AN ACTION RESEARCH STUDY USING STUDENT RESPONSE SYSTEMS IN AN INTRODUCTORY CHEMISTRY COURSE AT CSU SACRAMENTO

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Abstract

of

AN ACTION RESEARCH STUDY USING STUDENT RESPONSE SYSTEMS IN AN INTRODUCTORY CHEMISTRY COURSE AT CSU SACRAMENTO

by

Stuart David Hay

The use of student response systems, commonly known as ‘clickers’, is studied over two semesters in Chem 4, an introductory chemical concepts and calculations course at CSU Sacramento. While there is an abundance of published literature on the topic of using clickers in large enrollment, introductory science courses, the methods are varied and the results are inconclusive, yet promising. The proposed benefits from using clickers include increasing attendance and supporting more effective constructivist pedagogy via active learning, formative assessment and other traits to facilitate student learning. Many authors note the skill required to effectively integrate clickers into classroom lectures requires time and practice, as well as the myriad of possible uses of clickers. This study employs an active research design over the course of two semesters in order to modify the design and use of clickers. Every lecture contained between two and seven clickers questions, with each question belonging into one of three basic categories; “are you prepared?”, “are you learning?”, or “what do you think?” Data from the first semester show how strongly performance and attendance are related, thus several changes were made to encourage attendance during the second semester of the study. In addition, changes were made to the clicker questions in order to better address student learning, with the desire of having
students finding more benefit from these questions. The results from this study show that both student attendance and student performance improved while using clickers relative to historical data. Improvements were most significant during the 2nd semester of this study, supporting the idea that using clickers effectively is a skill requiring practice and revisions. Results from this study show that clickers can be an effective tool in facilitating greater attendance in large enrollment classes by monitoring and rewarding attendance and participation. In addition, clickers can be an effective tool in facilitating a more active learning environment relative to traditional lecture. This active learning environment may lead to improved student learning as well as improved student attendance. Some combination of improved attendance and improved pedagogy have led to improved student performance in this study, however the relative impact from each is not clear. Finally, the students enjoyed using clickers, saw benefit to their learning in Chem 4, and would like to use clickers in more of their courses.

___________________________________, Committee Chair
Dr. Jeff Paradis

______________________________
Date
DEDICATION

I would like to dedicate this thesis to my wife, Kate, for her unwavering support while I undertook this endeavor. Simply put, she has been amazing. I also dedicate this thesis to my three children, Ashley, Zach and Jake. My kids have been my inspiration and they have cheered me on every step of the way. And finally, I would like to thank my parents, Sandy and Barbara, who have encouraged and supported me throughout my life.
I would like to thank the faculty and staff in the chemistry department at CSU Sacramento as I feel I have received a tremendous education through their hard work and dedication. In particular, I would like to thank my advisor, Dr. Jeff Paradis, for the countless hours he has spent working with me throughout my graduate program and in helping me with this thesis. Jeff is an amazing instructor who I have learned much from over the past several semesters, and I cannot thank him enough for all that he has done for me. And I would like to thank Dr. James Miranda and Dr. Jacqueline Houston for their support being on my thesis committee. They provided many insights that challenged and encouraged me to write a better thesis. Thank you to all that have supported, encouraged and aided my experience at CSU Sacramento.
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Chapter 1
INTRODUCTION

Background

High attrition rates in entry level college science courses, especially those with very large enrollments and lecture format, are a common concern among educators (Crede et al., 2010). It is well documented, as will be discussed in the literature review, that attendance, in addition to pedagogy, are critical to student learning. There is a growing interest in student response systems (SRS), commonly known as clickers, among educators searching for methods to address this high attrition as well as for strategies to improving teaching. Significant technology improvements in recent years are making the use of clickers more feasible, producing a wealth of research articles discussing their use, and their impact on attendance, pedagogy and student attitudes.

Clickers are also referred to as audience response systems (ARS), electronic voting systems (EVS), classroom communication systems (CCS), voting machines, key-pads, zappers and handsets. These handheld devices often contribute to a more active form of learning, which is also seen as a benefit to enhancing student learning. They can be particularly beneficial in large classrooms where students, feeling more anonymous, often find it easier to withdraw from participating, or attending class altogether. In essence, clickers provide an opportunity for dialogue between teacher and student, even in the largest class setting. The process begins with the instructor posing a question to the class. Then every student has the opportunity to answer by using a handheld clicker. Using readily available software, the responses are tallied and can be immediately displayed for the class to see. Thus the instructor immediately receives feedback on how well the class understands a certain concept, as does each student.

Without using clickers, instructors in large enrollment classes might encourage class participation by posing questions and asking for a show of hands. This approach, however, has
the limitation of students not being entirely forthright with their responses. It is common that many students feel anxious about giving what might be a wrong answer, so they mask or modify their responses when seeing that the majority in the classroom answer with a different response. Alternatively, instructors could provide prefabricated response cards, such as “A”, “B”, “C”, etc., and ask students to hold up the cards after a question is posed. The benefit over a simple show of hands is that the responses are more anonymous, allowing students to feel more secure when providing an unsure answer. In either of these methods, however, the instructor and each student can, at best, eyeball a rough percentage of responses. In addition, use of either of these methods makes it difficult to allocate points towards students’ grades for attendance, participation or response accuracy.

When instructors consider using clickers, logistics and cost are two important considerations. There are two common logistical options for using clickers in the classroom. In one scenario there is a basket of clickers available by the door and students pick one up on their way in and drop it off on their way out after class. There is no cost to the students, however a few clickers are often lost throughout the semester in large enrollment courses. This is less of a concern with smaller class sizes where it is easier to quickly count or watch the students replace the clickers in the basket on their way out of the class. One aspect of this method is that it provides complete anonymity with respect to student responses. A more popular option, especially with large enrollment college courses, is that students are required to provide their own clicker, either by purchasing new or used from the bookstore, renting, using a friend’s, or re-using a clicker used in another class. The cost of one is typically around thirty to forty dollars, so this is generally not perceived as an economic hardship.

Companies selling clickers often provide software free of charge to the instructor, as well as installation and technical support, thus there is no cost to the university. The software used
with clickers is often compatible with standard applications, such as Microsoft PowerPoint, which can tabulate the clicker responses received and immediately display them, typically as a histogram. If an instructor is already using PowerPoint to present slides for the lecture, adding clicker questions is a simple task of adding new slides for the questions and the histograms will populate automatically in a new slide to show the class. If using PowerPoint or not, most systems are said to be easy to use, and fairly easy to implement.

Will the use of clickers help students learn? This is, of course, the key question of interest, and the answer to this question in not easily obtained or confirmed. While clickers have been available since 1966 (Kay, 2009), there has been a surge in research in the past decade pertaining to their use in college science courses as the growth in technology has enabled their use (Kay, 2009; Caldwell, 2007; Kenwright, 2009). We now have a wealth of information regarding perceived benefits and limitations, as will be discussed in the review of published literature. Prior research evaluates teacher and student reactions to the use of clickers in the classroom, strategies for successful implementation to maximize clicker effectiveness, thoughts on the pedagogical place of clickers in the classroom, and analysis of data that compares student achievement with and without clicker use.

All of the prior research concerning clickers is educational research, which is a behavioral science, suggesting that factual conclusions have not been made regarding their use. No two studies are, or can be, exactly replicated as the instruction changes, the students change, and the use of clickers changes between studies. In short, research in education is not an exact science. As such, a ‘triangulation’ approach should be employed when conducting educational research to include many inputs of data (none of which are concrete) in order to hone in on meaningful conclusions from the study. High quality research in education often follows action research design, allowing for the instructor to also be the researcher, as opposed to a distant third
party observer. It is understood that action research being used in education cannot, and therefore does not, attempt to control all variables such as student populations, instruction given during lectures, and so forth; there are no rigid control groups, and data cannot be compared between groups in order to draw absolute conclusions. Instead, action research is intended to be an iterative process design whereby instructors study the effects of changes in their instruction in order to improve their pedagogy. From the published literature, there is a range of ideas concerning the use of clickers that has been developed. Some theories withstand the test of time as new information seems to support them, while other theories are adapted to fit new data that is presented. Such is the nature of research, particularly in a behavioral science field such as education, where there are few, if any, absolute truths.

Statement of purpose

This research study will be conducted in California State University Sacramento (CSUS) Chem 4 classes during two semesters; fall 2010 and spring 2011. Chem 4 is a one semester chemistry calculations course consisting of three weekly lectures of fifty minutes each. There is no lab with Chem 4, and the class is designed for students who either do not pass the entrance exam for Chem 1A (general chemistry) or do not feel confidently prepared for Chem 1A. The Chem 4 curriculum covers basic math functions such as scientific notation and conversions between quantities, problem solving, and an introduction to the basic language and concepts of chemistry. The typical class size for Chem 4 is roughly one hundred to one hundred thirty students, with two or three sections being offered each semester. As with most classes of this size, attendance is not taken and has no direct influence on the students’ grades. Historically, 46% of the roughly 500 students enrolled in Chem 4 each year pass the course.
The focus of this research is to determine whether using clickers facilitates an improvement in learning with Chem 4 students and, if so, how the clickers may facilitate pedagogy that contributes to student learning. While student scores and pass rates may be used to quantify the possible impact on student learning, the scores will not help explain how the clickers have had any impact, if there is any. Other sources of data, such as student attendance, attrition rates during exams, instructor perceptions and student perceptions will be evaluated in a triangulation approach in order to draw qualitative conclusions regarding the use of clickers.

During this study, other variables in course design will change, in addition to the use of clickers, and are expected to affect student learning. For example, increased student interaction and engagement are expected when using clickers, which are expected to have an impact on student learning. Similarly, daily attendance is expected to increase which is also expected to improve student learning. It is important to note that the use of clickers supports the pedagogy used rather than defines it, and it is the pedagogy that has the most impact on student learning, not the technology.

The pedagogy used during this study will be strongly influenced by learning theory fundamentals. Strategies for using the clickers will be influenced by learning theory, prior research concerning the use of clickers, published findings regarding the relationship between attendance and student learning, and from data gained from this study. This study will follow action research design, thus findings from the first iteration of using clickers in this study will be used to influence how the clickers are used in the second iteration of this study. Thus, the use of clickers in this study is intended to evolve. Further, their use is intended to influence both attendance and student learning in order to maximize the total possible benefit from using the devices.
Limitations of study

There are a number of factors that lead to students’ success, and this study will not address variables such as ethnographic diversity, prior educational experiences or performance, work hours outside of school, and so forth. As is the norm with action research design, this study will not attempt to control such variables, but instead will assume the sample size is sufficiently large such that these variables will remain somewhat constant between semesters. When comparing student test scores during this study with historical data, it is understood that the students have changed, the lectures have changed, as well as a host of other variables. While a comparison in student performance between semesters cannot be used to empirically prove the effect of using clickers, the comparative data will be used in a triangulation approach to better understand the effects from using clickers. Instructor observations, student responses to surveys and other data sources will be used to corroborate and help explain changes in student performance. As with any behavioral science involving people as subjects of study, it is not expected that this study can be replicated with the precision one would expect as with the traditional sciences. While the same exam questions could be given to students in a future study, the students would be different, as would the lectures, class discussions, and so forth. Thus, the intent of this study is not to draw factual conclusions regarding the use of clickers; instead, it is hoped this study will be able to ‘paint a picture’ regarding the use of clickers in high enrollment introductory science courses which may build on an existing framework of knowledge regarding education.
As noted in the statement of purpose, both attendance and pedagogy play critical roles in student learning, with clickers being used in this study to influence both. The review of published literature will begin with a discussion of action research in order to identify how research in education should be conducted and what reasonable conclusions can be expected from this type of study. Next, current learning theories will be discussed to understand how using clickers may help instructors improve their pedagogy, and thus student learning. This will be followed by a review of perceived benefits from using clickers, and published results from instructors who have used clickers in their classrooms. This discussion will include a closer examination of several papers in order to better understand and critically evaluate the published results. A discussion of both student and teacher attitudes towards clickers will complete the discussion of clickers. Finally, a review of the relationship between attendance and student performance will complete this review of published literature.

**Action research**

Action research is an established form of research across many disciplines, and in particular, it is a widely accepted form of research methodology in the field of education. Many, if not most, introductory education texts (Denscombe, 2007; Gall, Gall and Borg, 2003; Cohen, Manion, and Morrison, 2007; Fraenkel and Wallen, 2006) contain chapters covering action research, just as an introductory organic chemistry text would contain a chapter on NMR spectroscopy. One fundamental difference in action research from the traditional sciences is that the focus is on human behavior, which cannot be controlled since people have minds of their own and do not necessarily behave according to researchers’ expectations. Further, with respect to
education, there is no universally valid science of pedagogy; there are no laws concerning pedagogy that is most effective. While action research is based on scientific principals, there are several fundamental characteristics that differentiate it from traditional forms of research, as outlined in Table 1 (Gall, Gall and Borg, 2003):

<table>
<thead>
<tr>
<th>Common Differences between Action Research and Formal Research</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic</strong></td>
</tr>
<tr>
<td>Training needed by researcher</td>
</tr>
<tr>
<td>Goals of research</td>
</tr>
<tr>
<td>Method of identifying the problem to be studied</td>
</tr>
<tr>
<td>Procedure for literature review</td>
</tr>
<tr>
<td>Sampling approach</td>
</tr>
<tr>
<td>Research design</td>
</tr>
<tr>
<td>Measurement procedures</td>
</tr>
<tr>
<td>Data analysis</td>
</tr>
<tr>
<td>Application of results</td>
</tr>
<tr>
<td>Reporting outcome</td>
</tr>
</tbody>
</table>


Action research is intended to bridge the gap between research and practice by putting the researcher at the center of the research, and not a distant third party observing the experiment (Denscombe, 2007). One objective of action research is to identify instructional behaviors that a teacher can alter within themselves to drive changes in student behavior. It is not research on
other people, or their students, but rather on how instructors can improve their craft (Denscombe, 2007). The goal is to gain a better understanding of the problems that arise in the local environment, and to design changes to address those problems in order to bring about practical improvement (Cohen, Manion, and Morrison, 2007). Action research is a disciplined process involving problem identification, data collection, data analysis, action that will result in changed behaviors, results evaluation, and then continuing with problem identification again in a cyclic fashion, as shown in Figure 2 (Ferrance, 2000):

Figure 1: Cyclic process of action research

Action research will often challenge the status quo and is intended to be a point of discussion, rather than a final word on a given topic. Results from action research are intended to be shared, discussed and debated as part of a dialogue to combine theory and practice in developing a deeper understanding of a topic (Cohen, Manion, and Morrison, 2007). The following list provides some of the proposed benefits of action research over traditional research (Denscombe, 2007; Fraenkel and Wallen, 2006):
1. It can be done by almost any instructor, at any school, for any grade level, and covering almost any classroom problem; no special training is required for instructors to adopt action research methodology.

2. It is seen as a powerful tool to empowering teachers – to be more aware of student behaviors, aware of their own practice, aware of critical theory, and to drive changes to improve their instruction.

3. While designing action research, instructors not only develop more effective methods to teach, but they investigate and research what others have done, thus broadening their knowledge concerning an instructional topic.

4. It provides instructors with a methodical, or systematic, approach to solving problems or improving the quality of their instruction.

5. It can encourage and support a community of research-oriented teachers, allowing for collaboration and teamwork among teachers.

Some of the challenges, or disadvantages, of action research include the following (Denscombe, 2007; Cohen, Manion, and Morrison, 2007):

1. Limited scope and scale - since active participation of the researcher is required, there are natural limits on the scope of the research. As a result, generalizations that can be made on the basis of the results are limited.

2. Lack of controls – by integrating research and participation, as well as conducting research in the classroom, it is not feasible to control all variables influencing student behaviors; there cannot be a true “control group.”
3. Impartiality – researchers have a vested interest in their findings and are in the middle of the research, thus it can be difficult to be completely impartial and detached, as may be the case with traditional science research.

4. Ethics – as with any type of research, ethical considerations must be taken into account when working with students, so as not to put any at a known disadvantage, for example, to test a hypothesis.

Action research is a practical method for instructors to gain knowledge about their own practice. It does not provide absolute truths, but instead can help provide some answers to localized problems. In addition to providing insight into a particular situation for a particular classroom environment, action research may help replicate prior research or generate ideas for future research. While the results from one individual study may lack generalizability, it may add to a body of research so that generalized conclusions can be made concerning the topic of interest.

**Learning theory**

The learning model commonly accepted until just recently was a positivist paradigm that suggested knowledge could be transferred from teacher to student, with educators focusing their efforts on finding new and better methods to improve this transfer of knowledge (Bodner, 1986; Coll and Taylor, 2001). Although not an entirely new concept, the model that knowledge is constructed in the mind of the learner, known as constructivism, has become formally developed during the 20th century (Coll and Taylor, 2001) and is now the norm in terms of thinking how knowledge is acquired (Taber, 2001). The fundamental basis of constructivism is that “…an individual’s knowledge represents a mental construct” (Coll and Taylor, 2001), meaning that knowledge cannot be transferred to, or passively received by a learner, but that it must be actively
built in the mind of the learner (Wheatley as cited by Coll and Taylor, 2001). Many models of information processing and memory have been developed, and a summary of the most currently accepted model will be discussed.

The formation of knowledge begins with information that must be received in the form of external stimulus. We experience a tremendous amount of stimuli that must be filtered so as to determine what we focus on and what we ignore (Lutz and Huitt, 2003). Our previous knowledge, biases, prejudices and preferences play a role in this filtration (Johnstone, 1997). Stimuli that passes through our filter goes into a “working space” of our mind, which has also been referred to as our short-term memory (STM) or our conscious (Hestenes, 1979). There is general agreement that the STM has limited capacity, being able to hold between 5 and 7 bits of information at any one time (Hestenes, 1979; Johnstone, 1997; Lutz and Huitt, 2003). Small children likely can hold 2 less bits of information, and children under 9 years of age likely have a capacity of one less bit (Lutz and Huitt, 2003). A bit of information can represent different things, and evolves as the brain matures and develops. For a young child learning to read, for example, each letter is one bit of information as they are learning to sound out words, but the entire word becomes 1 bit of information to a proficient reader (Johnstone, 1997). A bit of information can also represent images, symbols, or conceptual units of information of varying size and complexity (Hestenes, 1979). As the human mind develops, it learns to “chunk” bits of information, such as “chunking” individual letters into a word as noted previously. Through this chunking, the capacity of the STM is not being expanded, rather the processing time for information is improved (Johnstone, 1997). Once in the STM, chunks of information do not last more than 30 seconds, as new stimuli information passes through the filter and enters the STM, pushing out older chunks (Hestenes, 1979), unless a chunk is actively rehearsed which can prevent its replacement until it can be further processed. If the information in the STM is replaced before it can be processed, the
information is lost forever (Hestenes, 1979). The alternative is the transition of information into long-term memory (LTM). LTM has infinite capacity (Hestenes, 1979) and holds all previous perceptions, knowledge and information learned by an individual. Figure 1 from Johnstone (1997) illustrates the relationships between the STM (identified as working space), LTM, perception filter and stimuli (identified as events, observations or instructions).

**Figure 2: Information processing model**

Two additional transfers of information that have not been discussed yet in this review are illustrated as arrows in the diagram. The first is the feedback loop from the LTM to the perception filter. As noted previously, the perception filter identifies which stimuli are to pass through into the STM based on inputs from the LTM. Pattern recognition is the method in which new stimuli are recognized against the LTM information, and based on one of several pattern recognition principals, the stimulus is either discarded or passed on the STM (Lutz and Huitt, 2003). The second arrow beginning from the LTM is the connection with the STM. The chunks of information in the STM have four possible paths for being stored in the LTM (Johnstone,
The first, and most meaningful method, is when the new information is an almost perfect match with existing knowledge, and the new information is added to the existing mental representation, or structure, that is associated with this knowledge. Second, new information may seem to be a good fit with the existing structure, but in reality it is not. This type of information storage can lead to mistakes or misunderstandings (Johnstone, 1997). A common example of this is a result of semantics when someone misunderstands the meaning of a word in an explanation, and as a result, their understanding of the explanation, or concept being discussed, is not necessarily what the speaker intended. Third, information is stored in sequence, and that sequence is retained in the LTM. For example, when asked what the tenth letter of the alphabet is, most will start at ‘A’ and count through ‘J’ (Johnstone, 1997). The fourth, and least meaningful manner for storage in the LTM, is through memorization, or cramming. Since there are no meaningful connections with preexisting knowledge, the information is almost impossible to retrieve (Johnstone, 1997).

A second function of the STM referred to but not yet described, aside from holding chunks of information, is to process the information (Hestenes, 1979; Johnstone, 1997). We retrieve and use information from our LTM to add in missing pieces to an otherwise incomplete chunk of information brought in by our senses. Similarly, stimuli are not simply added to LTM if it is a “fit”, but new information is transformed, manipulated, or otherwise processed in order for the conscious memory to handle it (Johnstone, 1997). This processing requires space in the STM, and the result is that if the STM is busy processing, then it can hold fewer chunks of information (Hestenes, 1979). An example of this is carrying out multiplication of three digit numbers in your head. There are not many digits, or chunks of information to handle, however the STM can be over-loaded by the processing required. Thus, if there is too much information to hold, there is
very little room for processing, or if a lot of processing is required, there is very little room to store new information (Johnstone, 1997).

To summarize in the context of student learning, when new information is presented to a learner, the learner needs to have knowledge stored in their LTM which they can compare with the new information. New information, then, can most effectively be learned when it can be compared to, contrasted with, joined with, or modified to an existing structure of knowledge (Luttz and Huitt, 2003).

The implications for educators are numerous. From the information processing model previously described, the first point when information can be lost is at the perception filter. It has been shown that students with high anxiety levels have impaired levels of information processing, and that a higher level of anxiety can bias what information is received from the information filter (McKeachie, 1984). Students who do not feel comfortable in class are not passing the same information on to their short term memory as students who have higher levels of comfort. Not necessarily relating to anxiety, but relating to the perception filter, one study found that between 10% and 20% of the words spoken during a lecture were recorded, on average, by students in their notes (Johnstone, 1997). Clearly the students were selecting what spoken words they heard to retain and write down in their notes. This does not necessarily correlate with what information was transferred to their LTM, however a parallel exists in that the students used prior knowledge to determine what was important and worth noting, while also deciding what was not important. Numerous studies have shown that the anonymity of clickers reduces student anxiety and allows students to not only feel more comfortable participating in class, but allows them to be more honest when answering questions (Caldwell, 2007; Kay and LeSage, 2009).

Related to the capacity of the STM, Johnstone (1997) also identified that the average lecture in the study consisted of between 117 and 160 ‘units’ of information. Each unit of
information is defined in the study as an equation, formula, graph or definition. The study found that 75% of the units, on average, were recorded by students when the total unit count was on the low end of the range during a lecture, however only 52% were recorded when the unit count was at the upper end of the range during a lecture. As more information was required for processing, the students became less efficient at recording the information in their notes. Similarly, Hestenes (1979) notes the slow ‘write time’ from STM to LTM, noting that 5-10 seconds are required for each chunk of information to be transferred and only 1 chunk can be transferred at a time. By continually providing new information without allowing for the previous information to be processed and stored in the LTM, some of that information will be replaced in the STM as new information continues to pour in through the perception filter. A correlation was also found to exist between the quality of the notes and performance on exams. The students with inaccurate and incomplete notes performed the worst on exams, with increasing performance with improved accuracy and completeness of notes, and the best performance noted was with those students who not only took complete and accurate notes, but also elaborated on their notes with additional observations and thoughts (Johnstone, 1997).

Rowe (as cited by Hestenes, 1979) found that teachers rarely wait longer than 1 second for responses after presenting questions to the class. The information process model requires information to be extracted from the LTM in order for new information, or in this case a question, to be processed. While this time limit might be possible when pertaining to information that is already well known and whereby the learner has a robust knowledge structure allowing for fast retrieval of information, it would be nearly impossible for a learner just processing new material related to the question and who does not yet have a rich knowledge base to draw meaningful connections from (Hestenes, 1979). One noted advantage of using clickers in this context is the wait time required for students to enter their answers in the devices when a clicker question is
posed. The process of using clickers forces instructors to slow down and allow adequate processing time.

**Perceived benefits of using clickers effectively**

When considering any new technology for use in the classroom it should be noted that technology is worth using only when it addresses a specific instructional deficit (Draper, 1998). The use of clickers, by itself, will not benefit student learning just as installing computers in every classroom will not miraculously improve test scores. Instead, when clickers are used effectively, they can be used to support or enhance an instructor’s pedagogy and be one additional tool in the instructor’s toolbox to engage students and improve student learning.

As noted previously, clickers can be used to address attendance concerns by awarding points based on attendance or participation in class. In relation to current learning theory, it was discussed how using clickers promotes participation via anonymity as well as fosters information processing by allowing appropriate wait times by slowing down the pace of lecture. In addition, chemistry students enter the classroom with a lifetime of experiences and varying degrees of understanding those experiences stored in their LTM. Any misconceptions, or alternative concepts, play a vital role in student learning in the classroom as students will be accessing their LTM to understand and process new information. The students selectively absorb and incorporate new information, drawing on their previous understanding of the topic. With the constructivist model of learning in mind, student misconceptions cannot simply be corrected through cogent and logical lecture since students develop and construct their own models as they acquire new information and experiences, thereby continually building upon their existing framework of knowledge. This is especially so with chemistry, in which concepts are continually
being stacked one atop another, so that one misunderstanding will typically lead to future misunderstandings (Taber, 2001).

