience designed for them (Criswell, 2012).

**Possible Misconceptions:**

Students may think that the can crushed because there was water in it before it was flipped (Arizona State University, n.d.). While the teacher doesn’t tell students this portion, the teacher should use particle diagrams after the conclusion of the activity to show what happens in the 3 different steps of the activity. There were very few liquid particles when the demonstration was started, those particles quickly turned to gas expanding and driving any air left in the can out and when immersed in water, the water vapor turned into liquid decreasing the volume and pressure on the inside of the can allowing the crushing. Using particle diagrams and explicitly addressing this possible misconception can help improve students “mental modeling” according to Unal et. al (2006).

**Recommendations:**

The can demonstration is a teacher-centered activity followed by student question and discussion. It is recommended that the teacher walk around the room & encourage students to answer questions and ask questions during the demonstration. The entire engage should take about 20 minutes total including ancillary pages and demonstration with questioning.
Title: Giant Peeps and cold boiling water? Bell Jar Demonstrations

For use in the beginning of the day when the ideal gas law is introduced (Boyle’s law, Charles’ Law and Gay-Lussac’s Law) to engage students in chemistry!

Source/website: Modified by C. Christopher 9/22/13 from T. Bertrand Spring 2005

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<table>
<thead>
<tr>
<th>NYS Chemistry Standard:</th>
<th>Key Ideas:</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>3.4a The concept of an ideal gas is a model to explain the behavior of gases. A real gas is most like an ideal gas when the real gas is at low pressure and high temperature.</td>
</tr>
<tr>
<td></td>
<td>3.4c Kinetic molecular theory describes the relationships of pressure, volume, temperature, velocity, and frequency and force of collisions among gas molecules.</td>
</tr>
</tbody>
</table>

The standards above are addressed in a limited manner as they have no background knowledge. By the end of the engage portion, students are expected to ask questions like “how does this work?”, “Is it cold or hot?”, “What makes it do that?”

<table>
<thead>
<tr>
<th>Supplies</th>
<th>A vacuum pump connected to a bell jar, peeps (marshmallows or shaving cream), electricity to plug in, a beaker 2/3 full with water, and a thermometer.</th>
</tr>
</thead>
</table>

| Key Questions | To be asked before during and after the demonstration (referring to the peep and bell jar) **Tell me about what you are seeing. What could we do with these materials? What are you noticing? What could be causing this? What do you notice about it that makes you think that? If I took a handful of this substance now, what would you expect it to feel like? What kinds of things might you do to it to change its behavior? What observations can you make now (the peep stops increasing in size)? What might happen when I stop the vacuum pump?**  
(referring to the water and bell jar) **Tell me about what you are seeing. What could we do with these materials? How might we make this observation more quantitative with the materials we have here? How should we gather data? Now that the pump is on, what are you noticing? What could be causing this? What do you notice about it that makes you think that? What might happen when I stop the vacuum pump? What other information should we gather? (temperature of water after pump off).** |

| Summary of Engage: | Students will enter into an exciting and relevant engage piece on the day when the ideal gas law is introduced. The engage segment described below will be closely linked to their lives with “real world props” and will engage and excite students about the ideal gas laws.  
The teacher should have the bell jar with vacuum pump in a location where all students can see (front of room on a cart or on the demo table). Teacher should ask students to describe what a “peep” is. The peeps should excite students (food=good). The teacher should then refer to the contraption (vacuum pump) and ask students to make some predictions as to what the device is based on observations. After 3-5 observations and guesses, the teacher should tell the students that it is a vacuum pump. The teacher should then elicit student predictions as to what might happen if they were to put the peep into the vacuum pump. (Responses will vary). The teacher should place the peep into the bell jar and turn on the vacuum pump. As the peep enlarges in size the teacher should continue to ask key questions looking for observations and possible reasons why. “Ok, so now that we’ve looked at peeps in the bell jar, what else should we look at? Perhaps this water that just happens to be sitting here on the desk” The teacher should elicit student predictions as to what might happen to the water. The teacher |
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| should help students to make this a more quantitative prediction and to use the thermometer to measure the temperature of the water. The vacuum pump should be turned on and the teacher should continue asking key questions. Be sure to record the post temp (it should be *approximately* the same as before even though the water boiled).

At this point, students are expected to be “hooked” and excited about the bell jar, wondering how pressure is able to change a peep to be so large and boil water without it being hot. Students should have questions in their mind about how does this work, can I do that? Students will be given time to discuss as they are asked to begin their follow up *explore* activity. Students will be able to work with two different labs to explore the idea of pressure and temperature and pressure and volume. After these labs are done, the teacher will explain what happened in the bell jar to students. If the teacher notices that students are talking incorrectly about what went on in the bell jar, the teacher should use his or her discretion to determine if going over what happened in the jar should be done immediately or after the explore section. The discussion should help to avoid deepening misconceptions.

| **Rationale:**
| The demonstration described above helps to peek students’ interest in an otherwise “boring” and rather mathematical topic. The materials used in this demonstration (peeps, water thermometers) are everyday household items. Milne and Otieno have found that when students and teachers work together, the demonstration is more successful in terms of learning outcomes, better classroom communities and student engagement (2007). It is also suggested that since students are involved and the materials used are familiar to students, the students feel more comfortable with a “sense of control” within the classroom related to learning and outcomes (Milne, Otieno, 2007, p. 548).

| **Possible Misconceptions:**
| The bell jar activity may lead to students thinking that when pressure is decreased all types of matter become larger or change in state. It is important for the teacher to address what happens in the bell jar with particle diagrams to help students understand what occurred. As noted in the summary, this can happen immediately after the demonstration or during the explain phase later in the day. According to Unal et al., students need to be taught about the different levels of chemistry and how particles relate to the macroscopic world (2006). To address this with students is an essential to link it to chemistry and can be done using particle diagrams. These discussions should take place during the explain phase of the 5E model.

| **Recommendations:**
| The bell jar introduction is a teacher-centered activity that should lead into student questions. Be sure to not let students put the thermometer into the bell jar. The demonstration followed by question should take about 15 minutes total including the video and occur within the classroom.

| **Title:**
| Tug of War- who wins? *For use to introduce bond polarity to students. Students are given an analogy to compare difficult concepts with.*

| **Source/website:**
| Created by C. Christopher 10/14/13

| **Research Support**
<table>
<thead>
<tr>
<th>NYS Chemistry Standard:</th>
<th>Key Ideas:</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2k The electronegativity difference between two bonded atoms is used to assess the degree of polarity in the bond.</td>
<td></td>
</tr>
<tr>
<td>5.2l Molecular polarity can be determined by the shape of the molecule and distribution of charge. Symmetrical (nonpolar) molecules include CO₂, CH₄, and diatomic elements. Asymmetrical (polar) molecules include HCl, NH₃, and H₂O.</td>
<td></td>
</tr>
<tr>
<td>The standards above are addressed in a limited manner in this particular engage. Students have no background knowledge and the story combined with the analogy helps to engage students and give a “frame of reference” to refer to when talking about the idea of molecular polarity which they don’t know anything about yet. By the end of the engage portion, students are expected to ask questions like “how do you figure this out?”, “What makes an element “stronger” than another?”</td>
<td></td>
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</tbody>
</table>

| Supplies | A story told to the students about tug of war to gain students attention and focus their thoughts. |

| Key Questions | What can you tell me about tug of war? What would happen if kindergartners were set against your chemistry class? Tell me about what you would see. In terms of strength, compare the two groups. Compare this to the tug of war with the kindergartners? When I start the game, what would happen? Now, how can we relate this to chemistry? |

| Summary of Engage: | Students will enter into fun engage piece with “story time.” The teacher will start with a story: “Let’s talk about tug of war. What can you tell me? (rope, team that wins pulls other team over the center line, it’s fun (or not fun)). OK so we’ve got the basics of tug of war… lets think about a scenario, we have a class here of (#of students in class that day) and I am going to, in theory, set you against a class of kindergartners in tug of war. This is a serious competition, who would win the contest in all reality? (We would!) Ok so what would happen after you got set up, centered and I said START” (students respond with we’d win almost immediately, we’d pull them over, they might get hurt). Ok- so I heard the word PULL over. In terms of strength, what can you tell me about the two groups? (we are A LOT stronger). OK so this is one scenario you need to keep in mind for the chemistry we’ll be talking about next. The second scenario that I have: we take your class and you have a tug of war with my other Regents chemistry class. Now, the number of you is approximately equal and it is also a mix of sports players, musicians, dancers and 10th and 11th graders. Based on this information, what can you tell me about the tug of war between these two groups (Likey students will say their class wins so teacher will need to prompt). What can you tell me about the approximate strength of the two groups? Compare this to the tug of war with the kindergartners? When I start the game, what would happen (A STRUGGLE). WONDERFUL, so there is a pulling back and forth between two groups of approximate equal strength. Now, how can we relate this to chemistry? As you go into your POGIL groups remember these stories and try and determine what I was referring to. At this point, students are expected to be “hooked” and excited to complete the explore activity described in the story above. They should have questions in their mind about what is tug of war related to chemistry, how do chemicals work like that, |
and why won’t the teacher just tell us the definitions? Students will be given time to discuss as they are asked to begin their follow up *explore* activity. Students will complete the activity described.