It is critical to identify student misconceptions early, and take measures to address those before moving on to the next concept. Clickers are seen as a useful tool in this form of formative assessment for instructors (Beatty, 2004; Caldwell, 2007; Kay and LeSage, 2009). Beatty (2004) argues that “by providing frequent feedback about students’ ongoing learning and confusions, [clickers] can help an instructor dynamically adjust her teaching to students’ real, immediate, changing needs.” Another instructor who has implemented clickers in his undergraduate courses adds, “…the instructor benefits from the fact that he or she can measure during the class time the degree of learning that is taking place. The instructor can also modify his or her presentation during class time in response to the immediate student feedback from the clicker system” (Yourstone et al., 2008).

In order to identify student misconceptions during his lectures, Eric Mazur developed and used “concept tests” in his physics course while using clickers during his lectures (Mazur, 1997). The concept tests he developed were non-algorithmic in nature and designed specifically to identify misconceptions. He would pose questions to his students during his lectures and have students respond with their clickers, providing immediate feedback on their understanding or application of a topic. He found significant improvement in student learning when he combined these concept tests with peer instruction, which will be discussed in more detail later in this review.

In addition to instructor driven formative assessment, clickers also enable students to assess their own learning during a lecture. According to one student survey, the second and third highest ranking benefits of using clickers were the ability to relate performance relative to their peers, and to gauge their understanding of course material. The highest ranked perceived benefit
was that clickers facilitated participation in class (Graham, 2007). It is not clear why students like to compare responses, but studies show that this is important to them (Kay and LeSage, 2009). One instructor notes that students sometimes think no one understands the lecture, and thus the instructor is at fault. When they see 80% of the class answers a clicker question correctly, however, they are likely to change their perception, and become motivated to study more (Kenwright, 2009).

In addition to providing formative assessment feedback to both the instructor and the student, clickers are also a useful tool for promoting student interaction and peer instruction (PI) opportunities in the classroom (Caldwell, 2007; Graham, 2007; Kay and LeSage, 2009; Kaleta and Joosten, 2007). In one study involving 27 instructors spanning many courses at the University of Wisconsin, the teachers agreed that using clickers provided opportunities to use new pedagogies involving active learning strategies (Kaleta and Joosten, 2007). Studies show that collaborative learning and peer teaching can have a positive effect on student learning (Mazur, 1997; Lewis, 2008; Hockings, 2008). Peer instruction is an active form of learning, encouraging much greater attention and engagement from the students. It is also noted that peer teaching helps students clarify their thinking and discover flaws in their logic as they verbalize their ideas (Beatty, 2004). Nicole and Boyle (2003) found that the first step in peer teaching provided an opportunity for the students to develop or construct their own model of the concept. The students felt that the following step of peer discussion enhanced this constructive process by sharing their different interpretations and reaching a conclusion after a critical analysis of the various inputs.

In one survey of 384 instructors from a number of different institutions using PI, 303 definitely planned to continue using PI while only seven indicated they did not plan to use it again (Fagan, 2002). Student perceptions about PI are generally very positive. In one study, 92% of students agreed that discussing questions with others aided understanding, 82% agreed that
hearing others’ explanations helped them learn, and 90% of the students surveyed agreed that group discussion after first making their individual response led to deeper thinking about the topic (Nicol and Boyle, 2003). It is important to reiterate that peer instruction was the pedagogy that aided student learning, and not the clickers; the clickers were a tool to enable the pedagogy.

In addition to providing peer instruction opportunities, interspersing clicker questions into a traditional lecture is seen as having many benefits (Salemi, 2009; Kay and LeSage, 2009; Caldwell, 2007; King and Joshi, 2008; Boatright-Horowitz, 2009; Nicol and Boyle, 2003):

- Break the monotony of lecture and improve student attention
- Slow down the flow of new information
- Force more ‘wait time’ after posing questions to students to allow adequate time for information processing
- Foster active learning
- Foster constructivist base peer learning
- Foster participation (start discussions, involve peer interaction, collect votes after a debate)
- Assess student preparation and ensure accountability (paying attention during lecture, reading or homework questions and pre-lab questions).
- Formative assessment (assess students understanding of lecture material, reveal misunderstandings of lecture, test students’ understanding of previous lectures, assess ability to apply lecture material to new situation, determine if students are ready to move forward, allow students to assess their own level of understanding).
- Learn more about students (survey students, poll opinions or attitudes, probe pre-existing knowledge, ask about confidence or comfort with a problem).
- Fostering a feeling that the teacher was more invested in their needs by adapting instruction and using the clickers.
- Set expectations for students with level of difficulty they are expected to master with low risk or small repercussions.
- Administer quizzes and tests.
- Provide practice problems.
- Guide thinking or review (review for a test, lead students through process and ask which step comes next, facilitate a review at end of lecture).
- To make lectures more fun.
- Use as “clapometer” to continuously monitor when students are confused.

Summary of current clicker research

Many papers have been published describing the impact on student learning, however the problem that the data are not consistent or reproducible remains a challenge to drawing specific conclusions (Kay and LeSage, 2009). The published results from using clickers range from seeing a significant benefit on student learning (El-Rady, 2006; Fitzpatrick, 2011; Kaleta and Joosten, 2007; Shapiro, 2009; Sprague and Dahl, 2010; Nelson and Hauck, 2008; Pradham, 2005; Preszler et al., 2007; Shaffer, 2009; Schackow, 2004; Yourstone et al., 2008; King and Joshi, 2008; Mayer et al., 2009; Shaffer and Collura, 2009; Stowell and Nelson, 2007) to not seeing statistically relevant improvements (Addison et al., 2009; Bunce et al., 2010; Carnaghan, 2007; Crossgrove and Curran, 2008; Dill, 2008; Lunderberg, 2011; Martyn, 2007; Skinner, 2009). Very few studies have shown a negative effect on student performance, and a closer review of research design is warranted.
El-Rady (2006) found improvements of five percentage points using the same exam questions in two different sections of the same course. The study compared one section from the fall 2004 semester (N=126) when clickers were used and points were awarded as extra credit (up to 2.5%) with the spring 2005 semester (N=125) when clicker participation was mandatory. Only 25% of the students in the first semester regularly participated with clickers and earned the full 2.5% bonus points. During the second semester of the study when clicker participation was mandatory, daily attendance rose sharply from a 50% average attendance to 65%, in addition to the exam improvement previously noted.

Gauci et al. (2009) reported mean score improvements on mid-semester exams from 56% to 65% after implementing clickers in order to promote an active learning environment while no points were awarded for attendance or participation. The students were only told that using the clickers may make the lectures more active and interesting. End of semester exam results displayed similar results, with average scores improving from 66% to 72%.

Mayer et al. (2009) compared sections with and without clickers, and compared scores with historical averages in the same course and found students in the section using clickers earned, on average, one-third of a letter grade higher than students without clickers. Average exam scores were similar for students without clickers and in previous classes at 80.3% compared with an average of 83.4% for the students in the clicker section. Sample sizes were roughly 120 students in each section; the control group was identified as the students in the previous year’s section (2005), the study group given clickers the following year (2006), and the non-clicker study group in yet the following year (2007). Interestingly, there was less improvement on exam questions that were similar to the clicker questions than there was on exam questions that were dissimilar to clicker questions, suggesting the benefits from using clickers is not restricted to specific content from the clicker questions. The authors suggest this may be attributed to students paying greater
attention during lecture in anticipation of clicker questions, taking greater care to mentally organize the ideas from the lecture content so that they may be able to answer the clicker questions, and in developing the metacognitive skills to assess their level of understanding the material presented.

Contrary to the finding from Mayer et al. (2009), Shaffer and Collura (2009) found significant gains on exam questions that had similar content from clicker questions but saw no difference in student performance for other questions on the exam. Their study compared two sections of the same course during the same year, one with clickers (N=42) and one without (N=50). The section without clickers was given the same clicker questions, but students were encouraged to raise their hands to respond to the questions instead of responding via clickers and viewing the results on screen. Average performance on the eleven exam questions covering material similar to the clicker questions was 81% in the class without clickers and 89% in the class with clickers. Students from both classes performed similarly on questions that were not part of the clicker lectures. The heightened level of student engagement and participation while clickers are being used are believed to be the principal contributors to the change in performance between sections.

While not finding any change in the mean score, Addison et al. (2009) saw significantly more students in the highest performance level (91%-100%) while using clickers than with historical data. This study evaluated historical data from multiple instructors during multiple semesters from fall 2005 to fall 2007 as a baseline covering 15 sections without using clickers, while using one section in the fall 2007 semester as the experimental group. No points were awarded based on clicker use or attendance, and the targeted change with the experimental group was the inclusion of 4 to 5 clicker questions in order to promote opportunities for active learning. The authors hypothesize that higher achieving students benefit the most from clicker use because they are better able to interpret and answer the clicker questions in the time allotted than the lower
achieving students. Thus, these students receive the greatest benefit in terms of formative assessment and building a more complete framework of knowledge in their minds.

Knight and Wood (2005) also found a significant shift in scores after implementing clickers when measuring the number of students in five ranges of scores: less than 59%, 60-69%, 70-79%, 80-89%, and 90-100%. The authors focused the change in pedagogy on increased student collaborative learning opportunities with new formative assessment opportunities that were not previously available. The authors found a significant drop in the lower two ranges of scores, a similar number of students in the middle range, and a significant increase in upper two ranges after using clickers to implement the changes in their biology course. The authors concluded that the more interactive and collaborative course design was the cause for the improvement, but also that “A” and “B” students gained more benefit from the course changes than the “C” students, supporting Addison et al. findings reported earlier. The experimental design of their study used one fall 2003 section (N=73) as the control while using one spring 2004 section (N=73) as the experimental group their biology course.

Eric Mazur (1997) used the peer instruction method while using clickers and observed significant gains in student learning on the “Force Concept Inventory” (FCI) test. The FCI is a nationally used multiple choice exam designed to assess student understanding of basic Newtonian mechanics. It is often given to students at the beginning of a semester and again at the end of the semester, with normalized gains typically about 0.25 for traditionally taught classes. While using PI and clickers, Mazur noted normalized gains of 0.49 to 0.64 (Mazur, 1997).

One difficulty with the types of studies involving clickers is that they all lack external validation, and internal validity is a common threat. No two studies can be exactly replicated, nor can all possible variables be completely isolated or controlled for. This is especially true in
educational research when studying human behaviors. One method to address this concern is to understand and utilize research design that best supports educational studies.

A critique of clicker research

In the review of literature concerning the impact on student learning while using clickers that was previously discussed, nearly all articles include a form of action research as they are written by instructors who were implementing the research in their classrooms while they were teaching. Nearly all of the research did not adopt the cyclic nature of the action research, however, and did not build on what they learned from their first attempt at using clickers by implementing further changes. Thus, most papers are not good examples of effectively using action research methodology in studying the use of clickers. Further, many papers attempt to identify a control group in order to compare results and draw conclusions regarding the use of clickers, however, the authors fail to recognize the variables that do change during their study which would prevent drawing specific conclusions regarding the use of clickers. One good example of implementing action research in a college chemistry classroom for reference, although not related to clickers, is an article from the Journal of Chemical Education (Towns, Kreke and Fields, 2000) studying the effects of small group learning activities in a first semester undergraduate physical chemistry course. The conclusions reached in this study also provide a good example of education research studies, “Our findings gave us a better understanding of how and why small-group activities produce positive outcomes such as learning, achievement, and persistence.” The authors do not attempt to draw specific, or quantifiable, conclusions regarding the benefits from small-group learning, nor do they only evaluate test scores to base their conclusions. Instead, the authors rely on triangulation and an iterative process design to alter their study as they go, based on what they learn during the study in order to hone in on the objective.
The clicker studies found in the literature and discussed previously, did not follow a structured action research design, as in the small-group learning example. Thus, providing a closer review of a few of the clicker papers may provide insight regarding the validity of results, as well as providing examples of best practices, and pitfalls, to avoid in future research.

One study (Morgan, 2008) actually saw lower scores while using clickers as well as an increase in attrition, although the differences were not statistically relevant. The study involved 5 instructors teaching a variety of classes, each with an average of 30 students. Each instructor taught one course section without clickers to be treated as the control, and one course section with clickers as the experimental group. No points were assigned to the clicker questions, which included reading questions, opinion questions, formative assessment questions, and questions to spark discussion. Surveys were given to the students, however the survey results were not discussed in the paper. Before concluding that clickers hinder student performance, or do not aid student learning, several considerations deserve consideration. First, class size is very small, and if the instructors already encourage active participation by the students, using clickers may have no additional value in this area. Also, in such a small class and with no points being awarded for attendance or participation, there is likely no gained benefit from increased attendance. As there were several instructors, data may be blurred if some saw gains, while others did not, based on how the clickers were used. Also, this was the first time clickers were used for all instructors, and the study spanned just one semester. Thus, the instructors not only were novice clicker users, but there was no iterative process design to identify what worked well and develop those uses. It is unfortunate there is no discussion concerning the instructors pooling their experiences and sharing best practices in order to develop the use of clickers, which is one key element of effective action research design.
One study involving high school chemistry students (Vital, 2012) evaluates and compares exam scores from one year considered the control while not using clickers (2009), with scores from the two subsequent years when clickers were used (2009 and 2010). The author suggests the test scores support a conclusion that learning was enhanced while using clickers due to formative assessment opportunities and a safe environment where students can answer questions without ridicule or penalty. These are, indeed, two suggested benefits of using clickers from the published literature. There are some problems with the study, however, that make drawing these conclusions difficult. First, average scores decrease on more chapter exams than increase during the year, making it difficult to conclude that using clickers enhanced student learning. No discussion is provided by the author to explain why some score may have decreased. Also, clickers were used only one day for a review session prior to each exam, thus the overall impact clickers may have had on student learning was significantly limited. The sample size was 22-24 students for each sample group, thus variations in student ability could easily influence results, regardless of instructional pedagogy. While the author used clickers for two years, there is no discussion concerning how the use of clickers was altered based on what was learned while using the devices. The author suggests that the formative assessment benefits gained from their use was significant, but did not develop that idea by increasing the amount of use, or altering their use in any way.

While El-Rady (2006) found improvements of five percentage points, as noted earlier, there are questions about the study that remain unanswered. A number of quizzes were given at the beginning of lectures using the clickers and it is not clear if this practice was consistent with prior course sections with which the results are compared with. Thus, possible variables, such as the use of quizzes, may affect student learning outside the use of clickers. While this is expected practice in action research, it removes any pretense of the author conducting a controlled
experiment. Relating to action research methodology, the author indicated encouragement from performance results and student feedback after the first semester of using the clickers (fall 2004), however he does not provide specific examples of changes made in using clickers, or what worked well, or what did not work well. Thus, it is difficult to draw conclusions as to what specific changes in course design or pedagogy while using clickers has led to the improvement in student scores. One strength of the paper is that while the author notes the difficulty of obtaining reliable quantitative data, he does use student surveys in a triangulation approach in order to reach the conclusion that using clickers can be an effective tool to promote student engagement and active learning.

The best example of action research involving clickers is from Crossgrove and Curran (2008). First, the authors identify how clickers were specifically used to alter their teaching practices. Exam results were evaluated along with student surveys in a triangulation approach to develop an understanding of how using clickers may benefit the students. Most notably, however, is that the authors analyzed results from the first semester of using clickers and made conclusions regarding when using clickers had the most impact. They then altered how they used the clickers in the second semester of their study, focusing on higher order thinking skills such as comprehension, analysis, and application of new information, where they believed using clickers would have the most impact on student learning. There was no significant improvement in test scores while comparing a combined average of both semesters using clickers with historical averages of courses taught without clickers. When student scores from just the second semester of the clicker study was compared with historical averages, however, a significant improvement was noted in both courses used in the study. In their discussion, the authors note the growing pains associated with using clickers, and how they became more comfortable with incorporating them into their lectures. The change in student performance is likely a result from the
combination of the altered use of the devices with a general improvement in the quality of clicker questions.

As seen in the literature, there is a wide range of how clickers were used in studies and in the methodology of how the studies were carried out that lead to a range of results and conclusions made concerning their use. The following list of variables within the published literature is not exhaustive, but illustrates where some aspects of research design may influence the quality of the study:

**Sample groups**

Studies range from 5 students in one small class (Sevian, 2011) to over 3,000 students from many separate classes during the study (Kaleta and Joosten, 2007). Clearly, as sample size shrinks, influences from individual student abilities has more impact on average test scores. Also, some studies include two consecutive semesters when comparing clicker use, such as no clickers in the fall with clickers in the spring. This comparison may raise some concerns whether student populations, even with large sample sizes, are equivalent between semesters because it has been suggested that motivation or ability of students may fundamentally be different between semesters in undergraduate science courses (King and Joshi, 2008).

**Duration of research**

Most studies spanned one semester, while some studies were as short as one lecture (Shaffer, 2009). One problem with this is that it takes time and practice to develop good clicker questions and effectively integrate them into lecture (Caldwell, 2007; Crossgrove and Curran, 2008; King and Joshi, 2008; Lasry, 2008), thus most papers are written by novice clicker users who have not had the benefit from multiple iterations of practicing and improving their use of
clickers. As previously discussed, an iterative process is one critical element to effective action research methodology.

**Use of clickers**

As noted previously, technology supports pedagogy rather than defines it. Using clickers ineffectively, for example, would not be expected to have any impact on student learning. Or conversely, if an instructor already employs active learning strategies, adding clickers may provide limited benefit in this area. In the review of the published literature, there is a wide range of how instructors used clickers, varying the types of questions asked, frequency of questions, types of discussion following clicker questions, point structures tied to clicker questions and so forth.

Woelk (2008) identifies two broad types of clicker questions – “I am” and “I do” questions. The “I am” category allows students to voice “I am here”, “I am prepared” and “I am interested”, while the latter enables them to communicate “I learn”, “I understand” and “I apply”. Woelk suggests that many instructors are failing to integrate the “I do” questions, which are the questions best used for formative assessment, into their lectures, and are thereby limiting the possible benefit of using the devices. Agreeing with this perception, others have noted that writing clicker questions is seen as a skill that needs development (Caldwell, 2007; Ribbens, 2007; Martyn, 2007) and many fall back on solely writing questions that consist of factual recall (Caldwell, 2007).

Coll and Taylor (2001) suggest traditional lecture is effective for teaching simple factual material, however a constructivist based pedagogy is more effective for teaching the more challenging concepts. This idea is supported by the previous discussion concerning learning models whereby rote memorization is a simple activity of storing and retrieving bits of
information, requiring little to no mental construction. Assembling and combining new information with old, in order to understand relationships or meaning, however, requires more complex information processing in the mind of the learner and requires a different pedagogical approach. Slain (2004) found no benefit to student learning while using clickers on simple memorization questions, however did see a roughly five percentage point improvement in performance on questions involving higher order thinking. Similarly, after seeing no apparent benefits from using clickers after the first semester of use, Crossgrove and Curran (2008) continued their research, but focused on comprehension, application, and analysis types of questions. They found significant improvements in test scores, with an average performance increasing from 66.6% to 74.1% for non-biology majors in an introductory biology class. They also saw gains with biology majors in a genetics course, with average scores increasing from 65.9% to 71.4%.

Three separate studies also found the amount of clicker use had an influence on student perceptions, with more questions correlating to increased perceptions relating to their learning, impact on exam scores, improved participation and engagement, improved attendance, and making the class more interesting (Nelson and Hauck, 2008; Preszler et al., 2007, Trees and Jackson, 2007). The perceptions were highest when 4-7 questions were asked each lecture, with a decrease in responses when more than seven or fewer than four were used (Trees and Jackson, 2007).

Levels of student engagement

It has been shown that an interactive environment has greater benefit on student achievement (Knight and Wood, 2005), however the time lost to support this form of teaching is a primary concern among educators (Kay and LeSage, 2009). Schackow et al. (2004) compared
student performance on quizzes by comparing students in a traditional didactic lecture, students in an interactive classroom with questions and answers without the use of clickers, and students in an interactive classroom using clickers. Average student performance was lowest in the didactic classroom with an average score of 61%. The performance in the two interactive classes was very similar and significantly higher with average scores of 93% without clickers and 97% with clickers. This supports prior conclusions that an interactive environment, regardless of the tools used, enhances student learning over traditional lecture. Clickers appear to be a useful tool in creating such an interactive environment for some faculty, especially in large lecture classes.

Stowell and Nelson (2007) found no improvement in performance when using clickers compared with hand-raising or response cards, however did note a higher level of participation among students with the clickers as well as observing that clicker responses more accurately reflected student learning than the other response types since there was anonymity and less conformity. King and Joshi (2008) studied the effect of participation on performance with their general chemistry course and found students who were active participants in lecture as defined by responding to at least 75% of the clicker questions earned a higher course grade by up to ten percentage points than their non-active participants in the same course. Also, students who answered the clicker questions correctly during lecture were up to 13% more likely to answer a related exam question correctly.

Related to this topic concerning level of engagement, the amount of clicker questions has been found to affect student performance. Preszler et al. (2007) included six separate biology courses taught during one semester (fall 2005), including both lower and upper division courses, in their study and found that an increased use of clickers in lecture had a positive impact on performance on exams for all six courses. The improvement in performance increased sequentially with clicker use between the three groups in their study having low use of clickers
(0-2 questions per lecture), medium use (3-4 questions per lecture) and high use (5-6 questions per lecture).

One study measuring time spans of student engagement found students alternate between being engaged and not engaged in cycles as short as 4.5 minutes, and that the cycles decrease in time throughout a lecture (Bunce et al., 2010). The authors also found a carryover effect after a clicker question was used to engage the students, suggesting students may pay more attention to lecture material following an interactive activity than prior to the activity. The authors’ recommendation was to incorporate student-centered activities throughout a lecture to maximize student engagement.

**Student characteristics**

Student characteristics such as gender, motivation levels, performance levels and such are controlled for in some studies or assumed to be constant. A few studies have investigated some characteristics in particular to identify whether certain students benefit more from using clickers than others. Gauci et al. (2009) found students with the lowest scores in prerequisite classes benefited more from using clickers than middle-achieving and high-achieving students, supporting Crossgrove and Curran’s (2008) conclusions that the weaker students may benefit the most from a more active learning environment.

Student status and classroom experience affected the perceptions of using clickers; first and second year students saw more benefits from using clickers than third and fourth year students who also had more experience with large lecture classes (Trees and Jackson, 2007; Preszler et al., 2007; Crossgrove and Curran, 2008). Students who performed better in class generally thought clickers provided greater benefits (Preszler et al., 2007; Sprague and Dahl, 2010). Students at a disadvantage in the class, such as non-native speakers or international
students, found that using clickers help them participate in class and overcome barriers that would otherwise limit their participation (Sprague and Dahl, 2010). Women tend to be more active participants than men in using clickers when the responses are optional (King and Joshi, 2008), and women were more engaged during PI sessions, while the men were more intent on solving the problems by themselves (Hoekstra, 2008). While having different levels of participation with the clicker questions, however, there was no difference in overall grades between men and women (King and Joshi, 2008). Students who reported as having difficulty getting excited about class had a greater perception that clickers were enhancing their learning than students with a high level of cognition (Sprague and Dahl, 2010). One theory explaining this difference in perception was that the instant feedback students received regarding whether they provided a correct answer to the question provides more reward for the lower cognition students. Sprague and Dahl (2010) also identified a positive correlation between self-reported perceptions of learning with actual grades earned and found disadvantaged students benefitted more from clickers than their peers by overcoming barriers to participation and increasing their levels of engagement.

Type of course

Most studies involved large enrollment lower division courses (King, 2008; Addison et al., 2009; Stowell and Nelson, 2007; Mula, 2009; Morling, 2008; Shapiro, 2009; Yourstone et al., 2008) while some studies were conducted in small enrollment or specialty courses (Morgan, 2008; Pradham, 2005; Schakow, 2004) or upper division courses (Crossgrove and Curran, 2008; Gauci et al., 2009). As noted with the Morgan study (2008), class size may affect the results based on statistical relevancy of data, as well as pedagogy used before and after the incorporation of clickers. No apparent trend is seen between freshman courses and other courses in regards to
the impact on learning using clickers. No additional benefit is seen when using clicker based on a particular field of study, which includes chemistry (Bunce et al., 2010; King, 2008; Woelk, 2008; Wagner, 2009; Shaver, 2010; Hoekstra, 2008), biology (Brewer, 2004; Addison et al., 2009; Crossgrove and Curran, 2008; El-Rady, 2006; Lunderberg, 2011; Preszler et al., 2007; Gauci et al., 2009), business and accounting (Carnaghan, 2007; Mula, 2009; Sprague and Dahl, 2010; Nelson and Hauck, 2008; Yourstone et al., 2008), psychology (Mayer et al., 2009; Stowell and Nelson, 2007; Morling, 2008; Shaffer, 2009), medicine (Schakow, 2004; Pradham, 2005), library instruction (Dill, 2008), health sciences (Fitzpatrick, 2011), computer literacy (Martyn, 2007) and campus wide efforts spanning multiple fields of study (Kaleta and Joosten, 2007; Morgan, 2008).

**Faculty and student attitudes towards clickers**

Student attitudes towards using clickers are generally very positive (Caldwell, 2007; Kay and LeSage, 2009; Preszler et al., 2007; Gormley-Heenan, 2009; Trees and Jackson, 2007; Uhari et al., 2003). Trees and Jackson (2007) found that students want to be engaged and more involved in class, viewing a traditional lecture as sub-optimal and seeing clickers as a way to improve lectures. Students generally found that using clickers helped increase their engagement during lectures, increased their motivation and attendance, provided a more progressive learning experience, and helped provide opportunities for self-reflection while learning new material (Gormley-Heenan, 2009). While most students felt using clickers was beneficial to their learning, they also thought that it contributed to an improvement on their exam scores while also helping increase their interest in the subject matter (Prather and Brissenden, 2009; Preszler et al., 2007). Students also liked to see how they were doing relative to their peers (Kay and LeSage, 2009). In one survey, 85% of the students in a large enrollment undergraduate physiology course felt more “motivated to think” using clickers (Gauci et al., 2009). From the same study, 86% of the
students thought “carefully and seriously” about the clicker questions posed in class, with several students commenting that the clicker questions motivated them to study after class. Using clickers, as opposed to raising hands or response cards, increased participation and honesty in answering questions (Stowell and Nelson, 2007). In a large enrollment undergraduate biochemistry class, 86% of the students agreed that clickers helped their learning, 80% agreed that the clickers helped them focus and pay more attention in class, 83% felt using clickers helped improve their scores on exams, and 84% of the students would recommend clickers for future classes (Addison et al., 2009). In a survey from general chemistry courses over three semesters involving over two thousand students, 95% of the students found clickers at least somewhat useful, with 40% indicating the clickers were “quite” or “extremely” useful to their learning (Hoekstra, 2008). Similarly, from one study done with undergraduate biology students, only 8% of the students did not like clickers and 10% would not recommend clickers for future classes (Preszler et al., 2007). Students, only modestly, found using clickers makes the class more enjoyable or entertaining (Stowell and Nelson, 2007; Addison et al., 2009).

One point that has been questioned as being perceived as a possible detriment to using clickers is cost. The survey data suggest, however, that cost is not perceived as a burden to the students (DeBourgh, 2008; Boatright-Horowitz, 2009). Through student surveys, Kaleta and Joosten (2007) found that students accepted the cost of the clickers so long as the clickers were used effectively and frequently, and that there was an impact toward their final grade. While technical difficulties are one of the most common problems encountered with clickers for the instructors, students learn to use clickers easily and without problems (DeBourgh, 2008). In fact, very few problems are presented by students, especially in recent years as students have become more technologically savvy (DeBourgh, 2008). While not widely reported, some students prefer not to work in group environments often encouraged with clicker use, or feel more confused
about a topic after hearing or debating multiple viewpoints with peers (Nicole and Boyle, 2003). As mentioned earlier, some older students who are accustomed to traditional lecture can be resistant to change and can respond negatively to a new form of learning (Trees and Jackson, 2007).

The most noted types of challenges instructors find with using clickers are technology related and time related. The technology related challenges are centered on setting up the system and learning how to use the hardware and software. Generally, however, these hurdles are overcome fairly quickly (DeBourgh, 2008). There are also the occasional malfunctions or difficulties in receiving student signals, however radiofrequency clickers are improving the signal quality issues, with radiofrequency signal technology showing significant improvement over the older infrared signals (Caldwell, 2007).

From a time related concern, one of the more common concerns includes losing lecture time, thus resulting in less material covered during lectures (Kay and LeSage, 2009). The time and effort in creating the clicker questions and revising lectures to incorporate the clicker questions can also require a significant time investment (DeBourgh, 2008). Crossgrove and Curran (2008) mention “growing pains” associated with adapting lectures to accommodate clickers. Lasry (2008) notes the importance of sorting through the data to identify which questions are useful and those that work poorly, thus the time required reviewing and analyzing the data from the clicker questions also can strain instructors (DeBourgh, 2008). The comments from instructors, however, are that the benefits outweigh the challenges (Caldwell, 2007). In one study involving ten instructors, a pre-survey found the instructors had doubts that using clickers would help their students learn, were wary of the potential technological issues, and were concerned about the loss of lecture time and the increased workload in writing the clicker questions (Gauci et al., 2009). Only one of the ten instructors was “discouraged” by the technical difficulties and did not find the
clicker system easy to use. Half of the instructors did not remove any content from their lectures to accommodate the time for clicker questions, and one instructor indicated that he had saved time by devising a method of using the clicker questions more effectively. That instructor indicated “they had only just scraped the surface of how to use the [clickers] in lectures and how to get the best out of it” (Gauci et al., 2009). Others have referred to the ‘art’ or skill of effectively writing clicker questions that required practice (Beatty, 2004; Martyn, 2007; Kaleta and Joosten, 2007).

In summary, the results are mixed in being able to empirically demonstrate using clickers has a positive impact on student learning. This is not surprising when it is understood that pedagogy influences student learning, and not a piece of plastic. How clickers were used, sample size, student populations, research design and other factors contribute to data collected and, thus, the conclusions drawn from each body of research. It is suggested that the pedagogy used in the classroom is the most significant factor influencing student learning, and that clickers can be useful in creating an active learning environment. While the performance-based results do not consistently show improvements in student learning while using clickers, student and teacher perceptions overwhelmingly favor their use and suggest that clickers do improve the quality of learning. In addition to supporting a change in pedagogy, however, attendance has also been shown to affect learning and clickers are seen as a tool to influence attendance.

Attendance and motivation

A common frustration for many instructors is poor class attendance, especially in large lecture classes where students are typically anonymous. One author noted absenteeism rates as high as 40% in a large public university during the spring semester of an introductory economics class (Romer, 1993), while another noted attendance well below 50% by mid-semester in a high
enrollment introductory earth sciences course (Greer and Heaney, 2004). Similarly, numerous studies show what most teachers intuitively know; that student performance is linked to attendance (Herman, 2009; Moore et al., 2003; Slem, 1983; Dobkin et al. 2010; Soto, 2009; Clump 2003; Jones, 1984; Van Blerkom, 1982; Jenne, 1973).

While students acknowledge the importance of attending class (Moore et al., 2003), they decide not to attend for a variety of reasons, and some general trends in attendance that have been identified will be discussed. There are many theories on motivation and each includes possible factors contributing to a students’ decision whether to attend class, with no consensus as to which reason provides the greatest contribution. Several psychological theories attempting to understand people’s actions have been developed that explain action based on fulfilling intrinsic needs; the “Control Theory” of behavior developed by William Glasser asserts that behavior is determined by what a person needs or wants (Weiler, 2005), Abraham Maslow’s “hierarchy of needs” identified five basic needs – physiological, safety, belongingness, esteem and self-actualization (Weiler, 2005), and McClelland’s “Theory of Achievement Motivation” identified three non-hierarchical needs which are the need for achievement, for affiliation, and for power (Weiler, 2005). Without further exploring these theories, it may be interpreted that students may be motivated to attend class so long as it meets a need deemed as important to those students, and the contrary holds that a student will not attend if there is no perceived benefit.

While some students will be intrinsically motivated to attend class with gaining knowledge as their reward, others will be extrinsically motivated and need external rewards, such as earning points, to motivate them to attend class (Weiler, 2005). One study showed that providing an external motivation by affecting students’ grades had the greatest influence on attendance (Friedman et. al, 2001). To clarify this relationship between attendance and earned points, Shapiro (2009) compared the effect on attendance for one group subjected to pop quizzes,
one group using clickers for points, and a third group in which extra credit was offered randomly for attendance. The classes with pop quizzes (80% attendance) and clicker questions (79% attendance) showed significantly higher attendance than the class that was offered pop extra credit (61% attendance). The study shows that attendance increases when points are regularly tied to attendance or when grades are negatively affected by not attending class. The incentive of possible bonus points did not improve attendance by itself. The amount of points involved, or degree with which attendance impacts students grades, affects the magnitude of incentive to attend class and participate. One study showed that when clicker points accounted for 15% or more of the class grade, attendance levels rose significantly, and students were visibly more alert during class (Burstein and Lederman, 2001). Conversely, others reported that when clicker points accounted for less than 5% of the class grade, their affect on attendance was insignificant (Caldwell, 2007). While Friedman et al. (2001) found that an attendance policy superseded all other factors in influencing student attendance, Moore et al. (2003) added that students may assume attendance is not as important when attendance is not considered as part of their grades.

Contrary to the idea that affecting a students’ grade provides the most incentive, one author noted that when replacing pop quizzes with clicker questions having an equal effect on the course grade, student attendance rose sharply from roughly 50% at mid-semester when using pop-quizzes to as high as 90% at mid-semester when using clickers (Greer and Heaney, 2004). This may suggest that clicker use influences attendance by creating a more engaging and fun classroom, or by providing some other motivational influence for students to attend. Gump (2003) found the top reason for not attending class was how boring the students considered the class to be. Regardless of ranking, there are many common student perceptions and trends in attendance that have been found. For example, students in a small liberal arts college were found to attend more classes than in a medium sized or large university and, correspondingly,
Absenteeism was found to be lowest in small class sizes as opposed to larger classes (Romer, 1993). The same author also noted that students attend classes more consistently that have a significant mathematical component as well as in courses in the students’ field of study as opposed to general education courses. Friedman et al. (2001) similarly noted that class size influenced attendance and noted that students were more likely to attend classes of their choosing as well as courses in their field of study, noting a higher level of intrinsic motivation led to more frequent attendance.

One additional factor concerning students’ decisions to attend class was affected by the instructor (Romer, 1993; Friedman et al., 2001). Attendance was found to be highest with full time faculty as opposed to graduate teaching assistants, part time lecturers, or lab technicians (Friedman et al., 2001). Romer (1993) found a similar relationship between attendance and type of instructor, and through student surveys, also identified the students’ perception of the quality of instruction as having an important impact on attendance. From student surveys, other behavioral reasons for not attending class were if the teacher didn’t notice or care if the student was present, that the course content was available from another source, that the student felt tired or overslept because of having fun the previous evening, that the student dislikes the course subject matter, that the teacher is boring, that the student was using the time studying or working on an assignment for another class, that the student wanted a break, that it was the first or last day of class, or that it was a Friday (Friedman et al., 2001; Marburger, 2001; Gump, 2003).

Absenteeism was also found to increase as the semester progressed (Marburger, 2001; Van Blerkom, 1992). There are many theories to explain this phenomenon, including an increased work load as the semester progresses, a conscious decision to miss a class based on an increased awareness of what is required as the semester progresses, an increasing sense that missing one class will not affect their grade, and a sense of discouragement in the class leading to a
withdrawal from participation or attendance (Van Blerkom, 1992). Jones (1984) suggested a downward spiraling model in which students miss several classes early in the semester and then do not do as well on the first exam as they had hoped. This leads to discouragement, which results in more missed classes, followed by poorer exam results, and so on. This agrees with Van Blerkom’s (1992) conclusion that “if students view themselves as capable of successfully accomplishing a task, they will more likely attempt it, and if they view themselves as less capable, they are more likely to avoid that task.”

An additional theme noted in the literature to explain absenteeism is student expectations, and particularly when there is a gap between expectations and the reality of attending the course. Students may be more likely to skip class when they feel the course is not meeting their needs (Uren, 2001) or when they find either the contents or the requirements vary significantly from their expectations (Moore et al., 2003). Moore et al. (2003) suggested entering freshmen have spent less time studying yet have earned higher grades in high school and may not understand the importance of attending class regularly.

While many of the reasons noted may not be surprising, Friedman et al. (2001) also identified several common perceptions that were found to be false from their study; there was no significant differences in absenteeism between males and females, there was no finding of a “sophomore slump” or “senioritis” suggesting class standing might influence attendance, there was no evidence suggesting age affected attendance supporting some misconceptions that older students may be more mature and have a higher level of commitment, there was no evidence that student employment affected attendance or that living on campus or off campus had any significant effect on attendance, nor was the type of funding for their education a factor in attendance, and finally the number of units the student was enrolled in had no correlation with attendance. Additionally, the notion that the time of the class would influence attendance was
found to be false (Friedman et al., 2001). Instead, students were more apt to attend courses they chose to take and had more interest in, as well as courses with labs.

Regardless of the reason for attending, the question remains as to whether attending class has a direct impact on student learning. While the answer may seem obvious to many, there are many variables contributing to student learning that make it difficult to isolate just attendance as a criterion of student performance. Numerous studies have shown that, on average, poorer attendance accompanies poorer grades (Thatcher et al., 2007; Moore et al., 2003; Jenne, 1973; Marburger, 2001). It has also been shown that students who were absent during a given lecture were significantly more likely to miss test questions pertaining to the material that was covered during that lecture than students who were present (Marburger, 2001). Some have argued, however, that attendance is merely a proxy for motivation (Druden and Ellis, 1995) suggesting the more motivated students will not only attend class more frequently, but will also study more and, in general, take the class more seriously and therefore be more successful. Romer (1993) concluded that attendance does affect learning. In his study, he first performed a regression analysis of performance on the fraction of lectures attended and found a statistically significant and large relation between attendance and performance. He found that students who attend a quarter of lectures earned, on average, a ‘C-’ while students attending all lectures earned, on average, a ‘B+’. Romer wanted to control for motivation and student ability in order to determine if attendance had a true impact on performance. After limiting his data set to just those students who completed all nine homework problem sets and including student GPA as a control variable, his regression analysis showed that the relation between attendance and performance remained large and significant. His results indicated students with the average GPA and completing all problem sets would earn a ‘C+’ if attending a quarter of the lectures, however would earn a ‘B+’ if attending all of the classes. Romer acknowledges the possibility of other variables not
controlled for that could affect performance, however his conclusion was that attendance likely has a genuine affect on performance.

Dobkin et al. (2010) attempted to control for motivation by applying a mandatory attendance policy after the first exam of their economics course for students below the median score, thereby using a discontinuity in attendance rates for students to identify the affect of attendance on performance. The results showed that a ten percentage point increase in overall attendance rate led to a 0.17 standard deviation increase in the final exam score. Stanca (2006) collected and used survey data completed by his introductory microeconomics students to separate and quantify factors such as ability, effort and motivation in addition to attendance. His results also conclude that attendance does have a significant impact on test scores.

One additional method, and the most extensive study, to isolate and define the impact of attendance on learning is a meta-analysis of previously published results. Crede et al. (2011) created a database from 90 samples including over 28,000 students, which consisted of 99 correlations. The data set contained articles and dissertations from 1927 through 2009. The results showed that students with high class attendance are not simply those students with higher levels of motivation, but rather class attendance and student characteristics such as motivation, personality traits, and prior achievements make independent contributions to achievement rather than having an influence on each other. To quote their conclusion, “Class attendance appears to be a better predictor of college grades than any other known predictor of college grades – including SAT scores, high school grade point average, studying skills, and the amount of time spent studying. Indeed, the relationship is so strong as to suggest that dramatic improvements in average grades (and failure rates) could be achieved by efforts to increase class attendance rates among college students.” (Crede et al., 2011).
To summarize, the literature provides numerous factors influencing students’ decisions whether to attend class or not, and there is an overwhelming consensus that attendance is linked to performance and learning. It has been suggested that using clickers provides additional motivation for attending class by addressing students’ needs in areas where traditional lectures may lack (Weiler, 2005). Students may recognize and respond positively to instructors’ pedagogical commitments with using clickers, feeling the instructor was adapting to meet their needs (Trees and Jackson, 2007; Nicol and Boyle, 2003). Students also overwhelmingly feel their education is enhanced with the use of clickers, which was described in more detail in the section of this chapter titled, “Faculty and student attitudes towards clickers” (Nicol and Boyle, 2003, Kaleta and Joosten, 2007; DeBourgh, 2008; Prather and Brissenden, 2009; Preszler et al., 2007; Gauci et al., 2009; Trees and Jackson, 2007; Uhari et al., 2003). Attendance policies are difficult and time consuming for large lecture classes, thus they are seldom used. The use of clickers has been attributed with enabling an attendance policy, changing the landscape in this area of the classroom (Kay and LeSage, 2009). Clickers have been shown to provide instructors in any size classroom with a viable method to administer points towards students’ grades for being in class, or for answering questions correctly, thus providing a performance based incentive to pay attention in addition to being present (Caldwell, 2007).
Chapter 3

METHODOLOGY

Participants

This project was conducted over the course of two semesters, fall 2010 and spring 2011, at California State University Sacramento. Each semester included two sections of Chem 4 with enrollment for each section between 120 and 145 students; a total of 272 students enrolled in the fall and 244 enrolled in the spring. All four sections were taught by the same instructor, who has been teaching this course for several years and is a tenured professor at the university.

Research design

The design of this project is an action research study, indicating that the research intends to address a specific aspect of classroom behavior or performance by using students as active participants. Action research in an interactive process between instructor and student with the goal being to understand current behaviors and their underlying causes so that the instructor may change his/her behaviors. In short, action research is a study with the objective of generating new knowledge so instructors can do things better. As described in the literature review, it is a cyclical or iterative process, often used in education as educators are constantly trying to modify classroom behaviors and improve student learning. This study differs from the published literature involving clickers in that it does employ a better use of action research methodology by building on what was learned from the first semester to drive changes for the second semester of the study. Results from the second semester can be compared with the first semester and to prior semesters when not using clickers to understand if the changes made had any impact on student learning. The methodology used in this research is intended to study whether using clickers can affect student learning via altering pedagogy and influencing attendance.
The steps of action research are not unlike the steps used in the scientific method; both involve stating a problem, identifying research that can help answer the stated problem, collecting data, analyzing the data and drawing conclusions. Action research does not explicitly identify the formation of a hypothesis as in the scientific method, however it may be seen as implicit as there is a desired, or hypothesized, effect from studies involving this type of research. Action research quickly deviates from traditional research, however, because human beings are the subject of the research, who have minds of their own and do not necessarily behave as scientists might expect them to.

Traditional physical sciences, such as chemistry, are based heavily on propositional theories which are grounded in searches for certainty. There exist data which may prove or disprove these theories. Action research, however, is based on dialectical theories, which are grounded in contradiction and are based on real-life experiences. These behavioral science theories, therefore, are typically fluid and subject to change. Since human behavior is dynamic, it is often not feasible, nor is it required, to have a control with which to compare results while using action research. Comparing test scores from two sets of students does not lead to definite conclusions regarding the impact of a study; clearly individual students behave and learn differently. It is possible one set of students performs better than another simply because they are a better group of students and not due to an experimental design change. It can be misleading to draw specific conclusions from results based on one group of subjects’ behavior relative to another groups’ behaviors. The experimental data, therefore, do not provide concrete evidence of any results. Therefore a triangulation approach is used to collect all possible data, both qualitative and quantitative, in order to draw meaningful conclusions. Thus, experimentation using action research is often not designed as a chemistry experiment may be designed, nor can the results be expected to be the same in terms of reproducibility.
It is important to note that when collecting data concerning human behavior, not all data are quantifiable. For example, in studying human emotions, subjects may be described as being angry, frustrated, happy, or ambivalent. These are valid observations and there is no requirement of a numerical scale to quantify these observations. Similarly, it is valid to observe that there is “more energy in the classroom” or “the students appear to be more engaged during lecture.” These observations of human behavior do not require being quantified to justify their significance or legitimacy. As the objective of action research is not to prove any given idea or theory, many different inputs are used to qualitatively assess the situation using a triangulation approach.

One fundamental disadvantage of action research is that there is no external validation for the research. Since this study involves clickers when used by one instructor in one chemistry course, it is not possible to make broad generalizations of using clickers for all instructors in all courses. It may be possible, however, to gain insights into the impacts of using clickers, adding to the body of literature as one additional reference concerning the use of clickers in an undergraduate chemistry course. As is often stated throughout this paper, clickers support pedagogy and it is ultimately the instructor’s pedagogy that influences student learning. Any other instructor using clickers may likely incorporate a different pedagogy and thus obtain different results.

As discussed in the literature review, student learning is extremely complex with numerous variables that affect students’ decisions to attend class, their study habits and their performance on exams. Thus, internal validity is a primary concern with this study. Student characteristics such as age, gender, prior school performance, work commitments, school work load and other factors are not controlled in this study and are assumed to be somewhat constant between semesters and course sections. Careful consideration was taken when creating exams so as to ensure an equal level of difficulty between semesters that would not bias student performance. Since points were awarded for answering clicker questions each lecture period, it was predicted
that daily attendance would increase over prior semesters when clickers were not used. Also, as discussed in the literature review, the clickers were used as a tool to support the instructor’s pedagogy (Kaleta and Joosten, 2007). In this case, the pedagogy did change when clickers were implemented, thus changing the learning environment. It is this change in learning environment that is being evaluated, using clickers as an enabler of an active learning pedagogy to determine if student learning was enhanced as a result of using clickers.

In conjunction with following the methodology of action research in this study, a “backwards design” process was used in writing the clicker questions used in lecture. A backwards design process is an approach, as the name indicates, that does not start with the lessons and end with the evaluation of learning as might seem to be the more natural sequence of events in the classroom. Instead, a backwards design methodology starts with the desired results or objectives the instructor is pursuing; what should students know, understand or be able to do, and what enduring understandings are desired? Once the desired results have been identified, the next step is determining what is acceptable evidence of student learning; how will we know when students have achieved the desired results, and what will we accept as evidence of their learning? The third and final step is to plan the instruction that will facilitate the learning. This last step requires identifying what knowledge the students need to have prior to learning new information, what misconceptions or difficulties students may have with the information being taught, what materials or resources are available and useful for teaching the new information, and then evaluating the instructional design to determine if it is effective.

This backwards design approach is considered the best method in designing effective curriculum (Wiggins and McTighe, 1998). Instead of starting the process with a favorite lesson or time honored activity that may actually serve no purpose, this method focuses on developing curriculum with the end result in mind so that every aspect of the class activity can be viewed as a
means to an end. Also, by thinking about assessment before instruction begins and defining what
is considered appropriate evidence of student learning, more focused lessons can be created
which can ultimately lead to better student performance (Wiggins and McTighe, 1998).

Using prior experience teaching this class and his planned lecture material, the instructor
provided the researcher with content areas for which to write clicker questions for each lecture.
The researcher then wrote the clicker questions with a specific objective, or learning outcome, in
mind. Student misconceptions from published literature, prior student responses, and interviews
with the instructor providing his observations and experiences from prior classes were reviewed
in order to identify student misconceptions and topics that students have historically had trouble
mastering. The researcher included carefully chosen wrong answers for all clicker questions to
identify what mistakes the students were making, or what misconceptions they had for a given
topic.

**Iterative process and design changes during the study**

The literature reviews mentioned that using clickers effectively was a skill requiring practice
(Crossgrove and Curran, 2008; Lasry, 2008; Beatty, 2004; Martyn, 2007; Kaleta and Joosten,
2007) and it took time and practice to develop good clicker questions that would benefit the
students. The first semester of this study involved learning how to effectively use clickers, and
the data collected from the first semester was used to make changes for the second semester.
Several design changes, which will be discussed following an analysis of the first semester
results, were made between the first and second semester of this study in order to optimize the
effectiveness of using the clickers. Thus, the second semester of this study was not to validate or
replicate results from the first semester; the intent was to learn from the first semester in order to
make improvements during the second semester.
Types of clicker questions used

Several different types of clicker questions were used in this study (see Appendix A for a complete list), with explanations and examples for each that will be discussed in this section. The first type of clicker question is the review question for material covered in the previous lecture. This type of question is intended to be difficult and challenge the students since the material has already been covered and students are expected to have done the homework. The question may be conceptual or computational, depending on the nature of the previous lecture, but students should have completed the homework assignment in order to correctly answer the question. The review question may be an individual effort or students may be allowed to work together using peer instruction to facilitate learning. Since the clicker questions are worth points that affect the students’ final grades, there is motivation to come to class prepared to answer the questions correctly. Students who have successfully completed the homework should be able to successfully answer the review question. As is the case for most of the clicker questions, the instructor can adjust the content of the lecture based on the results from the clicker question. If many students are making a similar mistake or have a common misconception, the instructor can spend a few minutes to discuss the question and answer. However, if the majority of students correctly answer the question, the instructor can move right into the next topic for the day. The following example of a review question was asked concerning atomic isotopes and the atomic symbols:
Question: How many protons and neutrons are in this element?

\[
\begin{array}{c}
{^{26}_{12}}\text{Mg} \\
26&12
\end{array}
\]

A) 26 protons and 12 neutrons  
B) 12 protons and 26 neutrons  
C) 12 protons and 14 neutrons  
D) 14 protons and 12 neutrons  
E) 26 protons and 14 neutrons  
F) 14 protons and 26 neutrons  
G) None of these is correct

If the students grasped the previous lecture’s ideas concerning atomic number and mass number, and have had some practice identifying the number of protons and neutrons from the homework assignment, they should be able to successfully identify that “C” is the correct answer. Students who attended lecture but did not complete the homework might be grasping at straws and be inclined to guess. For example, option “A” is appealing for the student who has not grasped any of the ideas and hopes both the number of protons and neutrons are provided by the symbol. The student who chooses “B” correctly identifies there are 12 protons, but has forgotten how to calculate the number of neutrons and hopes the correct number is provided in the atomic symbol. While option “C” is the correct answer, option “D” is very closely related and can be mistaken for the correct answer if the student has not practiced enough. Options “E” and “F” provide two alternatives for students who want to use both numerals from the symbol and remember subtraction is called for. By providing logical wrong answers, it is more difficult for students to guess the correct answer, and they should learn it is best to read the book and do the homework in order to earn these points from the review clicker questions. There is also a time limit for each clicker question, and these review questions are typically meant to have a short time limit so that the students who are struggling to find the answers may not have enough time for some questions. This will provide feedback to the students for quiz and exam type situations and whether they are adequately preparing themselves for success. Additionally, the instructor can address any
common mistakes being made on these questions before moving on to the next topic. Typically a
reading question or a review question is asked at the beginning of class with a time limit for
student response, providing additional motivation to come to class on time.