<p>| Rationale: | Bond polarity is one of the more difficult topics for students to understand. The tug of war analogy in story form provides a reference to help students remember and understand what polarity is. The familiarity of the topic (tug of war) can benefit students according to Orgill and Thomas (2007). It is also stated that analogies can be combined with the 5E model to help with a better understanding of concepts. As this <em>engage</em> is the start of the 5E, this is an appropriate placement for a concept with the analog begin familiar and the target unfamiliar. According to Meyers et. al., when students are engaged in conversation, they can remember a concept more concretely (2003). Students are asked to participate in talking about a fun relevant and competitive topic. |
| Possible Misconceptions: | The tug of war story may lead to students thinking that there is always a huge difference in strength or no difference in strength. The difference in strength concept will be addressed in the POGIL and during the <em>explain</em> portion of the lesson. When discussing the explore activity after it is complete, teacher should prompt students to aide in how the tug of war relates to polarity. |
| Recommendations: | The story told is teacher-centered followed by an explore activity described in the <em>engage</em>. Teacher should gain students attention before starting the story and be EXTREMELY animated while asking questions and receiving answers. It is recommended that the teacher act the story out. Both parts of the story for this <em>engage</em> should take about 5 minutes total, occur within the classroom and then the <em>explore</em> activity can begin. |</p>
<table>
<thead>
<tr>
<th>Title:</th>
<th>Challenge: Let’s dissolve Sugar</th>
</tr>
</thead>
</table>
| Source/website: | Created by C. Christopher 10/6/13  
Modified from an activity done during spring 2011 C. Christopher |
| NYS Chemistry Standard: | Key Ideas:  
3.100A solution is a homogeneous mixture of a solute dissolved in a solvent. The solubility of a solute in a given amount of solvent is dependent on the temperature, the pressure, and the chemical natures of the solute and solvent.  
The standards above are addressed in a limited manner as students have limited chemistry background knowledge related to dissolving. The sugar challenge asks students to use prior knowledge along with their partner to be successful. By the end of the challenge, students have dissolved a sugar cube at a fast pace (usually less than 30 seconds). Students can identify some factors that contribute to speed of reactions. |
| Supplies | One sugar cube per group, water, and ancillary pages from appendix A. Students can also ask for other supplies with usually include a mortar and pestle, glass stir stick, hot plate (Bunsen burner not used for time and safety sake), and any other materials requested. |
| Key Questions | To be asked before the activity. *What are three properties of sugar cubes? What questions do you have related to your task?* |
| Summary of Engage: | The challenge activity allows students to work hands on with sugar cubes and familiar materials to dissolve the sugar as quickly as possible. Students are working quickly, talking with their partner to create the procedure that will be the fastest in the process of determining the factors that affect rates of reaction. The teacher should start by explaining: “I’d like you to think about sugar cubes. In your mind think of at least 3 properties of sugar cubes. Using those properties, combined with those of your partner, today you and your lab partner have a challenge. Your challenge is to create a procedure to dissolve a sugar cube the fastest. You may use anything around the classroom. If there is something that you’d like but don’t see, you may ask me and I’ll try and find it for you. That being said, take 5, yes FIVE minutes with your partner and determine a procedure and begin getting your materials. When everyone has a procedure started at the end of 5 minutes (with goggles on of course), we will begin. I will give every group a sugar cube and everyone will start the process at the same time. When you are done dissolving, you must call me (your teacher) over and show me. Best of luck. Turn to the person you’re sitting next to and describe what you’re doing and check for questions. (wait 2 minutes) Any questions? (Answer any and all). Let students get started.  
After all students have dissolved their sugar cube, they should clean up and complete the conclusion questions on the ancillary document. |
| Rationale: | The sugar cube dissolve challenge is an engage, but also asks student to use |
background knowledge to reach the end goal. According to Milne and Otieno (2007) this is beneficial to students to increase engagement. When the teacher asks students to engage in the planning process and conversation with their partner, the simple entering into that conversation can signify engagement (Milne, Otieno, 2007). The act of dissolving the cube is an authentic challenge which helps students to see through scientists eyes. According to Meyer, Schmidt, Nozawa, and Panee (2003), any authentic challenge is beneficial to students.

| Possible Misconceptions: | The sugar cube challenge engage activity may lead to students thinking that the more a solution is stirred the more solute (sugar) can be dissolved. Students think this because they have stirred the sugar and this aided in the process of dissolving. This is something that should be addressed immediately after the engage. The teacher should ask for the factors that affect rate of dissolving. If stirring comes up, the teacher should take a beaker of water and put in a sugar cube, and another and another and continue to stir. The visual should help students to see that no matter the amount the solution is stirred, no more sugar can be dissolved. As this engage doesn’t ask students to explain WHY the sugar dissolves, there shouldn’t be much concern about the molecular level of dissolving. The molecular levels will be addressed later in the unit. |
| Recommendations: | The challenge issued results in is a student-centered activity started with a teacher explanation. The teacher should gain students attention of all students before starting and help to create an environment where all students feel they can be successful at dissolving the sugar cube. The purpose is for students to get excited enough and passionate enough to “win” the challenge. The engage described above should take about 20 minutes total including the directions, discussion, planning, experiment and conclusion questions. |
| Title: | “Clumping” of little kids at Soccer? What does it mean?  
*For use in the beginning of the solutions unit to present a problem to students to solve and engage students in chemistry!* |
| Source/website: | Created by C. Christopher 9/28/13  
Website found at:  
http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/thermochem/solutionSalt.html |
| NYS Chemistry Standard: | Key Ideas:  
Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific Functions  
3.1ooA solution is a homogeneous mixture of a solute dissolved in a solvent. The solubility of a solute in a given amount of solvent is dependent on the temperature, the pressure, and the chemical natures of the solute and solvent.  
3.1rr An electrolyte is a substance which, when dissolved in water, forms a solution capable of conducting an electric current. The ability of a solution to conduct an electric current depends on the concentration of ions.  
*The above standards are addressed in a limited manner as they have no background knowledge. By the end of the engage portion, students are expected to ask questions like “how does this work?”, “what makes it do that?” and “what other substances would work like that”?* |
| Supplies | A story told to the students to gain and focus their attention as well as a computer with internet access to:  
http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/thermochem/solutionSalt.html |
| Key Questions | To be asked after the completion of the video and through the follow up activity.  
*When I say everyone, does anyone know what I’m talking about? Can you describe it? Tell me about what you would see? Why might I be telling you this in chemistry class? Your goal is to determine how this is related to chemistry and why I told you a story about soccer. What do you think this substance is? What do you notice about it that makes you think that? If I took a beaker full of this substance, what would you expect to happen to it? What kinds of things might you do to it to change its behavior?* |
| Summary of Engage: | Students will enter into an engage piece on the first day the solutions unit. The following story used as an engage segment will be closely linked to their lives (story) and the teacher and simulation will pose a challenge to them to learn more about a topic. The teacher will start with a story:  
“Have any of you ever seen little kid soccer- like 4-5 years old? Or do you
remember playing? When I think about the first few years of soccer, I distinctly remember playing defense because I didn’t want to be around everyone. When I say everyone, does anyone know what I’m talking about? Can you describe it? (ask for students description) Yes! Many times in “little kid soccer” you find that where the ball is, ALL of the kids go to that spot and you have at least 10 kids trying to get 1 ball (6 from the offense and at least 4 from defense/ midfield). Why might I be telling you this in chemistry class? Let’s watch. I want you to be looking for how this is similar to my soccer story and to see if you can figure out what is going on in this story.” After video is shown, ask students follow up key questions.

At this point, students are expected to be “hooked” and excited to try and figure out what is going on to cause this and why it works. They should have questions in their mind about what is the substance, what else works that way? Students will be given time to discuss as they are asked to begin their follow up *explore* activity. Students will be able to work on computers through a pHet simulation related to dissolving to help students dive deeper into the content.

**Rationale:** Salt dissolving in water is a concept that students know well. The issue is they do not know HOW it works on the particle level. Relating the salt (Na⁺ or Cl⁻) to the soccer ball creates an analogy for students to use as well as engages them with something familiar. The simulation then clarifies how the particles work related to salt dissolving and what happens with the water. Using the story to engage students and asking for their help should aide in making the *engage* more relevant and appealing to students.

**Possible Misconceptions:** While it is possible that students will take the soccer analogy incorrectly, any misrepresentation will be immediately addressed by the use of the online simulation showing salt dissolving in water. According to Aydeniz and Kotowski (2012), teachers need to facilitate how physical and chemical processes occur on a microscopic level as this is where students get confused. The simulation provides a visual of the microscopic interactions. Also, according to Bridle and Yezierski (2010), the particulate nature of matter is where many students have held misconceptions for long periods of time and need these ideas directly addressed. Most students really have not thought about HOW salt or sugar dissolves, they just know it as a fact. Part of chemistry is understanding why and how that process occurs. Students and teachers can explore HOW it works using computer programs and through interactions and discussions to ensure misconceptions are being revised, not created (Aydeniz and Kotowski, 2012).

**Recommendations:** The story starting the engage is teacher- centered used to grab students attention through their interaction followed by a simulation. Teacher should gain students attention before starting the story and be EXTREMELY animated while telling it or students won’t pay attention. It is recommended that the teacher walk around the room & not read from a script while telling the story. The simulation should already be cued up on the screen ready when the teacher finishes the story. The story followed by students looking at the simulation should take about 7 minutes total and occur within the classroom.

**Title:** Why do you have a bat? OR Home Run Winners!
<table>
<thead>
<tr>
<th>Source/website:</th>
<th>Created by C. Christopher 9/26/13</th>
</tr>
</thead>
</table>
| NYS Chemistry Standard: | Key Ideas:  
3.4b Kinetic molecular theory (KMT) for an ideal gas states that all gas particles:  
- are in random, constant, straight-line motion.  
- are separated by great distances relative to their size; the volume of the gas particles is considered negligible.  
- have no attractive forces between them.  
- have collisions that may result in a transfer of energy between gas particles, but the total energy of the system remains constant.  
3.4c Kinetic molecular theory describes the relationships of pressure, volume, temperature, velocity, and frequency and force of collisions among gas molecules.  
3.4d Collision theory states that a reaction is most likely to occur if reactant particles collide with the proper energy and orientation.  
*Standard 3.4d is directly addressed using this engage activity. 3.4b and 3.4d are both addressed in a limited manner as they have no background knowledge. By the end of the engage portion, students are expected to ask questions like “why does this have to work?” , “What makes it do that?”* |
| Supplies | A story told to the students to gain and focus their attention (Note: The use of a waffle bat and waffle ball can be added but is optional. The teacher could show the students the hits instead of using a story. If the teacher chooses to use a bat and ball, a room with limited technology or a place where the ball can hit the wall and do no damage (the school gym is another alternative) is an appropriate modification. |
| Key Questions | To be asked after the completion of the video and through the follow up activity. *Tell me about what you would see if I hit the “t” of the t-ball? What do you think happened when I was in gym class? Is this the “hit” I was looking for? Why or why not? What would my “ideal” hit be? Tell me about a “good” hit. So I said this was related to chemistry- in what ways do you think it is?* (think, pair share ➔ share out) ask follow up questions to how this is related to chemistry. *What do you think this is success criteria for related to chemistry? What do you notice about it that makes you think that? How can we depict this baseball scenario using chemistry particle diagrams (think pair share). What kinds of things might you do to it to change the behaviors of molecule creation?* |
| Summary of | Students will enter into a motivating and relevant engage piece on the first day of the |
**Engage:**

kinetics and equilibrium unit. The following *engage* segment will be closely linked to their lives and will give a demonstration of an idea to challenge students to learn more about a topic. The teacher will start with a story:

“I have a story to tell- at the end we’ll figure out how it might relate to chemistry. A long time ago in a land far far away- or really close, depending on where you grew up- did anyone learn (or TRY to learn) how to hit a baseball? I remember I was on a “t-ball team” and I distinctly remember hitting the “t” instead of the ball multiple times. I was not a natural. What was wrong with me hitting the “t” in t-ball? (Ask key question)? Ok so it was a few years later when I tried my hand again at baseball. I was up to bat in gym class. And if you are wondering, I was a rather competitive gym class student. With that being said, I was up to bat and the ball was pitched to me. I swung and totally missed. I tried again, same pitcher and this time I was SURE I was going to get it. What do you think happened? I did manage to hit the ball, but it went over my head and the catchers’ head. Is this the “hit” I was looking for? (Ask student). What would my “ideal” hit be? (Ask students and use their answers to come up with the next scenario). Ok so we’ve got the fact that I make complete contact with the ball using the baseball bat, that I swing hard enough and that I have the correct timing so they collide at the correct time. Well, the thing is, I knew all of this in my head, anyone think I did it the next time? I DID- I managed to actually hit the ball into the field and run to 1st!!!! But I sadly made it there after the first baseman had caught the ball and tapped me out. It was victorious, but sad at the same time. So let’s talk about what made a “good hit.” (Ask key questions).

At this point, students are expected to be “hooked” and excited about chemistry because it has been related to sports and high school gym class. They should have questions in their mind about how to “hit more home runs” or “successful attempts.” Students will be given time to discuss as they are asked to begin their follow up explore activity. Students will be able to work with a POGIL (process oriented guided inquiry learning) to dive deeper into the content.

**Rationale:**

Collision theory is not a difficult topic, but many students get confused and need a memory tool. The nature of this *engage* piece should peak student interest as well. The story should help students to see that there is a “real world” connection to what we learn in chemistry class. It has been found that if students have a connection to the material, they are more likely to remember, be interested in and have a deeper understanding of the concepts (King, 2012). It is also possible that students have done the same thing learning to hit a baseball and will feel more comfortable as they make connections to prior learning experiences. According to Chairam Somsook and Coll (2009) when students are engaged with concepts that can be or are related to the real world, they learn better and perceive their teachers in a more positive light. Therefore, this story should also help students to see that the teacher is indeed a real person, not a scary chemistry teacher.

**Possible Misconceptions:**

The t-ball story followed by questions related to “home runs” may lead to students thinking that all reactions where a product is formed are conducted at higher temperatures. During the *engage*, speed is a factor that should be discussed when looking at the collisions. Speed and temperature can HELP with reactions, but can still occur at low temperatures. The particle diagram portion of the key questions is very important. Students will express their ideas and if teachers are hearing incorrect
ideas about collision theory, they can be directly addressed. According to Papageorgiou (et al.) (2010), the teacher should listen to student conversations and discuss what is going on after the story has been completed. All discussions should take place during the *explain* phase of the 5E model.

<table>
<thead>
<tr>
<th><strong>Recommendations:</strong></th>
<th>The story is teacher-centered. The teacher should gain students attention before starting the story and be EXTREMELY animated while telling it or students won’t pay attention. The teacher should be half acting out the story and half telling the story. Acting is recommended to engage more students. The story with acting out and questions should take about 5 minutes total and occur within the classroom.</th>
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**Title:** Why Cheese?
For use before talking about catalysts in the kinetics and equilibrium unit to help student engage with the concepts.

<table>
<thead>
<tr>
<th>Source/website:</th>
<th>Created by C. Christopher 10/5/13</th>
</tr>
</thead>
</table>
| NYS Chemistry Standard: | Key Ideas:  
| | 3.4f The rate of a chemical reaction depends on several factors: temperature, concentration, nature of the reactants, surface area, and the presence of a catalyst.  
| | 3.4g A catalyst provides an alternate reaction pathway, which has a lower activation energy than an uncatalyzed reaction.  
| | *The above standards are addressed in a limited manner as they have no background knowledge. By the end of the engage portion, students are expected to ask questions like “how does this work?” “What makes it do that?”*  
| Supplies | A story told to the students to gain and focus their attention.  
| Key Questions | What do we know about making cheese? Tell me about what you would see looking at the non-homogenized milk? After the story for guiding questions if necessary (students need to talk about temperature readings, speed up reactions with citric acid instead of cultures from yogurt, microwave to speed up process, stirring to make sure heat evenly distributed and chemicals distributed, dissolving the citric acid and rennet in water.) What are some key ingredients to make cheese? How is this process similar to the calorimetry lab we did in September? Tell me about the time required to make THIS cheese. What component of the cheese making would change this? In what way (catalyst/citric acid and microwave (heat)). What are we looking for in the cheese making process before we get to the final product? Tell me about any information that I needed to gather during the cheese making process. What do you notice about it that makes you think that? What kinds of things might you do to the cheese to change the behaviors in the final state? Describe the purpose of the microwave. What is the purpose of the citric acid?  
| Summary of Engage: | Students will enter into a motivating and relevant *engage* piece before they learn and explore catalysts. The story of making cheese is closely linked to their lives and will give a demonstration of an idea to challenge students to learn more about a topic. The teacher will start with a story:  
| | “A few weeks ago I had a friend go to a cheese making class and return SO excited to make cheese (*key question*). I told them that I would love to learn (as cheese is my favorite food besides chocolate). That being said, we bought non-chlorinated water (distilled) and whole non-homogenized milk (*key question*). They explained to me that cheese usually takes more than 4 hours to make, but we were going to use citric acid to speed up the process instead of yogurt with the active cultures because then we could eat it for lunch instead of waiting until dinner. We mixed the citric acid and milk together on the stove and stirred and measured the temperature until it reached 55°C and then added the “rennit” tablet and continued to...
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| Rationale: | Catalysts are a familiar topic to students, but many students don’t understand how it is related to their lives. The nature of this engage piece should peak student interest as well. The story should help students to see that there is a “real world” connection to what we learn in chemistry class. According to King (2012), if students have a connection to the material (in this case food), they are more likely to remember, be interested in and have a deeper understanding of the concepts. The concept that cooking is chemistry, although not foreign, seems that way to students. Cheese making serves as a connection for students to connect chemistry to a hobby or something that is familiar to them. According to Chairam Somsook and Coll (2009) when students are engaged with concepts that can be or are related to the real world, they learn better and perceive their teachers in a more positive light. Therefore, this story should also help students to see that the teacher is indeed a real person, not a scary chemistry teacher. |
| Possible Misconceptions: | The cheese making story may lead to students thinking that reactions require heat to occur. This is only true for endothermic reactions as reactions can give off heat. Another factor that must be addressed is that where a catalyst is used, it is not used up, just used to speed the process of cheese curdling, not consumed. During the engage, speed is a factor that should be discussed when looking at the collisions. Speed and temperature can HELP with reactions as a catalyst acting microwave, but can still occur at lower temperatures, but require a longer period to occur. |
| Recommendations: | Since the teacher tells the story, the engage is a teacher centered activity. Teachers should gain students attention before starting the story and be EXTREMELY animated while telling it or students won’t pay attention. The teacher should be half acting out the story and half telling the story. Acting out the story is recommended to engage more students. In total, about 7 minutes are needed to tell the story and ask key questions. The story and questioning should occur within the classroom. |

| Title: | Equilibrium and Fish tanks |
For use before starting the equilibrium portion of “kinetics and equilibrium” unit to create a central community, and engage students in chemistry!

<table>
<thead>
<tr>
<th>Source/website:</th>
<th>Modified by C. Christopher 10/13/13 from Raviolo and Garritz (2008, p. 8)</th>
</tr>
</thead>
</table>
| NYS Chemistry Standard: | Key Ideas:  
3.4h Some chemical and physical changes can reach equilibrium.  
3.4i At equilibrium the rate of the forward reaction equals the rate of the reverse reaction. The measurable quantities of reactants and products remain constant at equilibrium

The above standards are addressed indirectly as students have limited background knowledge on what equilibrium within a system looks like By the end of the engage portion, students are expected to ask questions like “how does this work?” “What makes it do that?” and “in what ways is this related to chemistry”? |
| Supplies | A smart board or other type of technology that students can manipulate “fish” to students to gain and focus their attention. Document that contains 2 fish tanks one with a lot of fish and one with none (and the ability to join the fish tanks and move fish). |
| Key Questions | To be asked during the states of matter making. What can you tell me about fish and fish tanks? Let’s be specific about what you might see, hear, touch? Describe the conditions for the fish in the tank as well as the conditions in the empty tank. Turn to the person you are sitting next to and describe what you think might happen under these conditions. What the fish would do—how the conditions would change? In what ways could we represent this in chemistry class?” or “what phenomena could this be describing?” |
| Summary of Engage: | Students will enter into a motivating and relevant engage piece with scenarios that relate to their lives and help to understand the difficult concept of equilibrium. The teacher will start by saying “We are going to do an activity called (dun dun dun) WHO IS IN THE FISH TANKS!!! First, what can you tell me about fish and fish tanks” (Talking about fish tanks should get students excited and talking about old stories creating a community). The teacher should then refocus the classroom community. Continue “Your goal as a class is to determine to the fish and fish tanks under certain conditions. (Teacher should bring up smart board) and show the picture found below. The teacher should ask students to describe the conditions for the fish in the tank as well as the conditions in the empty tank. The teacher should then propose an opening between the two tanks (show second set of pictures). “Turn to the person
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you are sitting next to and describe what you think might happen under these conditions.” Teacher should be looking for student engagement and discussion as to what the fish would do, how the conditions would change. The teacher should then ask for students to share their thoughts with the class. If thoughts match picture 3, show to class. The teacher should then ask “In what ways could we represent this in chemistry class?” or “what phenomena could this be describing?” At this point, students are expected to be “hooked” and excited to see how the fish tanks apply to chemistry.