The second type of clicker question is a reading question for new material the students should
have read in preparation for lecture. The purpose of the reading questions is to motivate students
to come to class prepared and complete the reading assignment prior to class. The benefit is that
students will come to class with a basic understanding of the material being covered and the
instructor can spend more class time on the key concepts for that day, eliminating the need to
explain vocabulary and the rudiments of that particular lesson. The reading clicker questions are
conceptual in nature and are not meant to trick or confuse the students. Students are allowed to
use notes they took from the reading, but may not use the book or talk with each other. These
clicker questions focus on definitions and the big ideas while reinforcing the main points from the
reading. The students should easily identify the correct answer if they read the material carefully.
Here is an example of a reading clicker question covering the new reading concerning atoms,
isotopes and atomic mass:

**Question:** Which of the following statements is not true?
A) The mass number of an element is equivalent to the number of protons and number of
   neutrons in that element.
B) **Different isotopes of the same atom have different numbers of protons.**
C) The atomic mass of an element is an average mass for that particular element.
D) The average abundance of each isotope for any given element is needed to calculate that
   element’s atomic mass.
E) An element may have atoms with different masses due to different isotopes present.

The incorrect answer (B) that isotopes differ in the number of protons should “jump out” at the
student who has done the reading and has a basic understanding of the new material. These
questions provide a great opportunity for formative assessment in that possible misconceptions
can be addressed immediately. The reading questions are intended as a motivator and as a
confidence builder for the students, promoting preparedness and a desire to attend class.
The third type of clicker question is a conceptual question used during the lecture of new material. These are often referred to as “ConcepTests” (Mazur, 1997) and are used to gauge how well the students are grasping the new material being taught without using a calculator to solve a problem. These questions may be used as a formative assessment tool to quickly identify whether the students are getting the basics, or they can also be used to determine whether students can apply the current topic to a new situation by providing a more difficult problem. Misconceptions that have been published in the literature, as well as misconceptions identified from previous clicker questions, are used to provide “good” wrong answers to the questions. If a high percentage of the class answers correctly the instructor may speed up the pace of the lecture or move quickly to the next topic. If, on the other hand, a very low percentage of the class responds correctly, the instructor has different options. The instructor may go back and cover the main idea from a different angle, or may address the specific wrong answers selected by the students. Another option is that these are excellent opportunities to be used for peer learning interactions. Peer learning can be applied ‘on the fly’ whenever a clicker question has a poor correct response rate, thus taking advantage of the usefulness of immediate feedback or, as mentioned earlier, the researcher can provide cues to the instructor based on analysis from responses from the previous semester. After viewing the results from the students’ responses, the lecturer may ask the same question a second time, urging the students to chat amongst themselves for a specified time in order to gain some consensus for an answer. Students will then be prompted to answer the question a second time. Since Chem 4 is a preparatory chemical calculations course with an emphasis on problem solving, there are not as many opportunities for conceptual questions as there might be in an organic chemistry class, for example. But there are opportunities in Chem 4, as shown with this example that was used in a lecture covering significant figures and measurements:
Question: Your thermometer has markings every 0.1 °C. Your sample temperature reads between the 22.3 °C and 22.4 °C markings as seen in the picture. Which reading is reasonable to record in your lab note book?

A) About 22 °C  
B) 22 °C  
C) 22.3 °C  
D) 22.4 °C  
E) 22.33 °C  
F) 22.36 °C  
G) 22.337 °C

Less than 80% of the fall 2010 Chem 4 class answered this question correctly during lecture with the most common wrong answer being “G”, selecting an answer with too many significant figures than could reasonably be assigned. This question provides a good opportunity for the instructor to review the concept of significant figures while addressing the most common misconception of assigning too many digits. If the class had answered with 95% correct responses, however, the instructor would see the class had no difficulty understanding the concept from the reading and could quickly move on to the next topic. In this situation the instructor saves time by not elaborating further, but can direct students to the class website for a detailed answer for those students who need further explanation.

The fourth type of clicker question used in this study is a computational question during the lecture for new material being taught. Many concepts in an introductory chemistry course such as Chem 4 involve mathematical skills that many students have not yet mastered, such as calculating an element’s atomic mass from given isotopes and their respective natural abundances. In this case, students need to use percentages of two values to calculate a weighted average. After the instructor explains the concept of isotopes and atomic mass it might be beneficial to see if the students are able to apply the mathematics involved to calculate an atomic mass from an element with multiple isotopes. A sample question might be as follow:

Copper is naturally found as two isotopes; 69.17% is Cu-63 (62.9296 amu) and 30.83% is Cu-65(64.9278 amu). What is the atomic mass of naturally occurring copper?
If previous lessons have covered significant figures and units of measurement, wrong answers can include omission of units, such as “A” and “E”, or may contain an incorrect number of significant figures to reinforce prior lessons. For example, students who selected “A” calculated the correct answer but omitted the units of measurement. Students selecting “B” performed the calculations using the percentages as whole numbers instead of dividing by 100. Student’s selecting “C” calculated a simple average of the two masses of each isotope. Answer “D” is obtained if only the mass from Cu-63 is calculated but not added to the mass of Cu-65. Answer “E” represents a correct calculation using rounded atomic mass unit values instead of the precise values given. Answer “F” is the correct answer, of course, and answer “G” is provided to capture if students are coming up with any other possible answers that have not been predicted. This is another example of how question responses can be used for future class sessions. If a significant portion of the class is arriving at another possible answer, then it would be worthwhile to explore what mistake is being made which can be addressed in future class lectures, and then confirmed with future clicker questions. As with most of the clicker questions, one of the objectives is to help identify the misconceptions the students have so the instructor can adjust the lecture as needed to address those misconceptions.

A type of question related to the review or progress check questions is a ‘challenge’ question. As discussed in the literature review, Woelk (2008) identified these higher order types of questions as “I do” questions where the students can apply what they have learned. For
example, after learning how to calculate the atomic mass of an element given the isotopic masses and abundances, this challenge clicker question is given to the students:

Gallium has two naturally occurring isotopes: Ga-69 (mass = 68.93 amu) and Ga-71 (mass = 70.92 amu). Using only the information available on the periodic table, determine the % abundance of the heavier isotope? Hint: what do you know about the sum of the two abundances?

A) 39.70 %  
B) 39.95 %  
C) 60.05 %  
D) 60.30 %  
E) Not enough information is provided

While this question covers the same concept of calculating atomic mass as with previous questions, the students need to apply the idea that the sum of the abundances is 100% and incorporate that information into a formula to calculate the atomic mass. Sometimes it is useful to allow the students to repeat a process in a calculation, and sometimes it is useful give them the opportunity to apply what they have learned using higher order thinking. Good challenge questions can be difficult to write and may sometimes require multiple attempts after seeing they are too easy or too difficult. It is helpful to have an idea of what the learning objective is, using backward design methodology to facilitate the process.

Related to the reading or review questions, the “are you prepared?” question can be asked, particularly if the instructor has asked the students to work on a specific task. For example, after ionic nomenclature has been introduced the students were asked to begin learning the names of some common ions. The following “are you prepared?” question was asked:

Which of the following does not give the correct name for the ion shown?
A) BrO\(^{-}\), hypobromite  
B) C\(_2\)H\(_3\)O\(^2\)-(acetate)  
C) PO\(_4\)^{3-}, phosphate  
D) S\(^2\)-, sulfide  
E) OH\(^-\), hydroxide  
F) NO\(_2\)^{-}, nitrate  
G) CrO\(_4\)^{2-}, chromate  
H) They are all correct
This type of question is not necessarily intended to identify misconceptions, but to provide incentive to come to class prepared and stress the importance of material the instructor would like to ensure the students are spending time on.

A related type of clicker question is simply a homework question. It may be useful to stress a certain idea or ensure the students practice a calculation. By asking a clicker question at the end of class, points can be awarded for students who take the time to answer the question outside of class. At the following class session, the same clicker question will be posed to the students with just enough time allotted to input their answers. This type of clicker question is also useful for the more time consuming calculations where it may be beneficial to not spend class time giving the students ample time to work through a problem they are learning how to solve. For example, after learning about empirical and molecular formulas, and practicing with simple calculations, this homework clicker question can be asked:

Acetylsalicylic acid (aspirin) is 60.0% C, 4.48% H, and 35.5% O. If the molar mass of this substance is around 180. g/mol, what is the molecular formula of aspirin?

A) $C_8H_8O_4$  
B) $C_6H_{12}O_6$  
C) $CH_2O$  
D) $C_9H_8O_4$  
E) $C_2H_2O$  
F) $C_{12}H_6O_2$  
G) $C_{10}H_{12}O_3$  
H) $C_3H_{16}O_8$

This is a more complex example with three elements and will require a significant amount of time while the students are still learning this topic.

There are some topics where student familiarity is considered worthwhile, however the instructor may not wish to spend class time discussing them. After assigning reading and homework an “independent learning” clicker question may be asked to follow up and assess whether the students have learned the desired material. This is one opportunity in particular where using clickers can save time during a lecture by allowing an instructor to quickly review a topic without spending any class time lecturing or discussing the topic. One specific example used in this research is the following:
How many total atoms are in one unit of $\text{Al}_2(\text{C}_2\text{O}_4)_3$?

A) 3  
B) 8  
C) 16  
D) 20  
E) 24

The topic of molecular formulas had already been covered, and this seemed like a good opportunity for students to be able to understand and calculate the number of atoms in a molecular formula without spending class time specifically covering this topic. By using a clicker question on this topic, students are incented and rewarded for learning the material on their own outside of class time.

Using clickers can also be used in formal assessment by administering quizzes. For a quick quiz, the instructor can display the questions on the overhead, thus saving time without passing out and collecting paper copies. The responses are received and stored in the computer, allowing for quick grading and analysis of responses. By having data showing the percentage of students selecting each answer, the instructor is also provided additional data quantifying what mistakes the students are making, just as with all other clicker questions.

In preparing for an exam, exam readiness clicker questions can be given in a review session. The instructor can pose questions with a level of difficulty that is expected on the exam, and then allow a limited amount of time for student responses in order to provide students with a realistic expectation of how much time should be expended to answer the question.

There are occasions when a significant portion of the class fails to understand a particular question on a quiz or an exam that is considered important. A “quiz correction” or “exam correction” clicker question can be given after the quiz or exam has been returned with the expectation that the students are reviewing their mistakes and taking the necessary steps to learn the material. For example, only 45% of the students correctly answered the following question on the second exam during the spring 2010 semester:

What distance (in m) would you get if you added the following: 28 cm + 0.00098 km?

A) $1.3 \times 10^2$ m  
B) 1.26 m  
C) 1.2 m  
D) 1 m  
E) 1.3 m  
F) 28.00098 m
The topic of significant figures is a very important topic with which students have quite a bit of difficulty. To help stress the importance of the topic, therefore, and encourage students to learn from their mistakes, the following “exam review” clicker question was asked in lecture following the exam:

What distance (in m) would you get if you added the following: 0.00510 km + 608 cm?

A) \(1 \times 10^1\) m  B) 11.1 m  C) 11.2 m  D) 11 m  E) \(1.0 \times 10^1\) m  F) 11.18 m

The final type of clicker questions asked concerns attitudinal questions, probing the students for their thoughts on the use of clickers or insights into their behaviors. These questions are not worth any points towards the students grades and are optional for them to answer. None of these questions was asked during the first semester of the study. After reviewing the results from the end of semester survey from the first semester it was believed that asking these types of questions on an ad hoc basis in lecture might help clarify student opinions. For example, this question was asked during one spring 2011 lecture:

Based on your personal experience in this class, what do you feel is the most significant benefit from using the clickers?

A) Tells the instructor how well students are doing or if they are getting the new material.
B) Tells you, the student, how well you are doing on questions important to the instructor.
C) Helps keep you awake during class.
D) The points earned from clicker questions provide motivation for coming to class.
E) Using the clickers makes the class more personal and engaging.
F) Provides practice problems to solve while learning new material.
G) Stimulates discussion with classmates when you are allowed to work together on questions.
H) Other

These types of questions were not feasible on the multiple question surveys using the five point numerical rating scale, thus asking these questions during lecture and using the clickers to choose a response allows more flexibility to probe deeper into student opinions. One additional type of attitudinal question used was a “confidence level” question, asking students how confident they were in their answer for the previous clicker question. Because there was no penalty for wrong
answers to clicker questions, students were encouraged to guess if they did not know the answer, which could skew the results in identifying the percentage of students who understand a topic. This type of question can help clarify student understanding.

To summarize, the types of clicker questions used in this research include:

- Conceptual review
- Computational review
- Reading questions
- Conceptual progress check
- Computational progress check
- Challenge questions
- Are you prepared?
- Peer instruction
- Homework
- Independent learning
- Quizzes
- Exam readiness
- Corrected quiz or corrected exam
- Attitudinal
- Confidence level

**Data collection methods**

Data collection for this study involved several methods, including instructor interviews, classroom observations, student surveys, student responses to clicker questions, quiz questions, and exam questions. In order to address the question of whether using clickers influences student
attrition, attendance was recorded using clicker responses during lectures as well as exam participation to identify the number of students attending class or taking the exam. As this instructor has taught this course for several years, his observations concerning attendance, classroom behaviors, and participation are important tools to evaluate the student impact of using clickers relative to prior semesters when no clickers were used. There is no risk of an “observer effect” using the instructor’s observations, as his presence in the classroom is not affected by the use of clickers. There is potential risk of observer bias, however, and efforts were made to most accurately collect and recall observational data.

The responses from the clicker questions were analyzed to determine the students’ level of understanding and ability to solve problems. Review questions were typically given at the beginning of the following lecture, with the content and level of difficulty determined by the results from the prior days’ clicker questions. The results also gave the instructor the formative assessment information to guide his explanation or lecture content for that day’s lecture based on how well the students were responding to the questions. Also, the responses from the clicker questions and exam questions from the first semester were analyzed so that clicker questions could be modified in the second semester to better assess students’ understanding of the material. For example, if students did particularly poorly on an exam question, the clicker questions pertaining to that material were evaluated to determine if they were providing a good assessment opportunity for the topic. Sometimes the questions were altered and sometimes the wrong answers were altered in order to better determine if the students understood the material or, if not, what mistakes were being made.

Student surveys were administered to assess perceptions of using clickers and identify student behaviors in the course. They were told that the surveys were optional, anonymous, and would not have any influence on their grade. They were then asked to write down their clicker
identification number for the purpose of data analysis so that their responses could be correlated with their clicker responses to lecture questions and exams. The researcher did not have access to student names, only to clicker ID numbers. One survey was given at the end of the first semester and students were given the opportunity to earn bonus points if they wrote a two page essay and completed the survey. Only 50% students participated in the survey; 8 of whom did not provide their clicker number. Perhaps the students forgot, or perhaps they were not convinced there would be no impact to their grades. The following semester, three extensive surveys were given and several ad hoc questions were asked during lectures. Again, it was emphasized that participation was optional and anonymous, with there being no impact to student grades. Response rates were near 100% for the survey administered at the beginning of the semester, 68% for the survey given after the first exam, and 63% for the survey administered at the end of the semester. The survey instrument was a simple 5 point numerical rating scale correlating to the level of student agreement with statements in the survey. A simple average and standard deviation was determined for each statement for the student population taking the survey. Numerical averages to each response were also determined for students based on grade earned and by number of absences to evaluate if any correlations exist between student attitudes and performance, or between student attitudes and attendance behavior. During the second semester of the study, the students were asked to use their clickers and input their responses to the survey questions in addition to circling their response on the paper copy. While it was hoped that the clicker responses would save time in compiling the survey data, this proved to be incorrect. There were too many occasions of students skipping questions, altering the sequence of responses and making the automatic compilation of data not feasible. It was found that it took longer to read through the surveys and correct the response sequences than to simply input all of the responses. While there is a possibility of data entry error with this method, the researcher double
checked all keyed in data to ensure there were no errors with the data input. This was not the case with the ad hoc survey questions that were asked during lecture however, as only one or two questions were asked any given day. Thus, electronic responses were used without manual data entry.

**Resources**

All students were required to purchase, rent, or otherwise have a clicker for every class period. They could use a clicker they had previously used in another class or borrow one from a friend so long as they were not using the same clicker during the same class period. The campus bookstore rented clickers for $12, sold them new for $28 or sold used clickers for $20. In addition, usage of the clicker required a one-time registration fee of $20 per term. The instructor was required to have a receiver as well as software to receive, compile, and present the data from the student responses. Both were provided free of charge by the company selling the clickers. There were several companies to choose from, and eInstruction was chosen by the instructor, which used radiofrequency technology. The software was loaded onto the instructor’s laptop which was used during lecture to present clicker questions to the class on the projection screen, as well as to display the histograms of student responses to the class. Thus, the technology and hardware to present information from the laptop to the class using a projection screen was required in the classroom. Lastly, roughly one thousand surveys were printed and distributed.
Chapter 4

RESULTS AND ANALYSIS

Background observations from the instructor

Below are some excerpts from an interview with the course instructor in order to provide some contextual background concerning the instructor’s observations regarding the course and the students of Chem 4. The instructor’s observations of his class prior to using clickers, and while clickers are used, will provide important inputs into the final analysis of whether clickers are an effective tool as part of the triangulation approach. As discussed in the literature review of action research, there will be no empirical data to prove whether using clickers will improve student learning. Instead, all possible sources of information and opinions will be combined and included in the final analysis.

**Question:** How long have you been teaching Chem 4, and what has been your experience with the variation in students between sections you’ve taught?

**Response:** I have been teaching this class for about ten years, with two or three sections each semester. I see general trends and can diagnose general problems with the majority of students, but there is so much variation in students. All it takes is ten students with a really weak math background, for example, to completely change the whole environment. You might think, that even with a class of 120 students, variations in students would not be statistically significant, but they really can be. I definitely notice differences between one section and another.

Offering the same course at two different times is about as close to a control as I can get since I’m not changing any content between two lectures during the same day. The exception is when, for example, something really bombs in the first class, and I might be able to say it a little smoother in the second class, or add an extra problem to help the students, but that’s as close as I can get to giving two identical presentations. But the 10 am class invariably does better every
semester; their attendance is better, their energy is better, and I think it is just a matter of an 8am class means that you need to get these 20 year olds up at 6:30 or 7 am, and get them to class, and they just don’t do that very well. Perhaps they’re staying up too late. And so the 10am class invariably does better. After 10 years of the 10am class always doing better, we were at the point of looking at getting rid of the 8am class, and having a 10 am and 11 am, or 10 am and noon class since they seem to do better. And then this last semester (spring 2012) the 10 am class did worse. I don’t know what changed this year.

Similar to the trends between the early and late sections, I see trends where the fall semester students consistently do much better than the spring semester students. After looking at all the data, you can propose ideas why that might be….students who come into college and know they need to take this class right away, have all of their ducks in a row, do things by the book and enroll in the class right away, seem to do better in the class than students who didn’t take the class the first semester at campus. Maybe they needed a math pre-requisite course first because they were not math-ready and then enroll in Chem 4 in the spring. I’m guessing that will start changing in the next couple of semesters as classes become more impacted and students just can’t get the classes when they want, and even the good students can’t get the fall classes. There is really no way to control for this handicap, if you want to call it that. There is no way to say the 8am is always going to be controlled by this handicap, so let’s account for that…sometimes even that goes away, and it’s hard to understand why.

In an ideal world, you would be able to take data from two semesters and look at something specific, like a final exam. But you realize there is no nice, easy data to look at and say students learned more during one semester or the other. Some semesters, I’ll lose a lecture due to a holiday and I might have to combine two lectures or drop a topic. Or some semesters I might have an extra day, and I can add a topic. So some finals may have questions on a topic that
are not on other finals. So it just goes to show how difficult it is to say this ‘thing’ is evidence of student learning. You try to look at the big picture; certainly having more students get A’s and B’s, having more students pass the class, having more students have a higher grade on the final….those are the things you look at. But sometimes looking for data points that will provide hard and fast data between semesters can really be apples and oranges. It’s not a fair thing to definitively say why students did better one semester over another.

**Question:** What have you noticed about attendance in Chem 4 prior to using clickers?

**Response:** Before using clickers, in a large lecture, I don’t have good attendance data because there was no easy way to take attendance, or motivate students, or incorporate attendance into their grades. So I don’t have any hard numbers. By the end of the semester on non-exam days, I would see roughly 40-60% attendance in the class. Do I have actual numbers for that? No. But you know the difference from walking in to a full class and when half the students aren’t there. And that affects everything; it affects me, it affects my energy, and it affects the rest of the students. And the students are thinking, “Wait a minute…why am I here if no one else is?” It is a vicious cycle.

**Question:** What kind of classroom environment do you strive for in Chem 4?

**Response:** I’ve always tried to have an active classroom; very student-centric, even in big lectures. To be honest, I did use more questions while using clickers than I used to; the reading questions and review questions are new. But in a typical lecture, I had 2-3 questions that students would work on. Randomly during the semester, I would have students write down answers and pass those in. Those were for bonus points and students were usually pretty focused on those. But the other times I would ask questions, I would see students just staring up into space, and I would go up to students and ask “Why aren’t you working on this…this is your chance to see if you can do it?” It’s that distinction that in an ideal world all of the students
would be motivated by learning the material, but sometimes that’s not enough and you have to
give them a stick to get them to go to class, or to make the effort. But I think as soon as they start
seeing the benefit of those things, it’s a very positive reinforcement spiral where they continue
doing those good things; they’re coming prepared, they understood the material better, they do
better on the exam, and so on.

**Question:** You’ve mentioned before that you have been able to identify some of the
general problems the students are having in Chem 4…what changes have you made in the past to
address those?

**Response:** All of my classes are much like a five year action research project. Chem 4
has actually been longer than that, and has been more like a ten year project. But every semester
I am trying to address new things, but while not overwhelming myself. Not only do I try to focus
on one thing at a time due to workload, but that also provides better insight in terms of action
research, and whether the results likely happened because of this one thing I changed. It’s not
quite like a control group, but you can say there was some indication of improvement, or
whatever is observed, most likely due to the intervention. Some of the other things I’ve worked
on in this course were:

- Science literacy
- Math skills
- Online homework
- Proficiency quizzes
- Formal peer assisted learning
- Early alert advising – Using early warning signs, like when students fail the first exam, where it is really hard to get back on track, and then intervene to help them.
But again, it’s that action research process where, because you are the researcher, like when you are parent, you have the best knowledge of that person and can tell when something is off. I know it sounds a little touchy-feely, but I know when there have been some successes in my class, even though they may be hard to quantify, and when we’re moving in the right direction. And I know when something is not working...like the math worksheets that we implemented a few years ago. We implemented a math pre-requisite now, so that took care of that issue and we don’t need those anymore.

Results from the first semester using clickers (fall 2010)

Student attrition

For reasons that will not be explored in this study, a very low percentage of students officially drop or withdraw from the course. Instead, many students do not take the exams and simply fail the course. There are few cases of students obtaining an excused withdrawal from the course, thus official attrition rates, or number of students who officially withdraw from the course, do not provide useful insight into what effect, if any, using clickers may have had on keeping students in the classroom. Therefore the total number of students taking the final exam is compared with the total number of students registered during the semester, and the number of official withdraws is assumed to be low in number and constant between semesters. The percentage of students taking the final exam will be used to estimate student attrition, thus providing one data point in determining whether the use of clickers can facilitate an impact on student attrition in Chem 4. The attrition rate in the fall 2010 semester, as seen in figure 3, actually increased from the previous two fall semesters. A comparison of fall semesters is made to remove one possible variable of having different student populations during fall and spring semesters, as noted by the instructor as well as from the literature (King and Joshi, 2008).
Attrition in fall 2010 was 15% relative to the historical fall average of 12% with a standard deviation of 5%, thus showing no significantly relevant increase.

**Figure 3: Final exam absenteeism during fall semesters**

**Daily attendance**

Enrollment consisted of 272 students between two sections during the fall 2010 semester. Enrollment figures are identified by the number of clickers registered during the semester. As not all students have clickers on the first day of class, there is an increase in the number of clickers over the first two weeks of each semester. Also, as this was the first semester using clickers, there was some delay in getting data due to the instructor and the students becoming familiar with the technology and incorporating clicker questions into a daily routine, thus no daily attendance data are available for the first four lectures of the semester. As a result, attendance data are incomplete during those first several lectures. The percentage of registered clickers that respond to questions during lecture, however, is evaluated to determine absenteeism. Figure 4 illustrates the trend of increasing absenteeism during the fall 2010 semester (Marburger, 2001; Van Blerkom, 1992), with absenteeism reaching 30% by the end of the semester, similar with what
has been observed in the cited literature (Greer and Heaney, 2004; Romer, 1993; Marburger, 2001; Van Blerkom, 1982). The average rate of absenteeism over the course of the semester is 20% with a standard deviation of 6%. Absenteeism was roughly 30% on non-exam days by the end of the semester, which was visibly lower than previous semesters’ typical absenteeism of 40-60% by the end of the semester, as noted by the instructor.

Figure 4: Fall 2010 daily absenteeism in Chem 4

Attendance-performance relationship

In accordance with expectations and published literature (Thatcher et al., 2007; Moore et al., 2003; Jenne, 1973; Marburger, 2001 2010; Slem, 1983), an inverse relationship was observed between absenteeism and student performance on exams and overall course completion. Figure 5 illustrates the percentage of students passing the course in the fall 2010 semester relative to the number of lectures missed.
Performance on quizzes

Proficiency quizzes have not always historically been given, however they were administered in both the fall 2009 semester (without clickers) and in the fall 2010 semester (with clickers). In both semesters, three proficiency quizzes were given during the semester with a minimum grade of 80% required on each quiz in order to pass the course. Students who do not pass the quiz on their first attempt are given a second opportunity at the end of the semester. Figure 6 provides a comparison of average student scores between the two semesters, showing no significant change in performance between the semester using clickers and the prior fall semester without.
Performance on exams

Three exams and a final are typically given each semester with a minimum grade of 73% required to pass. Figure 7 shows the average student score for three fall semesters prior to implementing clickers (fall 2006, fall 2008, fall 2009) and the first semesters clickers were used (fall 2010).
At first glance, it appears the average student scores declined while using clickers for the first three exams, however there is an interesting trend worth noting. In each of the semesters prior to clickers, the average student score on the final exam (52, 71, and 64 in 2006, 2008 and 2009, respectively) was lower than the average of the three exams (73, 74, and 76 in 2006, 2008 and 2009, respectively). In the fall 2010, however, the average score on the final exam (73) was significantly higher than the average of the three exam scores (69).

While quizzes and exams can vary semester to semester, the instructor has noted a concerted effort to keep the final exam as consistent as possible between semesters in terms of difficulty. Although not a perfect instrument, performance on the final exam is considered to be a useful data point to draw conclusions from concerning student learning throughout the course. Figure 8 shows the percentage of students who passed the final exam (of those who took the exam) for the three previous fall semesters and the fall 2010 semester when clickers where used. Consistent with the higher average score during the fall 2010 semester seen in the previous figure, more students passed the exam while using clickers than in previous semesters.

Figure 8: Final exam pass rates during fall semesters
Student pass rates

One final summative data point concerning performance is the percentage of students who take the final exam and pass the course. While performance on individual quizzes, exams, homework assignments and such may vary for a variety of reasons, the historical course pass rate is typically is between 50-60%, as seen in figure 9, with just one significant outlier in the spring 2006 semester (fall 2006 is not considered significantly out of range at 49%). The results show that the percentage of students passing the course while using clickers is higher than any previous semester at 59%, however not by a margin that would indicate any significance.

![Figure 9: Course pass rate through fall 2010 semester](image)

Student attitudes

An end of semester survey was taken in the fall 2010 semester, with bonus points awarded for completion of the survey in addition to the students writing a two page essay titled, “Advice for future Chem 4 [students]”. The number of survey responses was 113 students of the 228 students who took the exam, with the majority of responses coming from students who passed the final exam. As a result, the survey responses may not comprise a valid representation
of the entire student population. The survey results, as shown in table 2, show the average response to each question with the standard deviation. The format for the survey was to rank each question with the following 5-point scale:

1 = strongly disagree (SD); 2 = disagree (D); 3 = neutral (N); 4 = agree (A); 5 = strongly agree (SA)

Table 2: Fall 2010 exit survey

<table>
<thead>
<tr>
<th>Question</th>
<th>Avg. (N=113)</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) The clickers are easy to use.</td>
<td>4.6</td>
<td>0.7</td>
</tr>
<tr>
<td>2) The clickers worked properly during lectures.</td>
<td>3.9</td>
<td>0.9</td>
</tr>
<tr>
<td>3) The clickers worked properly during exams.</td>
<td>3.9</td>
<td>1.0</td>
</tr>
<tr>
<td>4) The clicker questions provided additional incentive to attend every class.</td>
<td>4.7</td>
<td>0.7</td>
</tr>
<tr>
<td>5) I thought using the clickers was a valuable part of this class.</td>
<td>4.4</td>
<td>0.8</td>
</tr>
<tr>
<td>6) I thought working in groups during clicker questions was beneficial.</td>
<td>4.4</td>
<td>0.9</td>
</tr>
<tr>
<td>7) I went back and added the clicker questions to my notes after class.</td>
<td>3.8</td>
<td>1.2</td>
</tr>
<tr>
<td>8) I paid more attention to the lecture knowing clicker questions would be asked.</td>
<td>4.6</td>
<td>0.7</td>
</tr>
<tr>
<td>9) I would have preferred to just have lecture and not any clicker questions.</td>
<td>2.2</td>
<td>0.7</td>
</tr>
<tr>
<td>10) I felt the clicker questions were generally too hard.</td>
<td>2.6</td>
<td>1.0</td>
</tr>
<tr>
<td>11) The points from clicker questions were not enough to motivate me to prepare for class (text reading prior to class and reviewing previous lecture material).</td>
<td>1.8</td>
<td>0.9</td>
</tr>
<tr>
<td>12) The clicker questions helped reinforce the material from the lecture.</td>
<td>4.3</td>
<td>0.7</td>
</tr>
<tr>
<td>13) I would recommend clickers for future Chem 4 classes.</td>
<td>4.4</td>
<td>0.9</td>
</tr>
<tr>
<td>14) I realized I needed to do the homework after missing clicker questions.</td>
<td>3.7</td>
<td>1.1</td>
</tr>
<tr>
<td>15) The grades I earned on the quizzes and exams accurately reflected the amount of effort I spent preparing for them.</td>
<td>3.7</td>
<td>1.1</td>
</tr>
<tr>
<td>16) The clicker questions helped identify whether I understood the lecture or not.</td>
<td>4.1</td>
<td>0.9</td>
</tr>
<tr>
<td>17) I felt the clicker questions were generally too easy.</td>
<td>2.3</td>
<td>0.8</td>
</tr>
<tr>
<td>18) I found it beneficial to get instant feedback whether I could answer the clicker questions correctly.</td>
<td>4.3</td>
<td>0.8</td>
</tr>
<tr>
<td>19) I did not review previous material for class and was not concerned about the review clicker questions.</td>
<td>1.9</td>
<td>1.0</td>
</tr>
<tr>
<td>20) I felt compelled to read the textbook prior to class knowing there would be a clicker question from the reading.</td>
<td>4.1</td>
<td>1.0</td>
</tr>
<tr>
<td>21) I found it useful to download and review the clicker questions and answers after lecture.</td>
<td>3.9</td>
<td>1.0</td>
</tr>
<tr>
<td>22) I generally did not complete the homework assignments.</td>
<td>1.6</td>
<td>1.0</td>
</tr>
<tr>
<td>23) I preferred to work alone during clicker questions.</td>
<td>2.5</td>
<td>1.2</td>
</tr>
<tr>
<td>24) The cost of the clicker was worth the expense.</td>
<td>3.6</td>
<td>1.2</td>
</tr>
<tr>
<td>25) When I answered the clicker questions correctly, I assumed I didn’t need to do the homework.</td>
<td>1.5</td>
<td>0.8</td>
</tr>
<tr>
<td>26) The clicker questions had no influence on my attendance.</td>
<td>2.0</td>
<td>1.2</td>
</tr>
<tr>
<td>27) I would like to use clickers in more of my classes.</td>
<td>3.8</td>
<td>1.1</td>
</tr>
</tbody>
</table>

The survey results indicated that clickers were simple to use and did not create any new challenges for the students (statements 1, 2, 3)( Kay and LeSage, 2009). The students also
generally felt there was a benefit from using the clickers (statements 4, 5, 8, 9, 12) and they would like to use them again in future classes (statements 13, 27) (Addison et al., 2009; Gormley-Heenan, 2009; Trees and Jackson, 2007; Uhari et al., 2003). They felt clickers provided motivation for coming to class (statements 4, 26), motivation for being more prepared when coming to class (statements 11, 19, 20) and provided useful formative assessment (statements 16, 18) ((Gormley-Heenan, 2009; Prather and Brissenden, 2009; Preszler et al., 2007; Gauci et al., 2009).

Instructor perceptions

**Question:** What are some of the changes you have noticed in the classroom environment after you started using clickers?

**Response:** When I walk into a class on a rainy Friday and I see 85%-90% of the class there, I go “Wow”, and that’s going to be contagious and have an impact. The enthusiasm really can’t be underestimated, and the importance of that enthusiasm, I think, is very contagious for the students to walk in and say, “I’m glad I’m here today.” They realize that other people are making those same choices, and that it is the norm to come to class, not an aberration. The bottom line is I get better attendance, more students see my lecture, I’m excited about giving it, and they’re excited about being there. So it is a self-fulfilling thing and it doesn’t matter where the energy comes from as long as it’s there. Can you separate that from the impact of the clicker, no, but that’s part of what clickers facilitate.

**Question:** What is one of the most significant benefits you’ve seen from using clickers?

**Response:** It’s allowed me to do things I’ve wanted to do for a long time but couldn’t. For one thing, it’s allowed me to use the clickers as a stick, by penalizing students who don’t show up to lecture. Getting students to go to class is so important.
Question: What else can you say about incorporating clickers into your teaching?

Response: Ultimately, I would love to have 85-90% pass rate. But maybe I’ve got really great attendance and students are learning that important lesson. And maybe that hasn’t paid off yet in that one semester, but it is something they’ll carry with them and will impact their retention in the program and give them some skills that they can fall back on later on when they’re struggling in other classes too. For me, those are all important goals too, not just what they scored on that final.

I think the students, even the ones that don’t pass, truly believe that this was a fair playing field, and that they were given all the resources possible to be successful. I don’t think there was a perception like they had a really bad teacher so that’s the reason they didn’t pass. But, more likely, the ones that aren’t successful might think, “Maybe this isn’t the best thing for me.” And there’s no shame in that. If you’re in a class where everyone is attending and everyone is engaged, and you still don’t feel motivated to do those things, then maybe it’s really not for you. Ultimately, there’s probably 20% of the class that this isn’t the right direction for. But I still want them to have a positive experience with college science. And if they get through it with a C, they might walk away thinking, “It’s not my strength, but also it wasn’t horrifying.” And maybe they actually enjoyed the class and learned a few things. Not everyone is going to go on and get a degree in chemistry. But I think it is good to have a positive learning experience in a science class even if that’s not the direction they go.

Analysis of first semester data

There is no definitive data suggesting student learning has been enhanced by using clickers after this first semester of using the devices. The scores on quizzes and exams during the semesters show no significant improvement when compared with historical data. There is one
promising data point, however, as student performance on the comprehensive final exam does show significant improvement. It is difficult to explain why students would perform better on the final exam than on the other exams during the semester, which was the opposite effect from historical trends. Perhaps, the students simply studied harder for the final during this semester. Or perhaps student comprehension was enhanced, and that it took the full semester for the effects to be seen. According to the constructivism learning theory discussed previously, students are continually building a framework of knowledge, and the students are developing a deeper understanding of conceptual relationships throughout the semester (Taber, 2001). It is possible that students do not immediately feel there are any benefits from using the devices, especially those who have never used them before. But as the students begin to see the benefits from actively participating, with adequate time for information processing, as well as all of the other benefits that come with using the clickers, they can begin to become more engaged in class, thus developing a more robust understanding of the topics as the semester progresses.

The attendance-performance relationship is compelling, and the clickers provide an excellent tool to implement a reward (or penalty) system for attending class (or not attending). Improved attendance, positive instructor observations and very positive student perceptions all add important considerations in the triangulation approach of determining whether it would be beneficial to continue using clickers. It has been noted in the literature that it takes time to overcome the growing pains of using clickers, to develop quality clicker questions, and successfully incorporate them into lectures (Crossgrove and Curran, 2008; Lasry, 2008; Beatty, 2004; Martyn, 2007; Kaleta and Joosten, 2007). Taking all evidence into account, it was determined that there seems to be some benefit from using clickers, and that there is opportunity to further develop their use in Chem 4 to gain more substantive results.
Changes made for second semester using clickers

Several changes were incorporated in the second semester of this study in order to maximize the benefits from using clickers. The first change involved the point structure from the clicker questions. During the first semester, clicker points were totaled and normalized to account for 7.5% of the students’ grades. For each clicker question, one point was typically awarded for a correct response while zero points were earned for incorrect responses. During the second semester, points were again normalized to account for 7.5% of the students’ grades, however students could earn points for incorrect answers. The point structure was altered so that students typically earned two points for a correct response and one point for an incorrect response. Students earned no points for not attending lecture or not providing any response to the clicker question. Thus, after seeing the strong correlation between attendance and performance from the first semester, it was decided that additional motivation to attend class, would be beneficial to student learning, even if the students had not done the homework or were otherwise not prepared for class.

At the beginning of the second semester, the instructor displayed a graph to the students, as seen in figure 10, showing the correlation between attendance and student performance based on data collected the prior semester using clickers. The data were compelling, showing a relationship suggesting that missing just a few classes during the entire semester could have a significant impact on their success in the course. The instructor discussed the importance of attendance in addition to coverage of this topic in his syllabus. Clearly, clicker data supported the additional focus placed on attendance, which was not available prior to using clickers.
The third significant change in design between semesters concerns the clicker questions used during lectures. Clicker questions and exam questions from the first semester were analyzed to identify topics with which the students were having difficulty. The clicker questions were re-written in the second semester of the study to hone in on those problem areas and provide better problems. Some questions from the first semester were clearly too easy, with a 97% correct response rate for example, and some were on the other end of the spectrum being much too difficult. In other cases, the wrong answers did not help identify what problem the students were having, so the wrong answers were re-written to help identify what led to the students’ mistakes. On some questions that were known to be difficult for students, the researcher proposed peer learning opportunities, thus providing the instructor with cues about when it might be beneficial to use extra time for alternative teaching strategies such as peer instruction. Similarly, the researcher provided historical results with the clicker questions to alert the instructor what specific mistakes might be encountered, or misconception that might need to be addressed during the discussion following a clicker question. The literature also noted that using clickers requires
instructors to be able to “think on their feet” using the formative assessment information from the clicker questions (Caldwell, 2007). Having cues based on previously collected data could help better prepare the instructor for those moments to catch and address those mistakes or misconceptions.

The fourth change during the second semester concerned a deal the instructor made with the students following the second exam. The deal was intended to provide a way for students to pass the course who were, up to that point, not passing and at risk of losing hope of passing the course, possibly resulting in more absenteeism (Jones, 1984). The deal stated that students would pass the course with a “C” regardless of total points earned for the semester if they met the following four criteria:

1) Have perfect attendance starting on the following Monday. Any excused absence must be documented.
2) Pass all three proficiency quizzes (including, if they did not pass it the first time, clearing up their first quiz during "retakes" at the end of the semester).
3) Complete all homework starting with Assignment #20 which is due the following Monday. Note that they don't have to get it all right, but must complete all assignments.
4) Earn 80% or above on Exam #3 and the final exam.

Again, this deal was facilitated by the use of clickers, using daily attendance as one criterion, which would not have been possible without clickers.

The final change implemented in the second semester was to administer more survey questions to the students to develop a better understanding of their perceptions of using clickers. Also, it was decided it would be beneficial to administer surveys at the beginning, middle and end of the semester to learn if the student perceptions changed during the semester as the students become more accustomed to using the devices.
Results from the second semester using clickers (spring 2011)

Attrition

Figure 11 illustrates the historical trend of absenteeism during the final exam over the prior six semesters and the two while using clickers. While the fall 2009 semester had the lowest attrition value at just 8%, it also had the lowest final exam pass rate at just 29%. These performance related data will be evaluated in more detail in the following sections of this study, however it is important to note that the lower attrition rates in previous semesters do not correspond with improved test scores. The black lines are error bars to one standard deviation. The spring 2011 attrition rate is significantly lower than the average, suggesting the changes made during the spring 2011 semester did indeed have an influence on attrition.

Figure 11: Final exam absenteeism through spring 2011

Spring semesters typically have higher absenteeism during the final exam than fall semesters. The possible explanation lies with the motivation or the ability of the students, as was noted by the instructor, as well as in the literature (King and Joshi, 2008). Regardless of the reason why this may be so, the trend is noted, thus making it truly impressive that the spring 2012
semester had lower absenteeism (10%) than the both preceding fall semester (15%), as well as the previous two spring semesters when clickers were not being used (15% and 28%).

**Attendance**

For the second semester of this study, there were 244 students enrolled during spring 2011 semester, again split in two sections. Figure 12 provides absenteeism data during this semester, showing that average absenteeism for the semester was reduced from 20% in the fall 2010 semester to 16% in the spring.

![Spring 2011 Absenteeism](chart)

**Figure 12: Spring 2011 daily absenteeism in Chem 4**

While a greater percentage of students were attending class during each lecture in the spring semester, a smaller percentage was chronically absent. Figure 13 shows an 8% decrease in the number of students who missed four or more lectures during the spring semester as compared with the fall semester, and conversely an 8% increase with students missing three of fewer
lectures, which corresponds to 19 students from the spring enrollment of 236. There was a 3% (7 student) increase in the number of students with zero or one absence, a 5% (12 student) increase in the number of students with one or two absences, a 4.5% (11 student) decrease in the number of students with four or five absences, a 2.5% (6 student) decrease in the number of students with six or seven absences and a 1% (2 student) decrease in students with eight or more absences. These data suggest that the very specific modifications made with the use of clickers in an attempt to improve attendance, among other goals, resulted in a positive change in student behavior between the fall and spring semesters.

![Lecture absenteeism](image)

**Figure 13: Comparison of absenteeism between fall 2010 and spring 2011**

**Attendance-Performance relationship**

Data from the spring 2011 semester show a similar trend as with the fall semester data concerning student pass rates relative to the number of absences during the semester, as seen in Figure 14, but the spring 2011 data has a different slope. While the percentage of students in each band of absenteeism is similar from one semester to the next, the overall pass rate for all bands except the “0-1 absences” is higher in the spring semester. The decrease on the “0-1” band
is minimal between semesters and is not statistically significant, thus the noteworthy trends are with the other students missing more than one class during the semester and the vast improvement in course completion with these other groups of students that compose over half of the student population. It is also interesting to note that there were ten students missing six or more classes that scored 85% or higher on the final exam. It is likely that a subset of students exists who are proficient in math or have taken high school chemistry and are already familiar with the topics covered in Chem 4. These students may take this class either as an easy “A” or “B” to boost their student grade point average while expending a minimal amount of effort. For example, a student who missed all but three lectures (or simply did not care to use their clicker all but three days and forfeit the clicker points) scored a 90% on the final exam. This phenomenon appears to skew the data in the “6-7 absences” category where there is a small population of total students containing a handful of high performers despite their low attendance.

Figure 14: Spring 2011 student pass rate in Chem 4 by absences
As seen in table 3, the students who failed the first exam during the spring semester missed, on average, more than twice as many lectures as students who passed the exam.

Table 3: Attendance and exam 1 performance during spring 2011

<table>
<thead>
<tr>
<th>Grade on exam 1</th>
<th>N</th>
<th>Average number of absences per student</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (&gt;90%)</td>
<td>60</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>B (80-90%)</td>
<td>53</td>
<td>0.6</td>
<td>1.1</td>
</tr>
<tr>
<td>C (73-80%)</td>
<td>42</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Fail (&lt;73%)</td>
<td>89</td>
<td>1.3</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Table 3 does not, by itself, clarify whether students failed because they missed more classes or because they had poorer study habits. However, the downward spiral theory of Jones (1984), noted in the literature review, is evident from this study. Table 4 shows the number of absences following exam 1 for groups of students based on exam 1 performance.

Table 4: Attendance after exam 1 during spring 2011

<table>
<thead>
<tr>
<th>Grade on exam 1</th>
<th>N</th>
<th>Average number of absences per student between exam 1 and exam 2</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (&gt;90%)</td>
<td>60</td>
<td>1.1</td>
<td>2.0</td>
</tr>
<tr>
<td>B (80-90%)</td>
<td>53</td>
<td>1.3</td>
<td>1.8</td>
</tr>
<tr>
<td>C (73-80%)</td>
<td>42</td>
<td>1.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Fail (&lt;73%)</td>
<td>89</td>
<td>2.5</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Absenteeism for students who passed exam 1 was an average of 1.3 lectures per student for the period between the first and second exam, while it was 2.5 lectures per student, on average, for the students that failed the first exam. Similarly, the average absenteeism between the second and third exam for students who passed exam 2 was 1.2 lectures per student, while it was 1.7 for those who failed exam 2. It is important to reiterate that the deal the instructor made with the students likely had an effect on the absenteeism following the second exam, as it is seen to decrease for all students, including those failing the exams.
In comparing a similarly performing pool of students from the first exam, all students who earned a “C” on exam 1 (N=42) were split into two groups; the students who then passed exam 2 missed an average of 1.0 lectures per student following the second exam for the period between the second and third exam. Those who failed exam 2 missed an average of 1.3 classes per student for the same time period. In all cases evaluated, absenteeism was greater for the students who failed as opposed to the students who passed, regardless of previous absenteeism or grade performance, when comparing groups of students with similar performance prior to taking the exam. This downward spiraling theory between attendance and performance (Jones, 1984), combined with the idea that concepts in chemistry continually build on each other (Taber, 2001), lead to a conclusion that once students start to fail, it is increasingly difficult to recover and pass the course. An analysis of student performance on the first exam with those who fail the final exam in the spring 2011 semester, as seen in figure 15, shows the likelihood of failing the final exam is inversely related to the student’s performance on the first exam in a somewhat logarithmic fashion. The likelihood of a student who earned a “C” on the first exam to fail the final exam is nearly twice that of a student who earned a “B” on the first exam.

![Figure 15: Spring 2011 exam 1 performance and passing the final exam](image-url)
Performance on quizzes

Figure 16 shows the percentage of students passing each quiz for two semesters before clickers were implemented (fall 2009 and spring 2010) and the two subsequent semesters when clickers were used (fall 2010 and spring 2011). Only during the spring 2011 semester did 70% or more of students pass each of the three quizzes. The percentage of students passing the quizzes also increased throughout the semester.

Figure 16: Historical pass rate on proficiency quizzes

Performance on exams

As previously mentioned three exams and a final are typically given each semester with a minimum grade of 73% required to pass. Figure 17 shows the percentage of students passing each exam for six semesters prior to implementing clickers, and the two semesters clickers were used (fall 2010 and spring 2011).
There was improvement in the percentage of students passing all exams, including the final, during the spring 2011 semester compared with prior semesters, with the exception of exam 2. There is no clear understanding why the number of students who passed this exam decreased from prior semesters as the exam had similar questions with similar levels of difficulty with exams from prior semesters. Perhaps students became overconfident after having such success on the first exam and reduced their study habits. After the drop in performance on the second exam, however, there was a sharp rise in the percentage of students who passed the third exam. Using the possible explanation of students becoming overconfident after the first exam, it would follow that the second exam was a “wake-up call”, and the students subsequently improved their study habits or their engagement in class, resulting in the high scores on the third exam. This see-saw pattern of pass rates can be seen in most semesters, and it is interesting that not all start high, go low and then increase again. For example, the fall 2010 semester starts with low performance on the first exam, jumps up in the second exam, and then falls again on the third. The relative change in student performance on the first two exams is not statistically significant, however the
improvement seen on the third exam and the final exam during the spring 2011 semester is statistically significant with gains of greater than one standard deviation above the historical average.

Looking more closely at just the final exam, figure 18 shows average student scores on the final exam for the six semesters prior to using clickers and the two semesters when clickers were used, as shown as the solid bars, in addition to the absenteeism, as shown by the solid line.

Figure 18: Final exam performance and absenteeism

An important trend that is seen in the semesters prior to using clickers is that as absenteeism decreases, so do the average scores. When more students remained in the class for the entire semester and took the final exam, the average scores dropped. For example, in the spring 2008 semester there was a high average score on the final exam (73.0%), however there was 28% absenteeism on the final; only the strong students took the final, thus biasing the average score. Similarly, the fall 2009 semester had a very low average score (64.1%) while also having very
low absenteeism (8%); students who were failing the course remained to take the final, resulting in a lower average score. The results for the final exam while using clickers show the opposite effect, however. The most significant results are seen in the spring 2011 semester with very low absenteeism (10%), yet with a very high average score (75.3%). More students remained in the class to take the final exam, but instead of bringing the average down, the average scores improved significantly relative to the historical average.

While more students passed the final exam during the two semesters when clickers were used compared with all prior semesters and the average student score increased, the distribution of grades also shows a significant increase in A’s and B’s earned, with a decrease in C’s earned and number of students who did not pass, as shown in Figure 19 below. Students were failing less, and they were not just squeaking by, but they were succeeding with higher scores when clickers were used, as was also seen in the published literature (Knight and Wood, 2005).

Figure 19: Historical final exam grade distribution
A second view of this data is shown in Figure 20, omitting the failing grades so as to provide a more detailed view of the letter grades earned.

![Figure 20: Final exam grade distribution without failing grades](image)

**Student pass rates**

In addition to a decrease in attrition, as noted in the previous section, another effect of improved student performance on each of the exams was an increase in the number of students passing the course. Figure 21 shows the percentage of students who took the final exam that passed the course for six semesters prior to using clickers and the two semesters with clickers. The spring 2011 semester jumped to 69% relative to a historical average of 55%, or a 14% improvement over the historical average. The percentage of students passing the course in the spring 2011 semester is statistically relevant with a $t_{calc}$ value of 3.82 compared with the student $t$ value of 2.35, strongly suggesting that changes in course design influenced the outcome of more students passing the course.
Student attitudes

Based on the survey response rate and results from the fall 2010 semester, it was decided that it would be useful to make some changes for the fall semester. Specifically, a pre-survey would be useful to identify attitudes prior to using the clickers, then to assess how the students felt about using them after the first exam so as to understand how they felt about the usefulness of the clickers in preparing them for the exam. It was also decided that it would be useful to gain some deeper insights by deviating from the standard 5-point response method by asking some ad hoc questions throughout the semester.