Picture set 1.

They are now CONNECTED... WHAT HAPPENS????

Picture set 2.

Describe what has happened.

Picture Set 3.

**Rationale:** The fish tank analogy is used because the equilibrium is an extremely difficult topic for students to understand. In the studies reviewed by C. Christopher in the spring of
2013, equilibrium was the most discussed alternative conception. Students need something to help them understand that is familiar to them. The fish tanks help get a “real world” connection, which according to Criswell can help student to understand the material better with less confusion (2012). Fish tanks serve as the “anchor” to aide in the development of the concept within the students mind. Also, students who are working together talking about “fun” things like fish can help to create more of a classroom community. According to Chairam, Somsook, and Coll (2009), the familiar objects combined with the discussion can be beneficial for classroom dynamics and student to teacher relationships.

### Possible Misconceptions:

Students have the misconception about equilibrium often. The fish tank analogy may create the misconception that there is only one direction of flow, or that equilibrium means equal amounts (equal fish on each side). According to Raviolo and Garritz (2008), the teacher needs to address the size perception of the containers. The teacher should do this by creating another scenario with a tank that is half the size on the products, this shows that equilibrium won’t be equal, but that the fish still move to balance it out. Also, Ozmen (2007) suggests that students should be looking at the particulate nature of matter to modify misconceptions. Altering the analogy to use molecules is possible to do by altering the fish into molecules and taking the analogy one step further to have the students in the class come up with other examples and analogies to help explain equilibrium. Unal et al. as well as Raviolo and Garritz (2006, 2008) both suggest that teachers should use analogies, explain them AND their limitations to be the most beneficial to students learning. Chemical equilibrium alternative conceptions are held onto by students for years. Even students completing graduate work in chemistry hold onto simple analogies (Unal et al, 2006).

### Recommendations:

The analogy presentation is a teacher-centered activity followed by student discussion and possible need for prompting by the teacher. Teachers should be EXTREMELY excited when talking about fish and fish tanks. Explaining the fish tank, using the analogy and having a discussion resulting in an *engage* should take about 10 minutes and occur within the classroom.

| Title:     | LeChatlier: Color Changing Demonstration |
For use in after students have worked with LeChatlier’s principle to re-engage students in chemistry!

| Source/website: | Modified by C. Christopher 9/20/13 from R. Wheaton Spring 2013. |

**NYS Chemistry Standard:** Key Ideas:
4.2 Cite specific examples of how dynamic equilibrium is achieved by equality of change in opposing directions.

* explain how a system returns to equilibrium in response to a stress, e.g., LeChatelier’s principle

3.4h Some chemical and physical changes can reach equilibrium.

3.4j LeChatelier's principle can be used to predict the effect of stress (change in pressure, volume, concentration, and temperature) on a system at equilibrium.

The above standards are addressed directly with students as they have already been exposed to LeChatlier’s principle and have become frustrated with trying to understand the concept. The demonstration described here leads to a deeper and better understanding of these specific standards. By the end of the engage portion, students are expected to ask questions like how does this work?”, “What other liquids will do that,” and can hopefully answer the question: “What makes it do that?"

**Supplies**
Copper sulfate solution (1M CuSO₄), potassium bromide solution (4M KBr), two beakers (600mL to 1000mL are appropriate), ice, water, hot plate, two large test tubes, test tube rack, whiteboard (or smart board), and goggles. The following reaction should also be seen on the board behind the demonstration and address towards the end:

\[
\text{Energy} + \text{CuSO}_4(aq) + 4\text{KBr}(aq) \leftrightarrow \text{K}_2[\text{CuBr}_4](aq) + \text{K}_2\text{SO}_4(aq)
\]

Blue\quad \text{Colorless}\quad \text{green}\quad \text{colorless}

Light green overall \quad \text{dark green overall}

Low temp= reactants vs high temp= products

**Key Questions**
To be asked during the demonstration to encourage students to “help” the teacher. 
*Tell me about these two chemical. What can you say about them? What should I do with the chemicals now that we’ve observed them (Mix together). Describe what happened. With the supplies that I have here, what should I do next? (Heat it up/ cool it down). (For effect, heating works best first as the demo turns almost black.) What should I do now with these supplies? (Add to the cold water) What do you notice happening? Why might this be happening? What do you notice about it that makes you think that? What should I do now? (Should lead into going back and forth from hot to cold) How about now? What kinds of things are changing its behavior? What else might you do to it to change its behavior? Using written equation on the board: Given that this side is what I started with and this is what happens when I put it into the hot, what could have happened when I put it into the cold side (only 2 sides of reaction therefore must have shifted to the other side). What concept might this be related to?*
| Summary: | Set up two beakers at the front of the room with one on the hotplate with water in it turned on to keep warm (not boiling) and the other fill with an ice bath. The teacher should do this with goggles and a lab apron. Put test tube rack in front and pour 4M KBr into one less than half full and 1M CuSO₄ into the other less than half full. Have students move desks in a “U” shape so that all can see well. Start questioning with key questions and when students say to mix the two, pour the copper sulfate solution into the potassium bromide solution. Continue with key questions and when student say to place into hot water, get test tube holder (safety concerns). The teacher should act surprised when it changes to almost black and should ask students more of the key questions (describe what is happening). The teacher should continue to prompt students as to what else could be done and eventually shift test tube to the colder water. Again, the teacher should act surprised when it changes back to light green and continue asking questions to lead students to the idea that this is LeChatlier’s principle in action. The teacher should move the test tube back and forth between the two temperatures no less than 2 times each to show students it was not a “fluke” but really what happens. The teacher can then reference the reaction on the board and ask student to help decipher which color is on which side and what added and removed energy does. The students should help “explain to the teacher” what is going on in the reaction by careful questioning by the teacher. This will lead to understanding of the standards. At this point, students are expected to be “hooked” and excited about how the color change works. They should have a better understanding of LeChateliers’s principle. Students will be given time to discuss as they are asked to begin their follow up explore activity. Students will be able to work with cornstarch and water will be to help students dive deeper into the content. |
| Rationale: | LeChatliérs principle is one of the more difficult concepts for students to understand. The use of color in the demonstration helps students to see the concept in action and manipulate the variables themselves by telling the teacher what to do with the test tube. The nature of this engage piece should peak student interest as well. Even though students are 10th and 11th graders, color changing is still a fascinating thing to them. The LeChatlier’s demonstration also requires a lot of chemicals to be seen well and therefore is more appropriate as a demonstration than as an experiment for students to conduct on their own. |
| Possible Misconceptions: | The color changing manipulation of variables found in the demonstration has the purpose, other than to engage, is to help dispel misconceptions related to LeChatlier’s principle. In addition to the positives reported in the rationale section, having a class wide discussion about what is going on should bring out some misconceptions related to LeChatlier. Bringing out misconceptions allows the teacher to directly address any misconceptions related to equilibrium (Ozmen, 2007). The idea that taking energy away shifts equilibrium towards energy is difficult. This engage activity allows teachers to directly show students their misconceptions are incorrect. Teachers can then follow this engage up with an explore reading that, again, directly addresses LeChatlier’s principle. The teacher may use the alternative |
conception text (found in ancillary documents) provided by Ozmen (2007).

| **Recommendations:** | The demonstration is a teacher-centered activity with questioning that should allow for much student involvement. When this *engage* activity was tested with students, it was found that the students wanted to make half the test tube one color and the other half the other color. The teacher testing tried and followed their directions. The class thought that they were “distracting the teacher” or getting off task when in reality the students were extremely engaged in what was going on. The teacher can let students think they are getting the teacher off task. It is recommended that the teacher “pretend” to not know what is happening to increase student involvement and presentation of what might be going on. The demonstration including questions should take between 7 and 15 minutes total (not including setup) and occur within the classroom. |

| **Title:** | Rainbow demo- What’s going on? |
For use in the beginning of the acids and bases unit to engage students in chemistry!

**Source/website:** Adapted by C. Christopher 9/13/13 from You tube clip found at: : http://www.youtube.com/watch?v=arNyofkuBxM from Sally Mitchell

**RESEARCH SUPPORT**  

**NYS Chemistry Standard:**  
Key Ideas:  
3.1ss The acidity or alkalinity of an aqueous solution can be measured by its pH value. The relative level of acidity or alkalinity of these solutions can be shown by using Indicators  
3.1uu Behavior of many acids and bases can be explained by the Arrhenius theory. Arrhenius acids and bases are electrolytes.  
3.1vv Arrhenius acids yield H+(aq), hydrogen ion as the only positive ion in an aqueous solution. The hydrogen ion may also be written as H3O+(aq), hydronium ion.  
3.1xx In the process of neutralization, an Arrhenius acid and an Arrhenius base react to form a salt and water.  
3.1zz Titration is a laboratory process in which a volume of a solution of known concentration is used to determine the concentration of another solution.

The above standards are addressed in a limited manner with 3.1ss and 3.1xx and 3.1zz being the major focus of this demonstration. Students have no background knowledge so this will be the introduction and piece the teacher can refer back to when discussing these standards more in detail.

**Supplies**  
6 400 mL beakers, phenolphthalein (red/pink), p-nitrophenol (yellow), and thymolphthalein indicators, glycerin with concentrated sulfuric acid, pickle jar, 1L of sulfuric acid with alcohol and some water, two large Rubbermaid pitchers of the same color and 2L sodium hydroxide, glue stick (used in hot glue gun) or stir rod.