The pre-survey given in the spring 2011 semester had 220 responses of 244 total students enrolled in the course, with 121 students responding that they had never used clickers before. Table 5 summarizes the average results with the standard deviation for each question.
Table 5: Spring 2011 pre-survey results

<table>
<thead>
<tr>
<th>Statement</th>
<th>Avg (N=220)</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) I have used clickers before in my classes (circle “3” if you have never used clickers).</td>
<td>3.6</td>
<td>1.0</td>
</tr>
<tr>
<td>2) I liked using clickers in my other classes (circle “3” if you have never used clickers).</td>
<td>3.8</td>
<td>1.3</td>
</tr>
<tr>
<td>3) Knowing we will have clicker questions will help motivate me to attend lecture.</td>
<td>4.4</td>
<td>0.8</td>
</tr>
<tr>
<td>4) I think it will be important to attend every CHM 4 lecture.</td>
<td>4.8</td>
<td>0.4</td>
</tr>
<tr>
<td>5) I often get bored during lectures.</td>
<td>2.9</td>
<td>1.0</td>
</tr>
<tr>
<td>6) Using clickers will motivate me to complete the assigned readings before each class.</td>
<td>4.4</td>
<td>0.8</td>
</tr>
<tr>
<td>7) I am more likely to attend class if it is part of my grade.</td>
<td>4.5</td>
<td>0.8</td>
</tr>
<tr>
<td>8) I am not looking forward to using clickers in CHM 4.</td>
<td>2.4</td>
<td>1.0</td>
</tr>
<tr>
<td>9) I prefer classes with more student interaction and discussion.</td>
<td>3.6</td>
<td>1.0</td>
</tr>
<tr>
<td>10) Using clickers will help motivate me to keep up with the material on a daily basis.</td>
<td>4.3</td>
<td>0.7</td>
</tr>
<tr>
<td>11) I prefer classes that emphasize lecturing over student participation.</td>
<td>3.2</td>
<td>1.1</td>
</tr>
<tr>
<td>12) I sometimes skip lectures in classes that are boring.</td>
<td>2.1</td>
<td>1.0</td>
</tr>
<tr>
<td>13) I only complete all of the homework on time if it is worth points towards my grade.</td>
<td>2.6</td>
<td>1.3</td>
</tr>
<tr>
<td>14) I like to work in small groups when working on in-class problems.</td>
<td>3.5</td>
<td>1.1</td>
</tr>
<tr>
<td>15) I plan to complete the assigned textbook readings prior to each lecture.</td>
<td>4.6</td>
<td>0.6</td>
</tr>
<tr>
<td>16) Missing a few classes will probably not affect my grade for this course.</td>
<td>1.6</td>
<td>0.9</td>
</tr>
<tr>
<td>17) I am looking forward to using clickers in CHM 4.</td>
<td>3.6</td>
<td>0.9</td>
</tr>
<tr>
<td>18) I usually don’t read the assigned textbook readings in my classes.</td>
<td>1.9</td>
<td>0.8</td>
</tr>
<tr>
<td>19) I like to have practice problems during class so I can know how I am doing.</td>
<td>4.2</td>
<td>0.8</td>
</tr>
<tr>
<td>20) I often have difficulty paying attention during my classes.</td>
<td>2.6</td>
<td>1.0</td>
</tr>
<tr>
<td>21) I think I would earn a higher grade if I attended every CHM 4 lecture.</td>
<td>4.7</td>
<td>0.6</td>
</tr>
<tr>
<td>22) I prefer to work alone when working on in-class problems.</td>
<td>2.9</td>
<td>1.1</td>
</tr>
<tr>
<td>23) I do not think that using clickers will help motivate me to attend lecture.</td>
<td>2.0</td>
<td>0.8</td>
</tr>
<tr>
<td>24) I typically review my notes from the previous lecture before each class.</td>
<td>3.3</td>
<td>0.9</td>
</tr>
<tr>
<td>25) I was upset about spending money to purchase/rent and register my CHM 4 clicker.</td>
<td>2.8</td>
<td>1.1</td>
</tr>
</tbody>
</table>

The survey was given on the third lecture date after the instructor had reviewed the syllabus and shown data from the fall semester regarding the importance of attending every class. Based on the survey results, the students recognized the importance of attending class (statement 4, 16) and felt there would be a motivational benefit from using clickers in this class (statement 3, 6, 10, 23). Students only slightly agreed with statement 17, “I am looking forward to using clickers” with an average response of 3.6, even though recognizing that attending every class was important (statement 7 with a response of 4.5) and that clickers would provide extra motivation for attending class (statement 3 with a response of 4.4) and keeping up with the material (statement 10 with a response of 4.3). Of the 187 students who strongly agreed that it was
important to attend every class (statement 4 with a response of 5) only 102 students missed zero or one lecture during the semester. It appears some students understand what is needed to be successful, yet lack the discipline to follow through and consistently make the best choices for their education.

A survey with the same format was given after the first exam. There were 131 student responses out of the 244 students enrolled, with the results shown in table 6. There was strong agreement that the clickers provided motivation for coming to class prepared (statement 2, 8, 15, 23) and that attending class was still considered important towards their success in Chem 4 (statement 17). The students also agreed that the clicker questions helped prepare them for the exam (statement 27). The idea of clickers making class more fun, as suggested in the literature (Caldwell, 2007), is seen as less of an influence (statement 7), with an average response of 3.6, however students agreed that it was easier to pay attention in Chem 4 compared with other classes (statement 12). The strongest responses were concerned with the points affecting their grade (statement 2, 8) and the formative assessment of their level of understanding with the lecture material (statement 22).
There are a few comparisons between the pre-survey and the exam post survey that stand out. Students anticipated the clicker questions would provide motivation for attending every class (statement 3), and their attitudes after the first exam acknowledged this (statement 2). They also reaffirmed their position that missing a few lectures would harm their grade (statement 16 on the
pre survey and statement 19 on the post survey). One question where responses only slightly changed was in the statement, “I like to have practice problems during class so I know how I am doing.” The pre survey average response was 4.2 with a standard deviation of 0.8, and after the exam, the average response increased to 4.4 with a standard deviation of 0.6, indicating the students saw a benefit from the clicker questions used in class. The students’ perception of whether the money spent on the clickers was worthwhile increased (statement 25 on the pre survey and statement 29 on the post survey) as was their overall reception of using clickers; the pre survey question stating, “I am looking forward to using clickers in Chem 4” had a score of 3.6 while the first statement on the post exam survey, “I like using clickers in Chem 4” had an average response of 4.1.

Based on survey results additional questions were asked during lectures throughout the semester in order to obtain a better understanding of student motivation and behaviors. On 3/4/2011, at the end of the sixth week of the semester, students were asked a question regarding their motivation for coming to class, with the percentage of student responses shown below:

Which of the following provides the most incentive for coming to CHM4 classes? (N=191)
A) I am on campus anyways and have nothing better to do. (2%)
B) To earn points from clicker questions. (19%)
C) Hearing the lecture will help me learn the material. (31%)
D) To see friends. (0%)
E) I believe missing classes will lower my chances for passing the next test. (27%)
F) To see how well I understand the material on the clicker questions. (6%)
G) I’m paying for the class so it would be a waste of money not to attend. (3%)
H) I enjoy the class. (9%)
I) My strongest incentive is not listed above. (3%)

The students still agreed that attending class was important to learn the material and that points earned from clicker questions was motivating many to come to class. On 3/11/2011, at the end of the seventh week of class, the following survey question was asked two times to gain insight into the students’ perception of their top two perceived factors contributing to their success in this
course. The percentage of responses reported is consolidated totals from both sets of responses.

The highest percentage response was that they needed to attend class every day:

Which of the following do you believe is the most important contributor to student success in CHM 4? (N=375)

A) Taking good notes during lecture (10%)
B) Reviewing lecture notes before the exam (2%)
C) Working on practice exams before the exam (18%)
D) Reviewing clicker questions before the exam (1%)
E) Doing homework problems every week (16%)
F) Reviewing lecture notes regularly every week (5%)
G) Reading the assigned textbook each day before class (9%)
H) Being in class every day (37%)
I) Other (1%)

An interesting point is that students saw greater value from working on practice exams than reviewing the clicker questions given in lecture. The survey questions given were designed to understand what specific benefits from using clickers students believed were most significant to their education.

The following question was again asked two times so that students may provide their top two responses, with reported percentage of responses again being the combined total from both sets of responses:

Based on your personal experience in this class, what do you feel is the most significant benefit from using the clickers? (N=378)

A) Tells the instructor how well students are doing or if they are getting the new material. (12%)
B) Tells you, the student, how well you are doing on questions important to the instructor. (25%)
C) Helps keep you awake during class. (1%)
D) The points earned from clicker questions provide motivation for coming to class. (24%)
E) Using the clickers makes the class more personal and engaging. (6%)
F) Provides practice problems to solve while learning new material. (24%)
G) Stimulates discussion with classmates when you are allowed to work together on questions. (5%)
H) Other (1%)

The top three choices, and they were all close in scores, were points earned, feedback to their learning, and providing practice problems. It is interesting that the students place such high value
on practice problems when homework was assigned after every lecture. From the survey questions given on 3/11/2011 noted earlier, 40% of the students ranked doing homework regularly as one of the top two contributors to success. This might imply that students see an increased benefit from doing practice problems while they are learning the material as opposed to waiting until a later time when they complete their homework assignments. As seen before from the previous survey, the idea of making class more fun and engaging ranks considerably lower than the top three choices, and is not perceived as a significant benefit.

The literature cited indicates the amount of points earned from clicker questions is an important aspect by providing ample incentive for students to fully participate and realize the benefits of using clickers (Caldwell, 2007). In this class the points earned from clicker questions was worth 7.5% of the students’ final grade, which is lower than the 15% recommended by Caldwell (2007). The following survey question evaluated the students’ perception of the point total from clickers:

This semester, points from clicker questions are worth about 7.5% of your total grade. Select the answer that you agree with most. (N=176)
A) I think clicker points should not count towards my final grade. (3%)
B) I think clicker points should count, but be less than the current 7.5% of my final grade. (28%)
C) I think clicker points are just right at 7.5% of my final grade (32%)
D) I think the clicker points should be 10% of my final grade. (20%)
E) I think clicker points should be 15% of my final grade. (4%)
F) I think clicker points should be 20% or more of my final grade. (9%)
G) I don’t think we should be using clickers in this class. (1%)
H) Other (2%)

While the vast majority of students agreed that clicker points provided incentive for attending class, and that attending class is important for their success, roughly a third of the students thought the clicker points should not impact their grade as much as 7.5%. This may provide another example of the idea that students may understand what they need in order to be successful yet are not making the choices or sacrifices to follow through. A new point format
was implemented in the spring in which students often could earn two points for answering the question correctly and one point for effort if they answered incorrectly, as opposed to the point system used in the fall semester whereby there were no points awarded for a wrong answer. The idea for the change was to provide incentive for attending class, even if unprepared. It is interesting to note that there was a change in attitude from the final surveys given at the end of each semester. The statement, “The clicker questions had no influence on my attendance” was given in each semester’s final survey and the average response changed from 2.0 in the fall semester to 2.3 in the spring semester. Similarly, the statement, “The points from clicker questions were not enough to motivate me to prepare for class…” also changed; average response was 1.8 in the fall and 2.1 in the spring. Apparently, the students were more motivated by the clicker points in the fall semester when it was an ‘all or nothing’ scenario to both attend class, and attend more prepared. A second question was asked regarding the student attitudes regarding this format of the point system for the clicker questions:

*In terms of earning points for clicker questions…*(N=176)

A) I like getting 1 point for effort and 2 points for a correct answer.  
(72%)

B) I think there should be no points for effort; 1 point for correct and 0 points for incorrect responses.  
(2%)

C) I think there should only be 1 point for effort and no penalty for wrong answers.  
(23%)

D) I don’t think there should be any points for clicker question.  
(0%)

E) None of these reflects my opinion.  
(2%)

While the majority of the students like this new system for rewarding attendance and placing less emphasis on correct answers, 23% of the students believe clicker points should be based solely on attendance. This, again, shows the paradigm of students knowing what is best for them but choosing, or wanting, something else that provides an easier short term path.

The exit survey, as shown in Table 7, given at the end of the semester had 131 responses and 27 written comments. Of the twenty-seven written comments, ten praised the use of clickers and had positive feedback, four questioned the point system, four questioned their use on exams
and the remaining covered various other student perceptions, histories and anecdotes. The final survey revealed a very high agreement that the clickers worked properly during the exams (statement 2 with an average response of 4.4), revealing that this became less of a concern by the end of the course than it was from the first exam (statement 6 on exam post survey). There is likely some uneasiness for students using a new system that had not previously been used. This uneasiness seems to have been overcome by the end of the semester. The remaining survey responses reinforce previous assessments as well as the literature reviews in that the students enjoyed using the clickers (statement 5, 10), would recommend them for future classes (statement 16), and saw multiple benefits from their use (statement 4, 9, 13, 19, 24).
Table 7: Spring exit survey results

<table>
<thead>
<tr>
<th>Statement</th>
<th>Avg (N=134)</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) The clickers are easy to use.</td>
<td>4.8</td>
<td>0.5</td>
</tr>
<tr>
<td>2) The clickers worked properly during lectures.</td>
<td>4.4</td>
<td>0.7</td>
</tr>
<tr>
<td>3) The clickers worked properly during exams.</td>
<td>4.5</td>
<td>0.6</td>
</tr>
<tr>
<td>4) The clocker questions provided additional incentive to attend every class.</td>
<td>4.6</td>
<td>0.6</td>
</tr>
<tr>
<td>5) I thought using the clickers was a valuable part of this class.</td>
<td>4.4</td>
<td>0.7</td>
</tr>
<tr>
<td>6) I thought working in groups during clicker questions was beneficial.</td>
<td>4.3</td>
<td>0.9</td>
</tr>
<tr>
<td>7) The clicker points should count less toward my grade.</td>
<td>2.8</td>
<td>1.2</td>
</tr>
<tr>
<td>8) I went backed and added the clicker questions to my notes after class.</td>
<td>3.5</td>
<td>1.2</td>
</tr>
<tr>
<td>9) I paid more attention to the lecture knowing clocker questions would be asked.</td>
<td>4.1</td>
<td>0.9</td>
</tr>
<tr>
<td>10) I would have preferred to just have lecture and not any clicker questions.</td>
<td>2.0</td>
<td>0.9</td>
</tr>
<tr>
<td>11) I felt the clocker questions were generally too hard.</td>
<td>2.3</td>
<td>0.9</td>
</tr>
<tr>
<td>12) The points from clicker questions were not enough to motivate me to prepare for class (text reading prior to class and reviewing previous lecture material).</td>
<td>2.1</td>
<td>1.0</td>
</tr>
<tr>
<td>13) The clocker questions helped reinforce the material from the lecture.</td>
<td>4.4</td>
<td>0.7</td>
</tr>
<tr>
<td>14) I would attend more classes if clocker points were a higher percentage of my grade.</td>
<td>3.4</td>
<td>1.2</td>
</tr>
<tr>
<td>15) I think I would have done better in CHM 4 if I had stronger study skills.</td>
<td>3.4</td>
<td>1.2</td>
</tr>
<tr>
<td>16) I would recommend clockers for future Chem 4 classes.</td>
<td>4.3</td>
<td>0.8</td>
</tr>
<tr>
<td>17) I realized I needed to do the homework after missing clicker questions.</td>
<td>3.6</td>
<td>1.0</td>
</tr>
<tr>
<td>18) The grades I earned on the quizzes and exams accurately reflected the amount of effort I spent preparing for them.</td>
<td>3.6</td>
<td>1.2</td>
</tr>
<tr>
<td>19) The clocker questions helped identify whether I understood the lecture or not.</td>
<td>4.2</td>
<td>0.8</td>
</tr>
<tr>
<td>20) I felt the clocker questions were generally too easy.</td>
<td>2.4</td>
<td>0.9</td>
</tr>
<tr>
<td>21) I found it beneficial to get instant feedback whether I could answer the clocker questions correctly.</td>
<td>4.3</td>
<td>0.8</td>
</tr>
<tr>
<td>22) I would miss more classes if there were no clocker points that affected my grade.</td>
<td>2.8</td>
<td>1.3</td>
</tr>
<tr>
<td>23) I did not review previous material for class and was not concerned about the review clocker questions.</td>
<td>2.1</td>
<td>0.9</td>
</tr>
<tr>
<td>24) I felt compelled to read the textbook prior to class knowing there would be a clocker question from the reading.</td>
<td>4.1</td>
<td>1.0</td>
</tr>
<tr>
<td>25) I found it useful to download and review the clocker questions/answers after lecture.</td>
<td>3.9</td>
<td>1.0</td>
</tr>
<tr>
<td>26) I found the time management, note taking, and exam correction worksheets that Jeff posted on the CHM 4 website to be useful.</td>
<td>4.1</td>
<td>1.0</td>
</tr>
<tr>
<td>27) I generally did not complete the homework assignments.</td>
<td>1.7</td>
<td>1.0</td>
</tr>
<tr>
<td>28) I preferred to work alone during clicker questions.</td>
<td>2.6</td>
<td>1.0</td>
</tr>
<tr>
<td>29) The cost of the clocker was worth the expense.</td>
<td>3.6</td>
<td>1.0</td>
</tr>
<tr>
<td>30) When I answered the clocker questions correctly, I assumed I didn’t need to do the homework.</td>
<td>1.8</td>
<td>0.9</td>
</tr>
<tr>
<td>31) The clocker questions had no influence on my attendance.</td>
<td>2.3</td>
<td>1.2</td>
</tr>
<tr>
<td>32) I would like to use clockers in more of my classes.</td>
<td>3.8</td>
<td>1.2</td>
</tr>
</tbody>
</table>

The idea that the cost of the clickers was worth the expense remained constant between the exam post survey and the final survey with an average response of 3.6. One of the significant changes in students’ attitudes by the end of the semester relates to clickers helping keep students’ attention during lectures. The exam post survey had an average response of 3.6 to the statement,
“Using clickers helps keep me interested during Chem 4 lectures” (statement 7). On the final survey, however, the students average response was 4.1 to the statement, “I paid more attention to the lecture knowing clicker questions would be asked” (statement 9). This perception that the points earned from the clicker questions was significant, and combined with the other perceived benefits previously mentioned, it is not surprising the students arrived at the conclusion that they wanted to pay more attention in lecture!

**Performance-attitude relationship**

An evaluation of survey responses by grade earned on the first exam illustrates some interesting differences in student attitudes and behaviors. Table 8 shows the student average response from each grade earned on the exam from the spring 2010 post exam 1 survey. As is consistent with the literature (Preszlet et al., 2007), the results show the students who earned an A on the exam saw more benefit from the clickers than the other students (statements 2, 13, 15, 16). They also understood the importance of coming to class prepared (statement 3, 8, 15, 23, 24). The “A” students more regularly reviewed the clicker questions, and added those questions to their lecture notes, and they noticed there were exam questions that were very similar to the clicker questions. Nine of the exam questions were related to clicker questions posed during lectures.
Table 8: Spring post-exam survey results by grade earned

<table>
<thead>
<tr>
<th>Question</th>
<th>A (N=9)</th>
<th>B (N=51)</th>
<th>C (N=32)</th>
<th>Fail (N=37)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) I like using clickers in CHM 4.</td>
<td>4.1</td>
<td>4.3</td>
<td>3.9</td>
<td>4.0</td>
</tr>
<tr>
<td>2) Knowing we have clicker questions that count toward my final grade motivates me to attend lecture in CHM 4.</td>
<td>4.8</td>
<td>4.6</td>
<td>4.5</td>
<td>4.4</td>
</tr>
<tr>
<td>3) I work on CHM 4 (reading, homework, reviewing notes, studying, etc.) outside of class at least 5 days each week.</td>
<td>4.3</td>
<td>4.1</td>
<td>3.9</td>
<td>3.7</td>
</tr>
<tr>
<td>4) Using the clickers is too complicated.</td>
<td>1.6</td>
<td>1.5</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>5) I had to cram to prepare for Exam #1 in CHM 4.</td>
<td>2.0</td>
<td>1.8</td>
<td>2.2</td>
<td>2.6</td>
</tr>
<tr>
<td>6) I would prefer to not use clickers on future exams in CHM 4.</td>
<td>2.0</td>
<td>2.0</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>7) Using clickers helps keep me interested during CHM 4 lectures.</td>
<td>3.7</td>
<td>3.7</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>8) I am motivated to complete the assigned readings before each class because I know there will be clicker questions about the reading that will impact my grade.</td>
<td>4.6</td>
<td>4.4</td>
<td>4.4</td>
<td>4.3</td>
</tr>
<tr>
<td>9) After answering a clicker question, I like seeing how the rest of the class responded to the question (when the instructor shows the bar graph results).</td>
<td>4.8</td>
<td>4.4</td>
<td>4.1</td>
<td>4.4</td>
</tr>
<tr>
<td>10) I regularly review the clicker questions from class and add them to my notes.</td>
<td>4.4</td>
<td>3.7</td>
<td>3.4</td>
<td>3.8</td>
</tr>
<tr>
<td>11) I like that clicker questions count toward my overall course grade in CHM 4.</td>
<td>3.8</td>
<td>4.1</td>
<td>3.9</td>
<td>3.9</td>
</tr>
<tr>
<td>12) I find it easier to pay attention in CHM 4 over my other classes.</td>
<td>4.1</td>
<td>3.9</td>
<td>3.7</td>
<td>3.9</td>
</tr>
<tr>
<td>13) Using the clickers has no benefit on my learning in CHM 4.</td>
<td>1.4</td>
<td>2.0</td>
<td>2.1</td>
<td>2.2</td>
</tr>
<tr>
<td>14) I prefer working on clicker questions with other people.</td>
<td>4.1</td>
<td>3.5</td>
<td>3.3</td>
<td>3.4</td>
</tr>
<tr>
<td>15) Using clickers helps motivate me to keep up with the material on a daily basis.</td>
<td>4.6</td>
<td>4.3</td>
<td>4.1</td>
<td>4.1</td>
</tr>
<tr>
<td>16) I would prefer just lecture and no clickers in CHM 4.</td>
<td>1.8</td>
<td>1.9</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>17) I sometimes skip lectures in the classes that I find boring (any class, not just CHM 4.)</td>
<td>1.9</td>
<td>1.9</td>
<td>2.3</td>
<td>1.9</td>
</tr>
<tr>
<td>18) I prefer to work alone when working on clicker questions.</td>
<td>2.1</td>
<td>2.6</td>
<td>3.2</td>
<td>2.7</td>
</tr>
<tr>
<td>19) Missing a few classes will probably not affect my grade in CHM 4.</td>
<td>1.6</td>
<td>1.5</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>20) Using clickers in CHM 4 makes it easier to answer questions in class (compared to raising my hand, for example).</td>
<td>4.1</td>
<td>4.2</td>
<td>4.1</td>
<td>3.9</td>
</tr>
<tr>
<td>21) In CHM 4, I would get a lot more clicker questions wrong if I didn’t get to use my notes/textbook.</td>
<td>2.9</td>
<td>3.0</td>
<td>3.2</td>
<td>3.5</td>
</tr>
<tr>
<td>22) I like to have practice problems during class so I can know how I am doing.</td>
<td>4.3</td>
<td>4.5</td>
<td>4.3</td>
<td>4.5</td>
</tr>
<tr>
<td>23) I come to CHM 4 class more prepared than my other classes which do not use clickers.</td>
<td>4.1</td>
<td>3.9</td>
<td>3.7</td>
<td>3.8</td>
</tr>
<tr>
<td>24) I typically review my notes from the previous lecture before each class.</td>
<td>3.9</td>
<td>3.4</td>
<td>3.5</td>
<td>3.4</td>
</tr>
<tr>
<td>25) Using clickers for the exam made the exam more stressful.</td>
<td>2.6</td>
<td>2.5</td>
<td>2.9</td>
<td>3.0</td>
</tr>
<tr>
<td>26) In CHM 4, having time to discuss clicker questions with other students has helped me understand the material.</td>
<td>4.0</td>
<td>3.7</td>
<td>3.4</td>
<td>4.1</td>
</tr>
<tr>
<td>27) The clicker questions during class helped prepare me for the exam.</td>
<td>4.6</td>
<td>4.0</td>
<td>4.2</td>
<td>3.9</td>
</tr>
<tr>
<td>28) I recognized some of the exam questions from previous clicker questions.</td>
<td>4.4</td>
<td>3.6</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>29) I think the money to purchase/rent and register my CHM 4 clicker was worth it.</td>
<td>4.3</td>
<td>3.6</td>
<td>3.5</td>
<td>3.6</td>
</tr>
</tbody>
</table>
The results from the final course survey given at the end of the spring semester were evaluated by the students’ final course grade, shown in Table 9. A trend of survey response is often observed on many of the survey statements from the A students, to the B students, and so on. In most cases, the higher performing students saw greater value and enjoyed using the clickers more than the lower performing students (statements 4, 5, 10, 13, 16, 19, 24, 29, 32). Similarly, the study behaviors between the differently performing groups of students are also confirmed (statement 24, 25, 27). Students who earned a C, or failed the exam thought they would attend more classes if the clicker points were worth a higher percentage of their grade (statement 14). However, they felt less compelled to read the textbook and recognized that they lacked the study skills necessary to achieve higher grades (statements 12, 15). They also saw less benefit from using clickers, in general (statements 5, 19, 29, 32).
Table 9: Spring exit survey results by course grade

<table>
<thead>
<tr>
<th>Statement</th>
<th>A (N=12)</th>
<th>B (N=54)</th>
<th>C (N=32)</th>
<th>Fail (N=36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) The clickers are easy to use.</td>
<td>5.0</td>
<td>4.8</td>
<td>4.8</td>
<td>4.7</td>
</tr>
<tr>
<td>2) The clickers worked properly during lectures.</td>
<td>4.6</td>
<td>4.4</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td>3) The clickers worked properly during exams.</td>
<td>4.8</td>
<td>4.6</td>
<td>4.5</td>
<td>4.4</td>
</tr>
<tr>
<td>4) The clicker questions provided additional incentive to attend every class.</td>
<td>4.8</td>
<td>4.6</td>
<td>4.4</td>
<td>4.5</td>
</tr>
<tr>
<td>5) I thought using the clickers was a valuable part of this class.</td>
<td>4.7</td>
<td>4.4</td>
<td>4.5</td>
<td>4.3</td>
</tr>
<tr>
<td>6) I thought working in groups during clicker questions was beneficial.</td>
<td>4.5</td>
<td>4.2</td>
<td>4.4</td>
<td>4.4</td>
</tr>
<tr>
<td>7) The clicker points should count less toward my grade.</td>
<td>2.6</td>
<td>2.9</td>
<td>2.7</td>
<td>3.0</td>
</tr>
<tr>
<td>8) I went back and added the clicker questions to my notes after class.</td>
<td>3.8</td>
<td>3.4</td>
<td>3.3</td>
<td>3.6</td>
</tr>
<tr>
<td>9) I paid more attention to the lecture knowing clicker questions would be asked.</td>
<td>4.0</td>
<td>4.1</td>
<td>4.1</td>
<td>4.0</td>
</tr>
<tr>
<td>10) I would have preferred to just have lecture and not any clicker questions.</td>
<td>1.8</td>
<td>1.9</td>
<td>1.8</td>
<td>2.3</td>
</tr>
<tr>
<td>11) I felt the clicker questions were generally too hard.</td>
<td>2.3</td>
<td>2.0</td>
<td>2.4</td>
<td>2.6</td>
</tr>
<tr>
<td>12) The points from clicker questions were not enough to motivate me to prepare for class (text reading prior to class and reviewing previous lecture material).</td>
<td>1.8</td>
<td>2.0</td>
<td>2.1</td>
<td>2.2</td>
</tr>
<tr>
<td>13) The clicker questions helped reinforce the material from the lecture.</td>
<td>4.8</td>
<td>4.4</td>
<td>4.4</td>
<td>4.2</td>
</tr>
<tr>
<td>14) I would attend more classes if clicker points were a higher percentage of my grade.</td>
<td>2.9</td>
<td>3.2</td>
<td>3.7</td>
<td>3.5</td>
</tr>
<tr>
<td>15) I think I would have done better in CHM 4 if I had stronger study skills.</td>
<td>2.8</td>
<td>3.1</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td>16) I would recommend clickers for future Chem 4 classes.</td>
<td>4.7</td>
<td>4.4</td>
<td>4.3</td>
<td>4.2</td>
</tr>
<tr>
<td>17) I realized I needed to do the homework after missing clicker questions.</td>
<td>3.7</td>
<td>3.6</td>
<td>3.6</td>
<td>3.8</td>
</tr>
<tr>
<td>18) The grades I earned on the quizzes and exams accurately reflected the amount of effort I spent preparing for them.</td>
<td>4.5</td>
<td>3.9</td>
<td>3.6</td>
<td>2.9</td>
</tr>
<tr>
<td>19) The clicker questions helped identify whether I understood the lecture or not.</td>
<td>4.3</td>
<td>4.3</td>
<td>4.2</td>
<td>4.0</td>
</tr>
<tr>
<td>20) I felt the clicker questions were generally too easy.</td>
<td>1.8</td>
<td>2.4</td>
<td>2.5</td>
<td>2.3</td>
</tr>
<tr>
<td>21) I found it beneficial to get instant feedback whether I could answer the clicker questions correctly.</td>
<td>4.8</td>
<td>4.2</td>
<td>4.5</td>
<td>4.3</td>
</tr>
<tr>
<td>22) I would miss more classes if there were no clicker points that affected my grade.</td>
<td>3.1</td>
<td>2.9</td>
<td>2.7</td>
<td>2.6</td>
</tr>
<tr>
<td>23) I did not review previous material for class and was not concerned about the review clicker questions.</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>24) I felt compelled to read the textbook prior to class knowing there would be a clicker question from the reading.</td>
<td>4.6</td>
<td>4.2</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>25) I found it useful to download and review the clicker questions/answers after lecture.</td>
<td>4.2</td>
<td>3.9</td>
<td>3.9</td>
<td>3.8</td>
</tr>
<tr>
<td>26) I found the time management, note taking, and exam correction worksheets that Jeff posted on the CHM 4 website to be useful.</td>
<td>4.3</td>
<td>4.1</td>
<td>4.1</td>
<td>4.1</td>
</tr>
<tr>
<td>27) I generally did not complete the homework assignments.</td>
<td>1.3</td>
<td>1.7</td>
<td>1.7</td>
<td>1.9</td>
</tr>
<tr>
<td>28) I preferred to work alone during clicker questions.</td>
<td>2.7</td>
<td>2.8</td>
<td>2.7</td>
<td>2.3</td>
</tr>
<tr>
<td>29) The cost of the clicker was worth the expense.</td>
<td>4.3</td>
<td>3.7</td>
<td>3.7</td>
<td>3.2</td>
</tr>
<tr>
<td>30) When I answered the clicker questions correctly, I assumed I didn’t</td>
<td>1.6</td>
<td>1.7</td>
<td>1.7</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Looking at the ad hoc survey questions administered during lectures, there are some interesting differences between the students earning A’s from those that are not passing the course, as seen in table 10. In identifying the strongest incentive for coming to class, the majority of ‘A’ students identify with learning the material, whereas the students failing the class are also concerned with passing the next exam and earning the clicker points.

Table 10: Ad hoc survey question concerning attendance incentive

<table>
<thead>
<tr>
<th>Which of the following provides the most incentive for coming to CHM4 classes? (N=191)</th>
<th>A (N=15)</th>
<th>B (N=72)</th>
<th>C (N=42)</th>
<th>Fail (N=62)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) I am on campus anyways and have nothing better to do.</td>
<td>0</td>
<td>1%</td>
<td>5%</td>
<td>0</td>
</tr>
<tr>
<td>B) To earn points from clicker questions.</td>
<td>0</td>
<td>19%</td>
<td>19%</td>
<td>23%</td>
</tr>
<tr>
<td>C) Hearing the lecture will help me learn the material.</td>
<td>60%</td>
<td>24%</td>
<td>29%</td>
<td>35%</td>
</tr>
<tr>
<td>D) To see friends.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>E) I believe missing classes will lower my chances for passing the next test.</td>
<td>7%</td>
<td>32%</td>
<td>24%</td>
<td>27%</td>
</tr>
<tr>
<td>F) To see how well I understand the material on the clicker questions.</td>
<td>7%</td>
<td>11%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>G) I’m paying for the class so it would be a waste of money not to attend.</td>
<td>0</td>
<td>1%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>H) I enjoy the class.</td>
<td>20%</td>
<td>11%</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>I) My strongest incentive is not listed above.</td>
<td>7%</td>
<td>0</td>
<td>7%</td>
<td>3%</td>
</tr>
</tbody>
</table>

In terms of identifying the two most significant contributors to being successful in Chem 4, the A students believe being in class every day and keeping up with the homework are the most valuable, while the failing students identified working on practice exams prior to the exam followed by doing the homework each week, as seen in table 11. Failing students identified being in class every day as the third most important consideration.
Table 11: Ad hoc survey question concerning perceived success factors

<table>
<thead>
<tr>
<th></th>
<th>A (N=30)</th>
<th>B (N=144)</th>
<th>C (N=74)</th>
<th>Fail (N=120)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Taking good notes during lecture.</td>
<td>13%</td>
<td>7%</td>
<td>11%</td>
<td>13%</td>
</tr>
<tr>
<td>B) Reviewing lecture notes before the exam.</td>
<td>0</td>
<td>0</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>C) Working on practice exams before the exam.</td>
<td>0</td>
<td>17%</td>
<td>18%</td>
<td>26%</td>
</tr>
<tr>
<td>D) Reviewing clicker questions before the exam.</td>
<td>0</td>
<td>0</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>E) Doing homework problems every week.</td>
<td>27%</td>
<td>11%</td>
<td>20%</td>
<td>17%</td>
</tr>
<tr>
<td>F) Reviewing lecture notes regularly every week.</td>
<td>7%</td>
<td>4%</td>
<td>8%</td>
<td>3%</td>
</tr>
<tr>
<td>G) Reading the assigned textbook each day before class.</td>
<td>17%</td>
<td>9%</td>
<td>9%</td>
<td>8%</td>
</tr>
<tr>
<td>H) Being in class every day.</td>
<td>37%</td>
<td>51%</td>
<td>28%</td>
<td>26%</td>
</tr>
<tr>
<td>I) Other.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3%</td>
</tr>
</tbody>
</table>

In terms of identifying the benefits from using clickers, the A students top two responses are self-assessment and in providing feedback concerning their level of understanding to the instructor, as seen in table 12. The failing students perceive the greatest benefits in providing motivation for coming to class via the points earned and providing practice problems in class.

Relating to the previous ad hoc questions, one group is more concerned with learning the material while the other is trying to earn enough points to get through the course.

Table 12: Ad hoc survey question concerning perceived benefits of clickers

<table>
<thead>
<tr>
<th></th>
<th>A (N=29)</th>
<th>B (N=129)</th>
<th>C (N=66)</th>
<th>Fail (N=104)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Tells the instructor how well students are doing or if they are getting the new material.</td>
<td>7%</td>
<td>12%</td>
<td>15%</td>
<td>16%</td>
</tr>
<tr>
<td>B) Tells you, the student, how well you are doing on questions important to the instructor.</td>
<td>34%</td>
<td>28%</td>
<td>27%</td>
<td>21%</td>
</tr>
<tr>
<td>C) Helps keep you awake during class.</td>
<td>0</td>
<td>0</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>D) The points earned from clicker questions provide motivation for coming to class.</td>
<td>17%</td>
<td>26%</td>
<td>24%</td>
<td>19%</td>
</tr>
<tr>
<td>E) Using the clickers makes the class more personal and engaging.</td>
<td>0</td>
<td>6%</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>F) Provides practice problems to solve while learning new material.</td>
<td>28%</td>
<td>23%</td>
<td>26%</td>
<td>24%</td>
</tr>
<tr>
<td>G) Stimulates discussion with classmates when you are allowed to work together on questions.</td>
<td>14%</td>
<td>2%</td>
<td>0</td>
<td>8%</td>
</tr>
<tr>
<td>H) Other</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2%</td>
</tr>
</tbody>
</table>

Responses are similar between groups of students when surveyed about the points involved with clicker questions, with the majority in most groups agreeing with the administered
clacker points totals and all were strongly in favor of the change incorporated in the spring semester where students receive one point for effort and two points for a correct answer.

**Table 13: Ad hoc survey questions concerning point system of clickers**

<table>
<thead>
<tr>
<th>This semester, points from clicker questions are worth about 7.5% of your total grade. Select the answer that you agree with most. (N=174)</th>
<th>A (N=14)</th>
<th>B (N=65)</th>
<th>C (N=41)</th>
<th>Fail (N=54)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) I think clacker points should not count towards my final grade.</td>
<td>0 2% 7% 4%</td>
<td>0 2% 7% 4%</td>
<td>0 2% 7% 4%</td>
<td>0 2% 7% 4%</td>
</tr>
<tr>
<td>B) I think clacker points should count, but be less than the current 7.5% of my final grade.</td>
<td>29% 37% 27% 19%</td>
<td>29% 37% 27% 19%</td>
<td>29% 37% 27% 19%</td>
<td>29% 37% 27% 19%</td>
</tr>
<tr>
<td>C) I think clacker points are just right at 7.5% of my final grade.</td>
<td>36% 28% 32% 37%</td>
<td>36% 28% 32% 37%</td>
<td>36% 28% 32% 37%</td>
<td>36% 28% 32% 37%</td>
</tr>
<tr>
<td>D) I think the clacker points should be 10% of my final grade.</td>
<td>21% 22% 27% 13%</td>
<td>21% 22% 27% 13%</td>
<td>21% 22% 27% 13%</td>
<td>21% 22% 27% 13%</td>
</tr>
<tr>
<td>E) I think clacker points should be 15% of my final grade.</td>
<td>0 5% 0 7%</td>
<td>0 5% 0 7%</td>
<td>0 5% 0 7%</td>
<td>0 5% 0 7%</td>
</tr>
<tr>
<td>F) I think clacker points should be 20% or more of my final grade.</td>
<td>14% 6% 5% 13%</td>
<td>14% 6% 5% 13%</td>
<td>14% 6% 5% 13%</td>
<td>14% 6% 5% 13%</td>
</tr>
<tr>
<td>G) I don’t think we should be using clickers in this class.</td>
<td>0 0 0 4%</td>
<td>0 0 0 4%</td>
<td>0 0 0 4%</td>
<td>0 0 0 4%</td>
</tr>
<tr>
<td>H) Other</td>
<td>0 2% 2% 4%</td>
<td>0 2% 2% 4%</td>
<td>0 2% 2% 4%</td>
<td>0 2% 2% 4%</td>
</tr>
</tbody>
</table>

**Table 14: Ad hoc survey question concerning clacker points**

<table>
<thead>
<tr>
<th>In terms of earning points for clicker questions. (N=175)</th>
<th>A (N=15)</th>
<th>B (N=64)</th>
<th>C (N=42)</th>
<th>Fail (N=54)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) I like getting 1 point for effort and 2 points for a correct answer.</td>
<td>73% 67% 76% 76%</td>
<td>73% 67% 76% 76%</td>
<td>73% 67% 76% 76%</td>
<td>73% 67% 76% 76%</td>
</tr>
<tr>
<td>B) I think there should be no points for effort; 1 point for correct and 0 points for incorrect responses.</td>
<td>0 3% 2% 2%</td>
<td>0 3% 2% 2%</td>
<td>0 3% 2% 2%</td>
<td>0 3% 2% 2%</td>
</tr>
<tr>
<td>C) I think there should only be 1 point for effort and no penalty for wrong answers.</td>
<td>27% 27% 21% 20%</td>
<td>27% 27% 21% 20%</td>
<td>27% 27% 21% 20%</td>
<td>27% 27% 21% 20%</td>
</tr>
<tr>
<td>D) I don’t think there should be any points for clicker question.</td>
<td>0 3% 0 2%</td>
<td>0 3% 0 2%</td>
<td>0 3% 0 2%</td>
<td>0 3% 0 2%</td>
</tr>
<tr>
<td>E) None of these reflects my opinion.</td>
<td>0 0 0 0</td>
<td>0 0 0 0</td>
<td>0 0 0 0</td>
<td>0 0 0 0</td>
</tr>
</tbody>
</table>

**A comparison of performance between semesters with and without clickers**

It was previously shown that the most improvement in student performance occurred in the spring 2011 semester, and an evaluation in performance between the spring 2011 semester and the spring 2010 semester will follow. One benefit of comparing these two semesters is that one additional variable will be controlled in using two spring semesters, and not mixing spring and fall semesters. As previously discussed, there are often different types of students enrolling in the spring and fall semesters, and a difference in performance has been noted. It is expected a similar pool of students is enrolled between the two spring semesters, although no attempts have
been made to confirm this by way of evaluating student GPA’s or other possible criteria. Exams from each semester assess the same principles and are generally very similar in the number of questions, types of questions and level of difficulty. Performance between semesters on each exam will be reviewed.

The first exam focuses heavily on chemical nomenclature, properties of atoms and some calculations involving atomic mass. The first exam in the spring 2010 semester contained 31 multiple choice problems, split into three types of questions – algorithmic, conceptual and nomenclature. One of the algorithmic questions on the exam was:

*Naturally occurring lithium has two isotopes: lithium-6 with a mass of 6.0151 amu and lithium-7 with a mass of 7.0160 amu. Determine the percent abundance of lithium-6.*
A) 3.8 %  
B) 7.5 %  
C) 23.2 %  
D) 92.5 %  
E) 96.2 %

A typical conceptual question on the exam was:

*Which of the following statements is false?*
A) Compounds are substances composed of 2 or more elements in fixed, definite proportions.  
B) Compounds retain the properties of the elements from which they were formed.  
C) The law of constant composition states that every sample of a given compound will have the same proportions of their constituent elements.  
D) Chemical formulas indicate the elements present in the compound as well as the relative number of atoms of each.  
E) Any sample of rust (iron oxide, Fe₂O₃) will contain 3 oxygen atoms for every 2 iron atoms.

A typical nomenclature question on the exam was:

*What is the name for SnS₂?*
A) tin disulfide  
B) monotin disulfide  
C) tin sulfide  
D) tin(II) sulfide  
E) tin(IV) sulfide

Students in the spring 2010 semester without clickers had the most difficulty with the algorithmic questions, followed by conceptual questions, and performed the best on the nomenclature questions, as is seen on table 3. Overall, the average student score was 70.7% on the first exam in the spring 2010 semester and 56% of the students passed the exam with a 73% or greater. After using clickers in the spring 2011 semester, the first exam contained 29 questions, with the types
of questions and student performance by type listed in table 15. The average student score in the spring 2011 semester for the first exam was 75.8%, with 66% of the students passing; an increase of 11% of students passing the exam corresponds to 26 more students who passed the first exam when clickers were used, compared to the previous spring semester when clickers were not used.

Table 15: Comparison of exam 1 performance by year

<table>
<thead>
<tr>
<th>Type of question</th>
<th>Spring 2010</th>
<th>Average student performance</th>
<th>Spring 2011</th>
<th>Average student performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithmic</td>
<td>3</td>
<td>66%</td>
<td>5</td>
<td>77%</td>
</tr>
<tr>
<td>Conceptual</td>
<td>16</td>
<td>71%</td>
<td>14</td>
<td>76%</td>
</tr>
<tr>
<td>Nomenclature</td>
<td>12</td>
<td>75%</td>
<td>10</td>
<td>74%</td>
</tr>
</tbody>
</table>

While there were two fewer questions on the spring 2011 exam, there were two more algorithmic questions. They require more time for the students to answer, and seem to be more difficult, as indicated by the results from the first exam. Students in the spring 2011 semester performed much better on the algorithmic questions, slightly better on the conceptual questions and nearly the same on the nomenclature questions (Slain, 2004). The types of exam questions between semesters were the same. For example, one algorithmic question on the spring 2011 exam that is similar to the algorithmic question from 2010 noted previously was as follows:

*Naturally occurring europium has two isotopes: Eu-151 with a mass of 150.92 amu and Eu-153 with a mass of 152.92 amu. What is the percent abundance of Eu-151?*

A) 43.8 %
B) 46.0 %
C) 54.0 %
D) 56.2 %
E) 48.3 %
F) 51.7 %
G) not enough information is provided to answer this question

While only 57% of the students answered correctly in the spring 2010 semester, 73% answered the question above correctly in the spring 2011 semester. Since the content of lectures from both semesters was the same, the only significant deviation was the use of clickers. The lecture on 2/4/11 in the 2011 spring semester dealt with atomic mass and using the concept of isotopes as introduced in the previous lecture. Two clicker questions were asked on 2/4/11 involving atomic mass calculations, thus giving the students two opportunities to test their understanding of the
concepts and use of the formula for calculating atomic mass. The students performed very well with a 97% correct response rate for a simple atomic mass calculation when given percent abundances and masses of two isotopes. 71% correctly answered a follow up question in which they solved for the mass of a second isotope given the atomic mass with the abundance and mass of the first isotope. At the end of the lecture, the following “challenge” clicker question was posed as homework with the expectation that students would be presented with this question at the beginning of the following lecture and would only have enough time to input their answers without time to solve the problem:

\[ \text{Gallium has two naturally occurring isotopes: Ga-69 (mass = 68.93 amu) and Ga-71 (mass = 70.92 amu). Using only the information available on the periodic table, determine the \% abundance of the heavier isotope? Hint: what do you know about the sum of the two abundances?} \]

A) 39.70 %
B) 39.95 %
C) 60.05 %
D) 60.30 %
E) Not enough information is provided

27% of the students that responded correctly identified the correct answer; one likely reason is a large number of students had not come to class with a prepared answer to the question. It is surprising that such a dramatic increase in correct response is seen between this homework clicker question (27%) and the exam question (73%). While students were assigned homework both semesters involving atomic mass calculations, seeing the questions in class or perceiving that clicker questions were important may have helped students prepare for, and perform better on the exam.

During the spring 2011 semester, students deviated from historical performance by having the most success with these algorithmic questions, as shown in Table 15, while also improving on the conceptual questions and not sacrificing any performance on the nomenclature questions. While it is impossible to control all variables between semesters, it appears that the
use of clickers and, the improved attendance, both had a positive impact on student performance, especially on the algorithmic questions.

A comparison of the second exam from each semester is not as straightforward as was the case for exam 1. The mix of questions significantly varied between semesters as seen in table 16.

### Table 16: Comparison of exam 2 between 2010 and 2011 spring semesters

<table>
<thead>
<tr>
<th>Type of question</th>
<th>Spring 2010</th>
<th>Spring 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Average student performance</td>
</tr>
<tr>
<td>Algorithmic</td>
<td>6</td>
<td>69%</td>
</tr>
<tr>
<td>Conceptual</td>
<td>2</td>
<td>87%</td>
</tr>
<tr>
<td>Sig Figs</td>
<td>4</td>
<td>47%</td>
</tr>
<tr>
<td>Nomenclature</td>
<td>5</td>
<td>66%</td>
</tr>
</tbody>
</table>

Some exam questions provide good comparison between semesters, such as the following example of identifying significant figures used on the spring 2010 second exam:

**How many significant figures are in the following measured values: 45,010 and 0.0009099 ?**

A) 5 and 8  B) 4 and 4  C) 4 and 7  D) 5 and 7  E) 5 and 4

Only 54% of the students answered this question correctly in the spring 2010 semester while 86% of the students in the spring 2011 answered the following similar question correctly:

**How many sig figs are in each of the following two measurements: 0.0550010 and 1080.0 ?**

A) 8 and 3  B) 6 and 3  C) 5 and 5  D) 5 and 3  E) 8 and 5  F) 6 and 5

The topic of significant figures was first introduced on 2/25/11 during the 2011 spring semester, focusing on the identification of the number of significant figures in various numbers. The clickers were not operating correctly during this lecture so no statistical data are available as to how well students understood which values in a number are considered significant. This clicker question, however, was posed, thus allowing the students an opportunity to test their understanding of identifying the number of significant figures in a number:

**Which of the following measurements has the greatest number of significant figures?**

A) 605000  C) 0.06050  E) 0.0000605  B) 0.605  D) 6.0500  F) 605.0
The topic of using significant figures in calculations was introduced in the following lecture with 66% of the students answering the following question correctly:

**Determine the answer to the following calculation using the correct number of sig figs.**

\[
\frac{(13.001 \times 64)}{2.1}
\]

A) 400  C) 396.22  E) \(4.0 \times 10^2\)  B) \(4.0 \times 10^1\)  D) \(3.9 \times 10^2\)

F) 390

Addition and subtraction calculations were also introduced with a total of three clicker questions asked during this lecture. The lecture that followed was the third lecture covering the topic of significant figures, with the following review clicker question:

**Calculate the answer with the correct number of sig figs:**  \(0.2350 \times (10.35 – 3.564)\)

A) -1.182  D) 1.596  G) 1.60
B) 1.59  E) 1.59471  H) \(1.6 \times 10^2\)
C) 1.594  F) 1.59565

Determining the number of significant figures when mixing mathematical functions between addition/subtraction and multiplication/division has historically been very difficult for students in Chem 4, and only 36% of the students correctly answered this clicker question during lecture. It was hoped that emphasizing the importance of this topic and reinforcing active student participation with clickers would help students with this difficult topic. Again, there were ample homework opportunities for students to practice similar questions during both semesters, however the 2011 students were given the opportunity to practice and test their abilities during lecture using clickers. A similar question involving mixed calculations was on the second exam for each semester; 46% of the students answered correctly in the spring 2010 semester while 64% answered correctly in the spring 2011 semester. An improvement of 18% of the student population corresponds to 42 students.
Not every topic or question resulted in significant improvement while using clickers. In performing simple calculations using conversions of units to a raised power, this algorithmic question was asked in the spring 2010 semester with 86% of the students answering correctly:

How many cm\(^2\) are there in 0.056 ft\(^2\)?

A) 52 cm\(^2\)  
B) 0.0025 cm\(^2\)  
C) 3.8 cm\(^2\)  
D) 12 cm\(^2\)  
E) 6.0 \times 10^{-5} \text{ cm}^2

A similar question was asked on the spring 2011 exam with 88% of the students answering correctly.

Overall, 34% of the students in the spring 2010 semester passed the second exam with an average score of 64.8%. 39% of the students in the spring 2011 semester passed the exam with an average score of 64.6%. Aside from using clickers and the different ratio of questions on the exam noted previously, there were other variables that likely influenced exam scores between semesters. The topic of calculating formula mass of a compound was not on the second exam during 2010 while it was covered in 2011. Therefore additional material was covered with exam questions that have no similar question in 2010 to compare with. Also, some conceptual questions on the 2011 exam were taken from clicker questions and again had no similar question from the 2010 exam with which to compare. And a third significant variable between semesters was that a guest lecturer (a graduate student) gave two lectures covering the topic of specific heat and heat energy during the 2011 semester, therefore direct comparisons in student performance covering these topics would not necessarily reflect the influence of using clickers. This specific topic will be revisited again later comparing the two semesters when clickers were used and how students performed on similar exam questions concerning one specific heat algorithmic question.