**Key Questions**  
To be asked after the completion of the video and through the follow up activity. *Tell me about what you saw? Any thoughts on what I did? What do you think this substance is? What do you notice about it that makes you think that? What other kinds of experiments or additions to what I did today would change the result? What kinds of things might you do to it to change its behavior?*

**Summary of Engage:**  
Setup 6 beakers in front- 1-2 drops of phenolphthalein in 1st beaker for red, 1 drop in 2nd beaker for the orange with 1 drop p-nitrophenol, 2 drops of p-nitrophenol in the 3rd beaker, 4th beaker one drop p-nitrophenol and one drop thymolphthalein, 5th beaker 2 drops thymolphthalein, 6th beaker 1 drop thymolphthalein and one drop phenolphthalein. Take the glycerin with concentrated sulfuric acid and put a few pipettes full into the bottom of the pickle jar and allow it to spread around.  
Students will enter into a demonstration that is both engaging and extremely thought provoking. Then when starting the demo with the class, the teacher should have students move their desks so they are in a “U” shape around the demonstration stable and obtain goggles for each student. The teacher should then pick up the pitcher with the acid and add a small amount to each beaker and say “we are going to
start by adding a little bit from my blue pitcher to each beaker”. Then the teacher should put down the pitcher, stir by swirling at least 2 of the beakers while saying “we’re going to mix them and make sure they are ready”. Then the base pitcher should be picked up and “tease” by putting just enough base to see the color, but not have the whole beaker change color the first time. The teacher should ask the class “what observations do you have?” The second time the teacher should overshoot the endpoint by adding too much base and ask “what did I do differently this time?”. Keep the pitcher with base on the lab bench and say “we’ll leave this here in case we need more”. Then the glycerin with concentrated sulfuric acid (about 4 drops) should be added to each beaker to shift equilibrium. The teacher should ask students “what do you notice with the addition of the liquid?” Each beaker should then be stirred with a glue stick (or carefully with a glass stir rod not to break the beakers). The teacher should ask “what do you notice when I stir the beakers?” Then more base should be added to shift the color again. The center two colors (yellow and green) should be moved aside to place the pickle jar in the center. These same beakers should then be poured into the pickle jar simultaneously. Followed by the next two colors (orange and blue) and finally by the red and purple. When they enter the jar, they should be clear. While pouring the teacher should be asking students “what do you think is happening?” and “what observations can you make?”

After the completion of the demon, students are expected to be “hooked” and excited about the acids and bases unity to follow. They should have questions in their mind about what is the substance; can I do that, and what happened to allow for those different color changes? Students will be given time to discuss as they are asked to begin their follow up explore activity. Students will be able to work with indicators and common household substances to help students dive deeper into the content.

**Rationale:**

Students have used indicators before in living environment and have been exposed to phenolphthalein during the “Thinking like a scientist” explain portion, but have no experience with colors and how they work. The demonstration helps students to engage in the chemistry of “colors” and become excited about something new. The nature of this engage piece should peak student interest. The “wow” factor helps to get students motivated for the rest of the acids and bases unit and can serve as a point of reference for the teacher through the unit.

Also, the presentation of the demonstration is important. All of the questions that the teacher asks should lead to student engagement and be dynamic in nature. Students should be asking questions related to the content, shift in their seats, actively participate in classroom discussions and work harder as they try to determine what is going on when they are engaged (Milne & Otieno, 2007). The order or “chain of events” helps students to become more engaged making predictions and suggesting modifications to the experiment when they can follow the process. The rainbow demonstration has a clear order and is possible to follow. Students don’t often get the opportunity to engage in demonstrations actively, the goal is to ask questions, create a common goal and develop a community and a common frame of reference for the class (Orgill & Thomas, 2007, p. 42). The last reason for the use of this demonstration being done is that the completion of this in the laboratory for students would be unsafe and require too much of each chemical.

**Possible**

Based on the presentation of the activity and the appearance that the acid and base
### Misconceptions:

are the same thing (coming from the same color pitcher) may lead students to thinking that indicators can change to two different colors when the same substance is added to them. The use of equilibrium to shift the color is used to demonstrate LeChatlier’s principle. Since equilibrium is a difficult concept, addressing the nature of the shift in a “fun” demonstration can help to focus students more when the topic gets more complex (To avoid this misconception for the long term, the explore lab activity following the engage and the explain activity will directly address how indicators work).

### Recommendations:

The performing of the demonstration is a teacher-centered activity that can lead to student engagement through questioning. The goal is to get students to ask questions about what is going on in the demonstration as well as the chemistry concepts behind the demonstration. Teacher should gain students attention before starting by saying that the student goal is to ask as many “legal” questions as possible to determine what is going on. A “legal” question simply means that the teacher will answer and can’t be “what is in the container.” The rainbow demonstration as an engage should take about 15 minutes total and occur within the classroom. Fifteen minutes does NOT account for setup time prior to class starting.

### Title:

Why do numbers matter? Relating oxidation numbers to real life

*For use in the beginning of the redox unit to engage students in chemistry!*
<table>
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<tr>
<th>Source/website:</th>
<th>Created by C. Christopher 9/29/13</th>
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| NYS Chemistry Standard: | Key Ideas:  
3.2i Oxidation numbers (states) can be assigned to atoms and ions. Changes in oxidation numbers indicate that oxidation and reduction have occurred.  
The above standard is addressed in a limited manner as students have no background knowledge. By the end of the engage portion, students are expected to ask questions like “how does this work?”, “What elements always have the same numbers” “What rules must be followed?” |
| Supplies | A story told to the students to gain and focus students attention on the topic and engage them in oxidation numbers |
| Key Questions | To be asked during the story. Does anyone have a last name? How about a first name? In what ways do these “names” identify you? Does your name often change? How many of us have a favorite number? Any sports fans or players who have a number? What can you tell me about your sports numbers compared to your favorite numbers? Is it always the same number? Can you have a few “favorite numbers” and change depending on the day? So I said this was related to chemistry- in what ways do you think it is? (think, pair share ➔ share out) ask follow up questions to how this is related to chemistry. Let’s try and pick this apart, what do our first and last names have to do with chemistry? (Turn to a partner). What are some numbers on the periodic table that we KNOW for a fact? (atomic number, atomic mass number). There are new numbers act like the sports numbers and favorite numbers we talked about. What have we talked about in relation to sports and favorite numbers that might be applicable to these new numbers? |
| Summary of Engage: | Students will enter into a motivating and relevant engage piece on the first day of the redox unit. This engage segment will be closely linked to their lives and will pose a challenge to them to learn more about a topic. The teacher will start with a story:  
“Today we’re going to start with story time! I’m going to ask that no matter how ridiculous my questions sound, you’ll answer them and help me out with the story. Ok so- my first question is how many of you have a last name- let’s raise our hands. Ok- we all have a last name, how many of us have a first name? (All raise hands). WONDERFUL!!! Ok so now the question is, do you always have the SAME last name and first name? I hope so. Now I want us to think about our favorite numbers. Do you have a favorite number or a number you associate with success (a sports number or a just for fun number)? Wonderful- is it ALWAYS the same number? (Find someone who plays multiple sports and has 2 numbers as an example). Does anyone play 2 sports and have 2 different numbers? Do you have one number that you have more often or is your favorite number? For those of you who don’t play sports, do you have a “secondary” favorite number? For example, my two favorite numbers are 7 and 11, but if I had to pick one, I’d pick 11. |
So now that we’ve got some numbers in our heads, let’s try and figure out how this is all related to chemistry. Sadly, I didn’t JUST want to talk about numbers and names today. Therefore, how is this related to chemistry? Let’s try and pick this apart, what do our first and last names have to do with chemistry. Turn to a partner and see if you can come up with some ideas. (Ask for student input- if they determine elements always have the same name (and compounds) this is where they need to be. Otherwise the teacher must lead students there with questioning.) Now that we’ve figured out that elements are what the names represent, why were we talking numbers? (Give students 30 seconds to talk about how numbers relate to the periodic table). Ok so there are these numbers on the periodic table- in addition to the ones we already know like the atomic number and mass number. These new numbers act like the sports numbers and favorite numbers we talked about. Some elements ONLY have 1 “favorite number” or oxidation number. These are group 1 and 2 elements along with fluorine. Then there’s oxygen who is MOST of the time a 2- when its in compounds unless its paired with a metal or hydrogen to make a peroxide (X₂O₂ where X can be any group 1 element). Then, there were some of you who couldn’t tell me your favorite number. WELL there are some elements like you too! The transition elements are so fickle that every time they react, they likely have a different “favorite number” so you have to state what the number is every time. They “pick” their number based on the non-metal they are paired with. Wonderful! So now we know how chemistry and all of these numbers relate, let’s take it deeper and since you didn’t need to write all of these random facts down, let’s explore oxidation numbers.

At this point, students are expected to be “hooked” and excited about how the elements “favorite” numbers work in Students will be given time to discuss as they are asked to begin their follow up explore activity. Students will be able to work with oxidation numbers in a follow up POGIL activity to help students dive deeper into the content.

**Rationale:**

Oxidation numbers are a topic that students do not like because they don’t understand why the elements have all of these different numbers and why we have to know them. The story and engage activity helps to put a “face” on the numbers and make them important to students by relating them to their own favorite numbers.

The story should help students to see that there is a “real world” connection to what we learn in chemistry class. Orgill & Thomas (2007) suggest that ideas related to students’ ideas can help immensely which is what this analogy is doing. As silly as favorite numbers and sports numbers are, students are comfortable with these ideas and can make connections to prior learning experiences. Connections to prior learning will help with the classroom community aspect of teaching and students excited to learn.

**Possible Misconceptions:**

The story of favorite numbers for the engage activity may lead to students thinking that elements can only have one oxidation number. It is important that the teacher address the fact that most elements have multiple oxidation numbers. Papageorgiou (et al.) (2010) suggests that the teacher should listen to student conversations and discuss what the analogy means. The teacher should also address the analogy.
through the unit. It should be used in the beginning, middle and end to help identify any misconceptions it is causing as well as to point out any imperfections in how it is related to the science idea.

**Recommendations:** The story is a teacher-centered activity with student input to increase engagement. Teacher should gain students attention before starting the story and be EXTREMELY animated while telling it or students won’t pay attention. It is recommended that the teacher walk around the room & not read from a script while telling the story. The story followed by questions and answers should take about 7 minutes total and occur within the classroom.

| Title                      | You start at the anode!!! Music video on YouTube  
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<td></td>
<td><em>For use in the beginning of the topic voltaic cells to engage students in</em></td>
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| Source/website: | Created by C. Christopher 9/21/13  
You tube clip found at: [http://www.youtube.com/watch?v=-bxJXt_69yM](http://www.youtube.com/watch?v=-bxJXt_69yM)  
by M. Rosengarten ©2007 “Chemistry Music Video 27: You start at the Anode” |
|-----------------|-------------------------------------------------|
| NYS Chemistry Standard: | Key Ideas:  
3.2j An electrochemical cell can be either voltaic or electrolytic. In an electrochemical cell, oxidation occurs at the anode and reduction at the cathode.  
3.2k A voltaic cell spontaneously converts chemical energy to electrical energy  

*The above standards are addressed directly in the video. Also addressed in the video is how a voltaic cell operates. Operation of the voltaic cell is often a question that students struggle with and this adds to the benefits of the engage portion.* |
| Supplies | A story told to the students to gain and focus their attention as well as a computer with either internet access or a file stored on flash drive of the video found at: [http://www.youtube.com/watch?v=-bxJXt_69yM](http://www.youtube.com/watch?v=-bxJXt_69yM). |
| Key Questions | To be asked after the completion of the video and through the follow up activity. *Tell me about what you saw? What are some new vocabulary terms you heard? So I said this was related to chemistry- in what ways do you think it is?* (think, pair share ➔ share out) *What is your evidence that it’s related to chemistry? What do you think this idea is used for? What do you notice about it that makes you think that?* |
| Summary: | Students will enter into an *engage* piece on the first day of electrochemistry. The song from YouTube for the *engage* segment has a catchy tune and will pose a challenge to them to learn more about a topic. The teacher will start with a story:  
“A few years ago, I was looking at the topic that is next for us to talk about and I wanted to find something that would help students to remember and understand the key concepts. I started searching the internet for the topic and kept finding worksheets and nonsense related readings. Finally I decided to try YouTube because there has been MANY chemistry related videos that I’ve found. With that being said, I typed in the two main concepts and this wonderful amazing video with a song came up on the screen. The song you are about to listen to is THE BEST SONG that I’ve EVER FOUND about voltaic cells. In fact, past years students have memorized the song or sang along to it during the test. One even added it to their i-tunes library to help them learn it. It has so many important ideas. As we get into the song, feel free to sing along (I know I will!!!).  
The video found at [http://www.youtube.com/watch?v=-bxJXt_69yM](http://www.youtube.com/watch?v=-bxJXt_69yM) titled “Chemistry Music Video 27: You start at the Anode” will be shown. The teacher should feel free to sing and dance along to “sell” the song.  
At this point, students are expected to be “hooked” and excited about the unit. They should have questions in their mind about the silliness of the video and the repetition as well as trying to think if they can use the song to help them. Students will be given time to discuss as they are asked to begin their follow up *explore* activity. Students will be able to work to create a voltaic cell (battery). |
| Rationale: | The video is the best explanations of voltaic cells that I’ve seen and it hooks students. They are so excited. They go home, show their families, and show other
chemistry teachers and students in other classes. The idea of the song is to hook students to be engaged for the actual learning of the processes that goes on in the cell, but it actually DOES teach them what goes on in the cells. In addition, the way in which it is presented should help students see that the concept is not a hard one. With the teacher singing along, student should see that the teacher is indeed a real person, not a scary chemistry teacher. The nature of this engage piece should peak student interest and make them laugh. Laughing will help with the classroom community aspect of teaching. The engagement and “successful interactions” with this new concept allows the teacher a window into student’s thoughts (Milne & Otieno, 2007). Since questions are being asked of the students to explore the video and with the comfort that students have with their teachers and peers students can have success.

Students who are engaged and focused within the classroom usually ask good thought provoking questions inspiring more engagement from their peers. When students are engaged, they are more on task and focused and more willing to learn than if they are simply taking notes. Those students who share the video help to spark interest in others and spread the “fun” part of science class (Milne & Otieno, 2007).

Possible Misconceptions: The song for the engage activity may lead to students thinking that the anode is always on the left side. This video coupled with practice problems does have the anode most of the time on the left. Teachers should address this with students when talking about what the anode and cathode are as well as how to determine which metal is which. Addressing how to determine what is the anode and what is the cathode will be done in the explain portion of this activity.

Recommendations: The story to start the engage is teacher- centered followed by the video. Teachers should gain students attention before starting the story and be EXTREMELY animated while telling it or students won’t pay attention. It is recommended that the teacher walk around the room & not read from a script while telling the story. The clip from YouTube should already be cued up on the screen ready when the teacher finishes the story. The story followed by the video should take about 5 minutes total and occur within the classroom.

<table>
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<th>Title:</th>
<th>Challenge: Build a model like no other</th>
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<td>Source/website:</td>
<td>Created by C. Christopher 5/2/13</td>
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### Research Support

### NYS Chemistry Standard:
Key Ideas:
- 3.1ff Organic compounds contain carbon atoms, which bond to one another in chains, rings, and networks to form a variety of structures. Organic compounds can be named using the IUPAC system.
- 3.1gg Hydrocarbons are compounds that contain only carbon and hydrogen. Saturated hydrocarbons contain only single carbon-carbon bonds. Unsaturated hydrocarbons contain at least one multiple carbon-carbon bond.

*The above standards are addressed in a limited manner as they have not background knowledge. By the end of the challenge, students have created hydrocarbons and are able to identify the black spheres as carbon and the white spheres as hydrogen.*

### Supplies
Organic model kits (one for each group of 2), container for models to be poured into so they do not end up all over the floor and half sheet of brightly colored paper (different color for each group).

### Key Questions
To be asked after the completion of the activity. 
- Tell me about the difficulty to come up with a different model than the other groups? (the idea that there are millions of organic compounds)
- What are some thoughts on what you just made? What might the black spheres represent & why? What might the white spheres represent and why? What kinds of things might you do to it to change its behavior?

### Summary of Engage:
The challenge activity allows students to work hands on with model kits creating a “new” molecule. They do not know what they are making, but they are working quickly, talking with their partner to create the first or the coolest model in the class. Once a group has completed their model, no other group may “create” that model. Students will be given a piece of paper and asked to draw the model (in 3D) with spheres labeled with black and white. Students are proud of their models. At the end of the activity, I ask all students the key questions and to show their models to the class individually. The challenge to build a model engages students in a new concept with no prior knowledge and gets them motivated to learn how to name the model they created and make more models. Students get to chose how they make their model, allowing students some personal choice in the laboratory.

### Rationale:
Organic molecules are an important part of the Chemistry curriculum. Unfortunately it can be a rather boring topic. Building models with model kits and challenging other groups with time helps students by:
- Giving them opportunity to work kinesthetically with manipulatives surrounding a new concept
- Providing them with an authentic challenge which engages adolescents with their peers and the content. The authenticity of the challenge, according to Meyer, Schmidt, Nozawa, and Panee (2003), can help students to see through the eyes of “real chemists” who made significant discoveries. It does this by being more authentic and helps students to see that chemistry isn’t boring with cookbook labs and lectures all day. Working to create something “new” and authentic creates a community and increases “the personal relevancy of new learning” (Meyer, Schmidt, Nozawa, Panee, 2003, p. 432).

### Possible
Having students build models with plastic modeling kits may lead to students
**Misconceptions:** thinking that atoms are truly attached together with lines rather than sharing electrons to make bonds. Students also may believe that hydrogen and carbon are the only two things that can be connected to each other. Students need to be made aware that the bonds represent sharing and through the unit after building more molecules, student will build models with nitrogen, oxygen and halogens to help alter this possible misconception.

**Recommendations:** Start by pairing students up by placing bucket between two students. Show students the models (spherical) and ask why they might have buckets in front of them. Show students to dump the models into the bucket. Write on the board and say “your task is to create a model with only black and white spheres where there are not spaces unfilled”. What I have described is a challenge because no two groups can have the same model. When I give you the “OK” for a good model, you will draw it on the colored piece of paper. Be sure to have the black distinguished from white in your drawing. Students get started. Works well in pairs, would also work well individually. When the first group is done, the teacher should announce this and hand them their colored piece of paper. Explaining what to do followed by the students building models and drawing them takes about 10 minutes and should occur within the classroom.

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<th>Title:</th>
<th>The Radioactive Boy scout!</th>
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<td></td>
<td><em>For use in the beginning of the topic of nuclear chemistry to generate</em></td>
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Christopher 113

|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NYS Chemistry Standard: | Key Ideas:  
4.4a Each radioactive isotope has a specific mode and rate of decay (half-life).  
4.4b Nuclear reactions include natural and artificial transmutation, fission, and fusion.  
4.4c Nuclear reactions can be represented by equations that include symbols which represent atomic nuclei (with mass number and atomic number), subatomic particles (with mass number and charge), and/or emissions such as gamma radiation.  
4.4d Radioactive isotopes have many beneficial uses. Radioactive isotopes are used in medicine and industrial chemistry for radioactive dating, tracing chemical and biological processes, industrial measurement and nuclear power and detection and treatment of diseases.  
4.4e There are inherent risks associated with radioactivity and the use of radioactive isotopes. Risks can include biological exposure, long-term storage and disposal, and nuclear accidents  
4.4f There are benefits and risks associated with fission and fusion reactions  
Standard 4.4e is directly addressed using this engage activity. The other standards are addressed in a limited manner as students have no background knowledge. By the end of the engage portion, students are expected to ask questions like “why did he do that?” “What makes it so dangerous?” “How do we create reactors safely?” |
| Supplies | Story written by Ken Silverstein found in Appendix A and at the website: http://www.dangerouslaboratories.org/radscout.html |
| Key Questions | To be asked after the completion of the reading to start the conversation and if necessary to aide in the discussion. *Tell me about what we read. In what ways is this related to chemistry? What societal implications might this have? What sorts of risks are discussed in this portion of the article? Based on what we’ve read today, what might you expect us to read about tomorrow?* |
| Summary of Engage: | Students will enter into a motivating and relevant *engage* piece on the first few days of nuclear chemistry. The author of this *engage* has in the past assigned the reading as a homework assignment with limited engagement from students. The method |
described here increases student engagement and enjoyment of the story. Due to the title of the story, students are initially engaged. The title also poses a challenge to students to learn more about a topic. The teacher will start with an introduction: “Before we start our nuclear chemistry unit, we’re going to take some time at the beginning of the next few classes to learn about a boy... more specifically The Radioactive Boy scout”. The story that you hear from me, is in fact a TRUE story. None of what he tries should be repeated. The goal is to see what we can learn about nuclear chemistry through his eyes. I would like you to have some “real world” background knowledge related to nuclear chemistry. The radioactive boy scout is AMAZING!” The teacher should start by reading the first section of the article (stopping before the “concocted identity” section). Key questions should be asked as well as what predictions they have for the next day’s reading. The next day the teacher should ask students to explain what was read the previous day (particularly if any students were absent). The teacher should read the next section and stop at the “imminent danger portion” but tell students the title. The teacher should ask key questions and predictions as done on the first day. The last day should be repeated (summarize, finish reading and asking questions). The teacher should serve as facilitator for the discussion, not the center of the discussion. If necessary, the teacher can continue with the key questions.

At the end of the discussion, students are expected to be “hooked” and excited about nuclear chemistry. Students will be able to work with nuclear chemistry ideas diving deeper into the content.

Rationale:
The Tale of the Radioactive Boy Scout reading serves as a great “real world” connection for students. The title is shocking and engaging on its own. Splitting the reading between 3 days excites students many asking “what’s next” “What will he do?” “Is this safe?” “What happened to him after they found out?” The discussion at the end of the engage activity serves to create social awareness and community when students are engaging in discussion constructing their own knowledge. According to Vygotsky, knowledge must be constructed through the use of language and communication between learners will be helpful during and after the reading of the story (Chairam, Somsook, & Coll, 2009). The discussion surrounding the key questions should lead to student questioning which has been studied by Lang, Wong, and Fraser (2005) related to student perceptions and therefore learning. It has also been studied by Rop (2003) who looks at the different types of questions that are asked by students. The current activity allows for all types of questioning supported by the teacher looking for deeper answers and questions which, according to Lang, Wong and Fraser, should lead to a more conducive learning environment. King (2012) also revealed that students have a higher interest in the subject when they are engaged in real world problems and situations.

Possible Misconceptions:
The non-fiction story of the Boy scout may lead to students think that it is “easy” to make a nuclear reactor. Some may look up how to do it, or research more about David Hahn. To avoid this occurring again with the students who have heard David’s story, the teacher should emphasize the serious nature and danger that anyone working with radioactive materials must use. Marie Curie died because of her work with radioisotopes. This should be stated to students and explained the severe consequences that can occur when working with radioactive materials.

Recommendations:
The discussion after reading and summary of the story each day should be a student-
centered activity with minimal teacher input (minus the reading of the story completed by the teacher). The teacher should monitor student discussion and support and or bring up the article on the projector if the need arises to answer the question “what did the article say?” The reading and questioning should take about 15 minutes per day (45 total) with reading followed by the discussion.

**Personal Reflection**
When I started this project I was excited to begin, but also unsure of where it would lead me. I wanted to create something that I could use immediately in my classroom to engage students in chemistry. In the past, I’ve seen students who don’t care about chemistry, have no desire to do well or work. My goal with this project was to decrease the number of students who “don’t care” by engaging them in classroom activities as often as possible.

I started the process by taking some activities that I’ve done in my chemistry classroom in past years and modifying them to be real engage pieces. This is a process that I enjoyed as I was able to see the research background to what I already knew was “good instruction.” After seeing what I had been doing fit with research, I loved the expanding process. I took what I already had and made it better by organizing, finding research, misconceptions, creating a list of supplies, and writing the state standards. In addition, I created key questions to go with every engage activity. In my opinion this was one of the best sections because I am always pushing myself to create higher level thinking questions. Making questions takes time, effort and reflection. Completing the project in this document has helped me develop these types of questions for 30 wonderful activities. I also like the recommendation section of my project as I know that I am going to disseminate this information to my colleagues and this will be useful to their practice. The last, and definitely the most important portion, is the summary of engage activity. The summary of the engage activity portion details exactly what should be done for all of the “pieces” to fit together to engage students in the content.

Once I had worked with the activities I already had, I had to start digging into topics that I was less comfortable with and didn’t have activities for in my repertoire. As a professional, this was a necessary step for me to grow and enrich the learning of my students. I was able to find topics that were easy to fit “real life” stories into.
I am hopeful that as I continue to use these engage activities within my classroom that I see more students with questions, sitting up in their seats and excited to learn chemistry. The process of creating the above engage activities has shown me what it takes to make an engage segment with all of the “parts” necessary for it to be successful in the classroom. I look forward to sharing this document with my colleagues and hearing their results.

Discussion and Summary of Process
In the project titled *Improving chemistry Instruction via the 5-E Learning Model: Inventing, adapting, and incorporating the first “E”*, different methods of student engagement were researched as well as ways to engage students in learning. After determining the factors that led to student engagement, engage activities were created for specific concepts within the New York State Regents chemistry curriculum. These standards require detailed explanation. The purpose of the engage activities is to “hook” students on the more abstract or difficult topic.

Once this project was decided on, the format was constructed to include ten components. These ten components are essential when the information is disseminated to other chemistry teachers. The components are as follows: title, source/ website, research support, NYS chemistry standard, supplies, key questions, summary of *engage*, rational, possible misconceptions, and recommendations. The title gives a reference for the teacher as to what the activity might be about. The source/ website will give credit to those who the activity has been modified from. Research support allows others to find the research to support the engage (if the information cited later in the rationale and possible misconceptions aren’t enough). New York State chemistry standards are important so teachers know what standards that the engage will address. The supplies will allow the teacher to know quickly if the supplies needed are available without reading the entire activity. Key questions, in my opinion, are one of the most important components as they take time to create. It is important to make sure that students aren’t answering simple equations, but higher level thinking questions. Summary of the *engage* gives a detailed summary of the steps to complete the engage activity. The rationale section contains a variety of reasons why the engage might be used instead of “normal instruction.” According to Aydeniz and Kotowski (2012), Ozmen (2007) and Unal, Calik, Ayas and Coll (2006), teachers must know what student misconceptions are when planning lessons so they can be addressed directly to avoid the continuation of those alternative conceptions. The last section of
recommendations indicates “extra” information that may be useful to the teacher. The extra information includes time frame for the activity, if the activity should be student or teacher-centered and any information the author feels is important to the success of the activity that has yet to be mentioned.

The thirty engage activities that are detailed above with ten sections each should be used by teacher to increase student engagement. These engage activities are not boring, but thoughtful ways to help students get excited about the content. Research has shown, particularly King (2012) and Criswell (2012), that when students are engaged in the material, whether through a story, demonstration, activity or any other manner, they will learn more in the long run. When students are engaged in the material, they are not thinking about what is happening in the lunchroom, who is texting or tweeting or plans they have for the night. Students should feel like class “flies” by when they are engage in the material. Students should also always feel like they have learned something. In addition, question should be freely asked to clarify misconceptions and higher level questions and thinking should help students to understand that chemistry is more about understanding than getting the “correct” answer. This is especially true during one of the engage activities. Students should WANT to come to class and be excited for what their teacher will do next or what they will be learning next because it is exciting.

References
Aydeniz, M., & Kotowski, E. (2012). What do middle and high school students know about the


doi:10.1080/02635140802658933

Criswell, B. (2012). Framing inquiry in high school chemistry: Helping students see the bigger picture. _Journal of Chemical Education, 89_(2), 199-205.


**Appendix A:**

Ancillary documents for:
Improving chemistry Instruction via the
5-E Learning Model:
Inventing, adapting, and incorporating the first “E”
Thinking like a Scientist
(Engage Activity #2)

1. Describe the materials that you have been given in detail. List at least 10 different observations:

2. Given the materials you have, what could you do with both of the materials together? (Please remember safety). Write a hypothesis about what you think will happen when you perform the action. Please write it in the form "If I __________, __________ will happen".

3. Perform the action with the paper and bottle. Observe what happens. Write down at least 7 different observations.

4. Was your hypothesis correct? Answer in a complete sentence and back up your statement with observations.

5. Write at least one question based on what you saw after you completed the action.
6. Write a testable hypothesis based on one of your questions from number five (if ____, then ____).

7. Write a detailed procedure of how you might test your hypothesis.
Directions: Take a few minutes to read the article below either online (or on the back of this page.) Write responses to the statements or questions below. Cut/copy/paste is not allowed – use your own words and thoughts, based in research if needed. If you use a dictionary or website, be sure to cite the page (URL and title).


Fact-finding: List three facts that you learned in this article.
1. 
2. 
3. 

Vocabulary: List and define three unfamiliar words in the space below.

Implications: What are your feelings about this “discovery”? Express your feelings (tactfully) about whether this is an advancement of science or a bad idea.

A New Tool for Crime Fighters
Analyzing a person’s hair can help reveal where she’s been.

By Brittany Sauser on February 27, 2008

Identifying murder victims and tracking serial killers are daunting tasks for detectives when there is minimal scientific evidence available. Now, a strand of hair could provide valuable clues about a person’s travels. Researchers at the University of Utah say that they are able to determine a person’s recent travel history by comparing the isotope ratios of oxygen and hydrogen in a strand of his or her hair. The extent of the information that can be deduced is dependent on the length of the hair.

Hair is like a tape recording of your diet, says Thure Cerling, a co-leader of the study and a professor of geology, geophysics, and biology at the University of Utah.

The study, which was published February 25 in the Proceedings of the National Academy of Sciences, found a strong correlation between the isotopes in the water that a person drinks and the isotopes in her hair.

“Hair isotopes reflect body water, and, in turn, body water reflects drinking water,” says Jim Ehleringer, a professor of biology at the University of Utah, who is co-leading the study with Cerling.

Ehleringer and Cerling developed a model to predict the geographic region of origin and travel history of humans based on the stable isotope composition of their hair. The researchers collected samples of tap water from more than 600 cities across the United States, as well as hair samples from the “trash clippings” of barbershops in 65 cities in 20 states, says Cerling. “We chose barbershops in smaller cities, where travelers are less likely to be,” he adds.

Using a mass spectrometer, the researchers measured the levels of hydrogen isotopes (hydrogen-2 and hydrogen-1) and oxygen isotopes (oxygen-18 and oxygen-16) in the water and hair. Based on the correlation of the isotopes in hair to those in drinking water, the researchers generated maps (see image below) that indicate the isotopic makeup of a person’s hair with different regions in the country.

“Based on the map, we can ask whether or not the isotopes in hair are consistent with or not consistent with the region where the hair was found,” says Ehleringer. If they’re inconsistent, scientists can try to deduce what region the hair appears to come from and the travel history of that individual, he says.

Researchers have generated maps that show the predicted average hydrogen (top map) and oxygen (bottom map) isotope levels in human hair across the United States. The ratios of hydrogen-2 to hydrogen-1 are highest in the red and orange areas of the top map, and
lowest in the blue and darker green areas. The ratios of oxygen-18 to oxygen-16 are highest in the red and orange areas of the bottom map, and lowest in the blue and darker green areas.

Credit: University of Utah

**Hair analysis:** Using a mass spectrometer (top), researchers measured the hydrogen and oxygen isotope ratios in hair and drinking water.

After correlating the results, the team generated maps that show the predicted average hydrogen (top map) and oxygen (bottom map) isotope levels in human hair across the United States. The ratios of hydrogen-2 to hydrogen-1 are highest in the red and orange areas of the top map, and lowest in the blue and darker green areas. The ratios of oxygen-18 to oxygen-16 are highest in the red and orange areas of the bottom map, and lowest in the blue and darker green areas.
Engage Activity #9
Introductory Quiz
(Engage Activity #13)

A. 1.234679
   + 4.23

B. 362.2159
   - 52.1

C. 52.15 × 3.3 =

D. 101.6 ÷ 3.1 =
Metric mishap caused loss of NASA orbiter

By Robin Lloyd
CNN Interactive Senior Writer
September 30, 1999

(CNN) -- NASA lost a $125 million Mars orbiter because a Lockheed Martin engineering team used English units of measurement while the agency's team used the more conventional metric system for a key spacecraft operation, according to a review finding released Thursday.

The units mismatch prevented navigation information from transferring between the Mars Climate Orbiter spacecraft team in at Lockheed Martin in Denver and the flight team at NASA's Jet Propulsion Laboratory in Pasadena, California.

Lockheed Martin helped build, develop and operate the spacecraft for NASA. Its engineers provided navigation commands for Climate Orbiter's thrusters in English units although NASA has been using the metric system predominantly since at least 1990.

No one is pointing fingers at Lockheed Martin, said Tom Gavin, the JPL administrator to whom all project managers report.

"This is an end-to-end process problem," he said. "A single error like this should not have caused the loss of Climate Orbiter. Something went wrong in our system processes in checks and balances that we have that should have caught this and fixed it."

The finding came from an internal review panel at JPL that reported the cause to Gavin on Wednesday. The group included about 10 navigation specialists, many of whom recently retired from JPL.

The navigation mishap killed the mission on a day when engineers had expected to celebrate the craft's entry into Mars' orbit.

After a 286-day journey, the probe fired its engine on September 23 to push itself into orbit.

The engine fired but the spacecraft came within 60 km (36 miles) of the planet -- about 100 km closer than planned and about 25 km (15 miles) beneath the level at which it could function properly, mission members said.

The latest findings show that the spacecraft's propulsion system overheated and was disabled as Climate Orbiter dipped deeply into the atmosphere, JPL spokesman Frank O'Donnell said.

That probably stopped the engine from completing its burn, so Climate Orbiter likely plowed through the atmosphere, continued out beyond Mars and now could be orbiting the sun, he said.

Climate Orbiter was to relay data from an upcoming partner mission called Mars Polar Lander, scheduled to set down on Mars in December. Now mission planners are working out how to relay its data via its own radio and another orbiter now circling the red planet.
Climate Orbiter and Polar Lander were designed to help scientists understand Mars' water history and the potential for life in the planet's past. There is strong evidence that Mars was once awash with water, but scientists have no clear answers to where the water went and what drove it away.

NASA has convened two panels to look into what led to the loss of the orbiter, including the internal peer review panel that released the Thursday finding. NASA also plans to form a third board -- an independent review panel -- to look into the accident.

Climate Orbiter and Polar Lander were designed to help scientists understand Mars' water history and the potential for life in the planet's past. There is strong evidence that Mars was once awash with water, but scientists have no clear answers to where the water went and what drove it away.

That review panel's findings now are being studied by a second group -- a special review board headed up by John Casani, which will search for the processes that failed to find the metric to English mismatch. Casani retired from JPL two months ago from the position of chief engineer for the Lab.

"We're going to look at how was the data transferred," Gavin said. "How did it originally get into system in English units? How was it transferred? When we were doing navigation and Doppler (distance and speed) checks, how come we didn't find it?"

"People make errors," Gavin said. "The problem here was not the error. It was the failure of us to look at it end-to-end and find it. It's unfair to rely on any one person."

**Error points to nation's conversion lag**

Lorelle Young, president of the U.S. Metric Association, said the loss of Climate Orbiter brings up the "untenable" position of the United States in relation to most other countries, which rely on the metric system for measurement. She was not surprised at the error that arose.

"In this day and age when the metric system is the measurement language of all sophisticated science, two measurements systems should not be used," Young said.

"Only the metric system should be used because that is the system science uses," she said.

She put blame at the feet of Congress that she said has squeezed NASA's budget to the point that it has no funds to completely convert its operations to metric.

"This should be a loud wake-up call to Congress that being first in technology requires funding," she said, "and it's a very important area for the country."
Questions- use complete sentences to answer

In a paragraph, summarize this article. Include at least 4 key points.

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

4. If you could ask one question to NASA about this miscommunication what would it be and why? YOU MUST HAVE A QUESTION and it may not be a yes or no answer.
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
What are we doing with an Aluminum Can?

(Engage Activity #17)

Supplies: List the supplies needed for this experiment

Before: What do you think I will be doing with these supplies? Be as specific as possible. You may not write anything like “I do not know” (NOTE: No points will be deducted for incorrect predictions)

During: What do you notice about the can while it is being heated? Does this change what you think is going to happen?

After: What happened when the can was inverted (flipped over) into the cold water (use at least 3 of your senses)? Why do you think this happened?
Using your observations, write down a description of what you saw so that someone who did not see the demo would be able to understand what happened. Use complete sentences.

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

The science behind the collapsing can:

When the can was heated, the water in the can boiled. The vapor from the boiling water pushed air out of the can. When the can was filled with water vapor, it was cooled suddenly by inverting it in water. Cooling the can caused the water vapor in the can to condense, creating a partial vacuum. The extremely low pressure of the partial vacuum inside the can made it possible for the pressure of the air outside the can to crush it.

A can may be crushed when the pressure outside is greater than the pressure inside, and the pressure difference is greater than the can is able to withstand. You can crush an aluminum can with your hand. When you squeeze on the can, the pressure outside becomes greater than the pressure inside. If you squeeze hard enough, the can collapses. Usually, the air pressure outside the can is the same as the air pressure inside the can. However, in this experiment, the air was driven out of the can and replaced by water vapor. When the water vapor condensed, the pressure inside the can became much less that the air pressure outside. Then the air outside crushed the can.

When the water vapor condensed, the can was empty. You may have expected the water in the beaker to fill the can through the hold in the can. Some water from the beaker may do this. However, the water cannot flow into the can fast enough to fill the can before the air outside crushes it.

What is one question that you still have about this demo? (Yes, you must have a question)

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

____________________________________________________________________________________
Can You Dissolve it?

(Engage Activity #20)

Your Task: Create a Procedure to dissolve a cube of Sugar.

Why is this a Challenge? The group to Dissolve the Sugar cube the Fastest gets extra points on their lab.

What you must do:

1. Create a procedure (below) and get it approved by Ms. Christopher.
   a. You have 7 minutes to create this procedure.
   b. Make sure that it is safe and detailed.
   c. Include a materials list

2. Obtain supplies (including chemical splash goggles) and begin your procedure. All groups will start at the same time trying to dissolve their sugar cube the fastest.
   a. If you decide you need to change your procedure when in the middle of the experiment, you may do so, but be sure that you make a note of this in your procedure section and conclusion.

3. Write a conclusion statement. What factors affect how fast a substance will dissolve?

Materials List:

Procedure:
Conclusion— Answer the following in complete sentences

1. Approximately how long did it take you to dissolve your sugar cube?

2. Did you change anything in your procedure once you began dissolving? If so why and where, and if not why did you not change it?

3. What factors determined how fast your sugar cube will dissolve? Be specific!

4. In what ways is the process of dissolving sugar in water related to the “real world”?

5. Write a conclusion statement. What did you do? What did you determine? What would you do differently next time? Must be in at least 3 complete sentences.
Conceptual Change Text provided by Ozmen (2007)

The Approach to Equilibrium

(Engage Activity #25)

Introduction: When does a system reach equilibrium?

Students generally believe that when there are equal concentrations of substances on both sides of an equation, chemical equilibrium is reached. This is incorrect. While explaining the equilibrium, we can say that when the rates of forward and reverse reactions become equal, dynamic equilibrium is established and there are no further changes in concentrations at equilibrium. It is likely that one could interpret this statement by saying that the concentration of reactants and products become equal at equilibrium. However, on the other hand, it must not be forgotten that if the concentrations become equal on both sides of the equation, the numerical value of the equilibrium constant, \( K_{eq} \), is always equal to 1 when the total stoichiometric coefficients of the reactants equal the coefficients of the products and the numerical values of the equilibrium constants of forward and reverse reactions must be equal. However, we know that the values of the equilibrium constants of forward and reverse reactions are reciprocals of each other. For example, while the equilibrium constant for the formation of HI, \( H_2(g) + I_2(g) \leftrightarrow 2HI(g) \), is \( K_{eq} = 54.5 \), the constant for the reverse reaction, \( 2HI(g) \leftrightarrow H_2(g) + I_2(g) \), is \( K_{eq}' = 1/K_{eq} = 1.83 \times 10^{-2} \). If the equilibrium concentrations are equal, equilibrium constants must also be equal. Moreover, we know that \( K_{eq} \) takes different values for the same reaction, depending on the temperature. It must not be forgotten that for a particular reaction at a specific temperature, the ratio of concentrations between reactants and products will always have the same value. This is because it does not depend on the amounts of reactants and products mixed together initially, \( K_{eq} \) remains the same i.e., the concentrations themselves may vary, but the ratios between the concentrations in a given situation do not. As a result, when the rate of forward reaction becomes the rate of reverse reaction, chemical equilibrium is reached.