Exam questions on the third exam were fairly similar between semesters providing another good opportunity to compare student performance on exams when using clickers and without using clickers. There are two fundamental types of questions on exam 3, being algorithmic and conceptual. As seen in table 17, the ratio of questions varied somewhat, and
performance improved significantly with the conceptual questions and only slightly improved on the algorithmic question during the semester with clicker use.

**Table 17: Exam 3 comparison between semesters**

<table>
<thead>
<tr>
<th>Type of question</th>
<th>Spring 2010</th>
<th>Spring 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithmic</td>
<td>N 11</td>
<td>N 7</td>
</tr>
<tr>
<td>Average student performance</td>
<td>74%</td>
<td>76%</td>
</tr>
<tr>
<td>Conceptual</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>Average student performance</td>
<td>71%</td>
<td>82%</td>
</tr>
</tbody>
</table>

The two sections in the spring 2010 semester had two separate exams for this third exam, although the exact types of questions were written on each using different chemical compounds and different numerical values. For purposes here, the pairs of questions from each exam are assumed to be of equal difficulty and the student response rate is aggregated between the two exams. As was the norm, the exact same exam was used in both sections of the 2011 spring semester allowing for simple aggregation of scores. This exam covered concepts relating to mass, Avogadro’s number, molar masses and writing balanced equations using solubility rules to predict products that may form. One algorithmic question that was similar between the two semesters involved calculating the mass of a sample when the number of atoms was given for one of the constituent elements in the compound. For example, the following question was on the spring 2010 exam, with 45% of the students answering correctly:

* A sample of ammonia (NH₃) contains 2.5 x 10²⁴ H atoms. What is the mass of the sample?  
  A) 1.4 g  B) 24 g  C) 27 g  D) 0.28 g  E) 71 g

A similar question was asked on the spring 2011 exam involving Ca(NO₃)₂ as the compound, making the question slightly more difficult. 60% of the students answered correctly in the 2011 exam showing a significant improvement over the class not using clickers. While lectures from both semesters covered the same material concerning the mole, molar relationships and Avogadro’s number, the clicker questions used in the spring 2011 semester seems to have helped
students learn the material. For example, the following clicker question was given to the students near the end of lecture on 4/8/11 and was the fourth clicker question that lecture concerning this topic:

*A sample of potassium chromate has $4.55 \times 10^{24}$ O atoms. What is the mass (in g) of Cr in the sample?*

A) $9.822$ g Cr  
B) $393$ g Cr  
C) $9.82 \times 10^{47}$ g Cr  
D) $1.3 \times 10^{4}$ g Cr  
E) $98.2$ g Cr  
F) $131$ g Cr  
G) $1.57 \times 10^{3}$ g Cr  
H) None of these is correct

This clicker question is not identical with the exam question, however it provides an opportunity to use the same relationships to solve the problem. 80% of the students answered this clicker question correctly in class. Again, there was ample homework with these types of questions during both semesters, however students probably benefited from lectures employing active learning opportunities while working on the clicker questions in class to reinforce the new material they were learning.

In calculating the molar mass of a compound given its name, as opposed to the formula, students performed better in the 2011 class as well. While 73% of the students answered correctly in identifying the correct molar mass of silver chromate in the spring 2010 class, 85% correctly identified the molar mass of lead(IV) sulfate in the spring 2011 class. Similarly, the students were more successful in balancing equations in the spring 2011 class. For example, 68% of the spring 2010 class correctly answered the following question:

*What is the coefficient in front of the CO$_2$ when the following reaction is balanced?*

$$\text{____ Fe}_2\text{O}_3 + \text{____ CO} \rightarrow \text{____ Fe} + \text{____ CO}_2$$

A) 2  
B) 3  
C) 4  
D) 5  
E) 6

In the spring 2011 class, however, 91% correctly answered this similar question:
What is the coefficient in front of the \( N_2 \) when the following reaction is balanced?

\[
\begin{align*}
\text{_____ } N_2H_4(g) + \text{_____ } N_2O_4(g) & \rightarrow \text{_____ } N_2(g) + \text{_____ } H_2O(g)
\end{align*}
\]

A) 4  B) 2  C) 1  D) 6  E) 5  F) 3

Similarly, 74% of the students correctly balanced a combustion reaction of decane in 2011 while 64% of the students were successful with nonane in 2010. Balancing the decane combustion reactions is more difficult as it requires the students to multiply all coefficients by a factor of two to remove a fraction with the oxygen coefficient. Thus the improvement in the 2011 semester is even more impressive. The topic of balancing reactions in the 2011 spring semester was covered in one lecture on 4/15/11 and two progress clicker questions were given to the students during that lecture. The students had difficulty on the first question with 40% answering correctly and had more success on the second question, with 88% of the students answering correctly. On the following lecture, however, two additional ‘review’ clicker questions were given to the students to reinforce the topic. The first of the two questions was challenging, requiring the students to correctly identify the formula of compounds and then balance the reaction:

\[
\text{In solid rocket boosters for spacecrafts, solid ammonium perchlorate and solid aluminum react to form solid aluminum oxide, solid aluminum chloride, gaseous nitrogen monoxide and water vapor. What is the coefficient in front of the aluminum chloride when the reaction is balanced?}
\]

A) 1  B) 2  C) 3  D) 4  E) 5  F) 6  G) 7  H) 8

56% of the students correctly answered the question. A second review question was asked with a chemical reaction given and the students were asked to solve for one of the coefficients, much like the exam questions, with 56% of the students answering correctly. Although the students did not have great success with these questions, it provided an opportunity for the instructor to quickly revisit the previous material and engage the students with an opportunity to see how well
they could apply what they learned from the previous lecture. This also provided students with a reminder that the instructor thought this was an important topic worth revisiting.

In testing the students’ understanding of mass percent, the following question was asked on the spring 2010 exam, with 63% of the students answering correctly:

*Which of the following has the smallest mass percent P?*

A) $\text{H}_3\text{P}$  
B) $\text{H}_3\text{PO}_3$  
C) $\text{H}_3\text{PO}_4$  
D) $\text{Na}_3\text{PO}_3$  
E) $\text{Na}_3\text{PO}_4$

The following similar question was asked on the spring 2011 exam showing significant improvement year over year with 85% of the students answering correctly:

*Which of the following has the greatest mass percent of N? You should be able to do this problem without using your calculator.*

A) $\text{HNO}_2$  
B) NO  
C) NO$_3$  
D) $\text{NH}_3$  
E) $\text{HNO}_3$  
F) NO$_2$

The topic of mass percent was introduced during the lecture on 4/11/11 in 2011, and the formula for calculating mass percent is relatively straightforward. From a clicker question asking students to calculate the mass percent given masses, 86% were able to use the formula and answer correctly. However, the students have more difficulty in being able to understand and apply the concept. The following ‘reading’ clicker question was given to the student in 2011, with just 65% answering correctly:

*Which of the following has the highest mass percent of silver? See if you can determine the answer without doing any calculations.*

A) 100-g sample of AgNO$_3$  
B) 75-g sample of AgO  
C) 200-g sample of AgNO$_2$  
D) 25-g sample of AgS

Nearly 20% of the students chose “C” with the highest total sample mass, indicating they had not read the material or did not understand the concept. This reading question did, however, provide the students with some feedback regarding how carefully they were reading the material as well as if they understood the concept of percent mass. Perhaps the students paid a little closer attention in class following this reading question, or perhaps they recalled seeing this type of
question, but for whatever reason, the students performed significantly better on the exam with a similar question and significantly outperformed their 2010 counterparts who did not have clickers in their class.

As a final example, in understanding and applying the solubility rules, 71% of the students from the spring 2010 class answered the following question correctly:

What is the formula of the solid that is formed when an aqueous solution of zinc chloride is added to an aqueous solution of sodium sulfide?

A) NaCl  B) ZnS  C) Zn$_2$S$_3$  D) ZnCl$_2$  E) Zn$_3$S$_2$

A nearly identical question involving the same solubility rule was asked on the spring 2011 exam, with 87% of the students answering correctly, again showing significant improvement over the class without clickers.

While some questions varied between the two exams, improvement was seen in the spring 2011 class on every occurrence where questions that were similar between semester exams. 57% of the students passed the exam in 2010 with an average score of 72.6 while 73% of the students pass in 2011 with an average score of 79.7. It is possible some of the questions were less difficult in 2011 which would have influenced the overall average and pass rate, however it is clear from the questions that were similar between exams that the students in 2011 performed much better than their 2010 counterparts on this third exam, and improvement is seen on both conceptual and algorithmic questions.

In evaluating retention over the course of the semester, students in the 2011 semester performed better on the final exam than the students in the 2010 spring semester. 43% of the students who took the final in 2010 passed the exam and the class average score was 68%. In the 2011 semester, however, 63% of the students passed who took the exam and the class average score was 75%. This 20% increase in the number of students passing the final corresponds to 43 students. Many of the questions between semesters were similar and, as on previous exams
during the semester, the scores show that students in 2011 performed better than 2010 students on most conceptual and algorithmic types of questions.

Relating back to percent abundance as was discussed from the first exam, a similar question on the final exam involved three isotopes instead of two, making the question more difficult. In 2010, 57% of the students correctly answered the question on the first exam while 68% answered the question involving three isotopes on the final. In 2011, 73% of the students correctly answered the exam question while 85% were correct on the final involving the three isotope question. Clearly students from both semesters retained the concepts to solve these percent abundance type of questions, and students from both semesters showed improvement from the first exam to the final, but having 85% of all students answer a challenging question correctly is truly impressive and indicates some merit to the quality of learning in the spring 2011 semester.

Concerning the topic of significant figures, 74% of the students from spring 2010 correctly answered the following question:

*How many significant figures are in the answer to the following calculation:  (8.05 + 5.8) / 0.166*

A) 2  B) 3  C) 4  D) 5  E) 6

A nearly identical question was asked in 2011 on the final, with 91% answering correctly. With a more difficult calculation involving mixed calculations, however, it was clear that the majority of students from both classes still had not mastered the topic. The question from the spring 2010 final was as follows, with the 2011 final question being nearly identical:

*How many sig figs are in the answer to the following calculation:  (120.90)(0.55)+(122.90)(0.45)*

A) 1  B) 2  C) 3  D) 4  E) 5
Only 33% of the students from the 2010 class answered correctly while just 35% were successful in 2011. While the students from the 2011 were more successful with a simpler problem, these students still had not mastered the subject. This topic of students learning the concept of significant figures will be reviewed further in the following section with a discussion of how clicker questions were modified between the first and second semesters of this study to help improve student learning.

In converting units to raised power, 83% of the students were successful in 2010 on the final exam while 86% correctly answered on the second exam as mentioned previously. In 2011, however, there was no decline in performance between the exam and the final with 88% answering correctly on both exams. Contrary to the prior example involving percent abundance where student performance improved on the final exam from the first exam, student performance declined slightly on this topic in 2010, however remained flat when clickers were used.

While there are many examples of student performance improving from the spring 2010 semester to the spring 2011 semester, one final example will be discussed as it involves several concepts taught during the semester. This question was from the 2010 final with a nearly identical question asked in 2011:

What is the molar mass (with correct significant figures) for tin(II) hydroxide?

A) 152.7 g/mol   B) 152.72 g/mol   C) 135.7 g/mol   D) 135.71 g/mol   E) 254.4 g/mol

This question requires students to know their nomenclature, rules for significant figures and molar mass calculations. While 80% of the students answered correctly on the 2010 final exam, 86% were correct on the spring 2011 final exam.

While students showed improvement in 2011 compared with 2010 on the overwhelming majority of questions, there were cases of a decline in performance. One example showing the worst decline in performance was this conceptual question from the 2010 final exam:
How many electrons does the tin ion in Sn(CN)_4 have?

A) 46  B) 48  C) 50  D) 52  E) 54

52% of the students in 2010 answered this question correctly while only 26% of the students from 2011 answered a similar question involving Mo(CO)_3 correctly. No clear explanation is readily apparent to explain the poorer performance while using clickers, however it provides one example that reminds us that using clickers is certainly not the panacea for learning. Using clickers provides an opportunity for active learning and helps provide readily accessible data regarding student learning so that teaching strategies can be altered to help students learn when they are struggling with any given concept or problem solving technique. Specifically to this point, the following section reviews two examples of how clickers were used and an evaluation of student learning.

A comparison of final exams between the first and second semesters using clickers

While it appears clear that student performance improved from the spring 2010 semester when clickers were not used to the spring 2011 when clickers were used, it is believed that there was an iterative process to reach the point where such significant gains could be observed. Data from the first semester of this study were used in modifications to the clicker questions for use in the second semester to improve their quality and effectiveness. The data previously discussed showed that there was only marginal gain in student performance in the fall 2010 semester, the first semester clickers were used. Thus, an evaluation of what changed between the first and second semester of clicker use will be provided with some test results to identify if specific actions focusing on changes implemented between semesters had a benefit on student learning.

The final exam given in the spring semester was nearly identical with the exam given to one section from the fall semester, providing an opportunity to compare performance between the two
semesters. An evaluation of performance on final exam questions that are the same may be useful in identifying whether modifying the use of clickers had any impact on learning, or if improved attendance, which was facilitated by the use of clickers, was the sole contributor of student improvement. Of the thirty-one questions that were identical between the two final exams, the students from the spring semester performed better relative to the fall semester students on twenty-one of the questions, and performed worse on ten. Eleven of the twenty-one questions with improvement showed gains of more than five percentage points; five of the ten questions that declined in performance decreased by more than five percentage points.

One of the areas identified from the fall semester with which students struggled was in significant figures. It was clear from the clicker questions and the exam scores from the fall semester that many of the students were not mastering the topic of significant figures, particularly when mixed mathematical functions were involved. Using this information, several changes were made with the clicker questions in the spring semester to reinforce the topic of significant figures. Aside from adding more carefully chosen wrong answers involving significant figure errors, other methods of utilizing the clickers were explored. For example, it was known that only 39% of the students from the fall semester correctly answered the following clicker question during lecture, so it was decided to follow Mazur’s “concept test” methodology in the spring semester and ask the students to first try to answer the question on their own, then show the students the histogram of answers, followed by a second effort where students were encouraged to work together:

What volume (in cL) would you get if you added the following: 760 µL + 1 mL?

A) 0.176 cL  E) 1.8 cL  
B) 0.2 cL  F) 0.1 cL  
C) 770 cL  G) 0.0770 cL  
D) 0.8 cL  H) 0.18 cL

23% of the students (N=210) answered correctly after working on the problem by themselves in the spring semester. After working on the problem in small groups, the class re-submitted their
answers with 64% of the class responding with the correct answer. A similar question was asked
the final exam in the spring semester, using scientific notation in the problem which added one
additional challenge, with 41% of the class answering correctly:

*What volume (in cL) would you get if you added the following: 2.65 x 10^3 µL + 9 mL?*

A) 1 cL   B) 1.165 cL   C) 1.2 cL   D) 1.17 cL   E) 1.1 cL

There is no comparable question from the final exam during the fall 2010 semester to compare
with, however a significant improvement is seen from the 23% of students that correctly
answered the clicker question on their own to the 41% of students that correctly answered the
question on the final exam.

Also during the spring semester, wrong answers were continually included that used
incorrect significant figures. For example, the following review clicker question was asked on
3/11/11 to test students’ ability to convert to metric units:

*A car gets 35.0 mpg (miles per gallon). Calculate this fuel efficiency in metric units.*

A) 82.3 km/L   E) 14 km/qt
B) 4.9 x 10^4 ft/L   F) 14.9 km/L
C) 4.6 x 10^4 ft/qt   G) 4.88 x 10^4 ft/L
D) 15 km/L   H) 82 km/L

This two step problem involving conversion of both the numerator and denominator proved to be
a challenging question with 59% of the students (N=203) answering correctly in lecture. “D” was
the most common wrong answer with 36 students, or roughly 18% of the students, making the
mistake of using two significant figures instead of the three required to correctly answer the
question. As with all other similar situations, students who were present during this lecture
received immediate feedback, even though they lost a point due to using the incorrect number of
significant figures. The importance of significant figures was reinforced using active learning.

Another type of clicker question used to help students evaluate their learning was used on
3/11/11 at the end of a lecture concerning units to a raised power and multistep conversions.
Near the end of the lecture, the following progress check clicker question was given concerning the day’s topic:

*Calculate the mass (in kg) of a Zn cube having a volume of 15.00 in\(^3\) given its density is 7.14 g/mL.*

A) 0.0344 kg  E) 1.76 kg  
B) 0.03443 kg  F) 1.755 kg  
C) 0.272 kg  G) 6.54 \times 10^{-3}\ kg  
D) 0.2720 kg  H) 6.536 \times 10^{-3}\ kg

This challenging question requires five steps including a conversion from cubed inches to cubed centimeters, which was new material for the students. Only 44% of the students correctly answered “E”, while selection “F” was the most commonly chosen wrong answer getting 27% of the votes. Before displaying the histogram of answers or providing the correct answer to the students, the instructor posed this optional clicker question to the students:

*How confident do you feel about your answer to the previous question? Answering this question is optional and will not be part of your grade.*

A) 100% confident  
B) Pretty confident (< 100%, but more than 50%)  
C) Not too confident (<50%, but more than 0%)  
D) I guessed (0%)

Of the 47 students who chose “F” with the significant figure error, 28 students (60% of population) chose either “A” or “B” in the follow up question, indicating they were confident with their previous answer. After the instructor revealed the answer to the progress check question, these 28 students who were confident in their answer yet answered incorrectly should have learned a valuable lesson that mistakes with significant figures will cause them to answer questions incorrectly despite knowing how to solve the problem. Not surprisingly, of the 23 students who answered the progress clicker question incorrectly and who did not chose “F” only 1 indicated they were confident with their answer. Clearly, the vast majority of the students who could not correctly answer the question recognized they were not yet adequately prepared to answer this type of question. Interestingly, this was one area of improvement on the final exam.
There was one question on the final exam involving units to raised power, and this question was identical between the fall and spring semesters:

*How many inches\(^3\) are in 1.8 \(\times 10^8\) \(\mu m\)^3?*

A) \(7.1 \times 10^{-9}\) inches\(^3\)

B) \(4.6 \times 10^{-12}\) inches\(^3\)

C) \(2.9 \times 10^{-15}\) inches\(^3\)

D) \(1.1 \times 10^{-5}\) inches\(^3\)

E) \(7.1 \times 10^3\) inches\(^3\)

This is an easier question than the five-step clicker question described earlier, but the conversion of units to raised power is tested and students performed better on the spring final exam. 81% of the students correctly answered in the fall while 88% correctly answered in the spring. Multiple clicker questions were asked during lectures from both semesters providing students opportunities to practice and assess their ability to solve problems involving units to a raised power. Perhaps the attitudinal question, which was asked only in the spring semester, helped provide some students with the metacognition by asking them to rate their confidence in their ability to solve such a problem.

Returning to the topic of significant figures, the final exam contained two calculation problems specifically designed to test the students’ ability to use significant figures in calculations and the two questions were identical between the fall and spring semesters’ final exam. The first of the two questions was as follows:

*Report the answer to the following calculation with the correct sig figs: \((190.05 - 5.8)0.166\)*

A) 30.5855

B) 30.6

C) 30.586

D) 31

E) 30.59

91% of the students from both the fall and spring semesters answered this question correctly. Being a relatively easy question with such a high student population answering the question correctly, it is not surprising that the scores were not improved in the spring semester. The second significant figure question provides a different story, however. The question was as follows:
How many sig figs should be reported for the following calculation: \((140.10)(0.33) + (144.10)(0.67)\)
A) 5
B) 2
C) 4
D) 6
E) 3

This question is more difficult in that the products from the multiplication results in a value with two significant figures, but when added together a three digit sum is obtained and must be reported to three significant figures. 36% of the students answered this question correctly in the fall semester and 35% answered correctly in the spring semester. The change in performance is not statistically relevant between semesters, showing the increased focus on significant figures with the clicker questions throughout the semester added no benefit to student learning. While continually adding wrong answers to clicker questions throughout the semester and many students losing points due to significant figure errors, there was apparently not enough incentive for those students to go back and ensure they learned from their mistakes. Perhaps this supports Caldwell’s recommendation that 15% of the total course points should be tied to clicker questions so that students will not only come to class more prepared, but will have enough incentive to not repeat their mistakes and continue to lose points throughout the semester. One other possibility is that the students have considerable difficulty learning this topic, and many students don’t ever truly master it. Repeated testing of students’ understanding of the topic throughout the semester is not adding additional benefit to their learning, and perhaps the initial method of introducing the concept should be revisited. If nothing else, using clickers provided valuable insight into the students’ comprehension of significant figures, suggesting that the simple fix of more practice may not be the solution to this particular hurdle in their learning.

As noted previously, however, students performed significantly better in the spring semester than in the fall semester on ten of the thirty-one questions that were identical. For several of
these questions, the exact same clicker questions were used in both the fall and spring semesters and there was no change in lecture material. For one question concerning specific heat, a guest lecturer (a graduate student working with the instructor) led the two lectures covering this topic in the spring semester using similar lecture notes and the following clicker question was used on both final exams:

A 20.0 g sample of a metal is heated to 203°C and then dropped into 80.0 g of water at 25.0°C. The water temperature rises to 29.0°C. What is the specific heat of the metal?

A) 1.66 J/g°C
B) 0.802 J/g°C
C) 0.447 J/g°C
D) 0.385 J/g°C
E) 0.0192 J/g°C

44% of students in the fall semester answered correctly on the clicker question and 65% answered correctly on the final exam question. Students in the spring semester had more trouble with the lecture clicker question, with only 34% of the students answering correctly, however 85% answered correctly on the final exam question. One possible explanation may be that having an inexperienced lecturer led to the students having more difficulty understanding the topic during the lecture, resulting in them reviewing the material more thoroughly afterwards. It is unknown what the reason for the improved exam scores is for this particular question, however this example provides insight into the complexity of student learning. There are many variables affecting student learning, and isolating all variables except the use of clickers is extremely difficult, if not impossible.

**Case studies**

Four specific student case studies will be evaluated in this section. Case studies can be a useful tool by providing an in-depth account of events which may reveal certain relationships that would otherwise not be evident from a broad survey or average exam scores. While there were
hundreds of students to choose from for this purpose, the four chosen provide particular examples that seem worthy of discussion. One proposed benefit of case studies is that they may be better able to illuminate the general by looking at the particular (Denscombe, 2007). The case studies are not intended to prove or quantify any specific hypothesis, but will be used in the triangulation approach to add additional inputs to the sum of available data to evaluate.

**Case study 1 - A failing student**

With over one third of the students not passing the course, the first case study follows one particular failing student to provide some insights into their behaviors and attitudes. Student #80 from the 10 am section is like many of the students from the spring semester who attended every lecture prior to the first exam. Responses from the post exam 1 survey indicated this student enjoyed using clickers (question #1 with a response of 5) and strongly agreed that the clickers helped maintain their interest during lectures (question #7 with a response of 5). This student’s responses varied somewhat when relating to study habits; they were not keeping up with material daily (question #3 with a response of 3), but thought the clickers helped motivate them to come to class prepared (question #8 with a response of 5 and question #15 with a response of 5), and strongly agreed that they come to Chem 4 class more prepared than their other classes (question #23 with a response of 5). This student earned only 45% of the points possible from the clicker questions during these first nine lectures, and was not coming to class prepared. For example, 94% of the students correctly answered the following reading question from the second week of the semester while this student answered incorrectly:

*Which letter corresponds to the main topic you were asked to read about for today’s class?*

A) “Forming ions”  
B) “Compounds”  
C) “Isotopes”  
D) “Metric system”  
E) “Chemical formulas”  
F) “Conversion factors”
These questions, and other reading questions, are meant to be easy if the students have done the reading, and to encourage the students to come to class prepared. This student did not answer correctly, indicating a start to the semester having poor study habits. Similarly, there are often review clicker questions that encourage students to review their notes and do the homework problems. Typically if the students do the homework, they should be able to answer. On 2/9/11 the following review clicker question was asked:

*Pure water is 88.8% oxygen by mass. What mass of hydrogen can be isolated from 95.0 g of water?*

- A) 8.6 g
- B) 13.8 g
- C) 84.4 g
- D) 85.4 g
- E) 21.2 g
- F) *None of these answers is correct*

This topic was covered in the previous lecture and 70% of the students answered the question correctly, which is typical for a review clicker question. This student did not answer correctly, suggesting they had not spent much time completing the homework assignment, or reviewing their lecture notes so as to work on the concepts they may not have readily understood from the lecture.

From the post exam 1 survey, this student disagreed that they had to cram for the exam (question #5 with a response of 2), and their homework score for the semester was 21.6 points (50 possible), which was among the lowest in the class. To recap, this student was not having success with the clicker questions and felt like they did not need to put in the extra time studying for the exam, on which they scored a 42%. They then missed two lectures between the first and second exam, and their clicker scores dropped dramatically on the final four lecture days preceding the second exam, earning just two of twelve possible points. They were not consistently answering easy reading questions or review questions, suggesting no change in study habits. They earned a 47% on the second exam. This is the point in the semester when the instructor gave the deal to students with an opportunity to pass the course despite low grades up
to that point in the semester, and this seemed to have an effect on this student who did not miss a lecture leading into the third exam. Similarly, their clicker scores improved and they earned 60% of possible clicker points between the second and third exams, but only a 45% on the third exam, thus losing any hope of passing the course. While they tried to recover, there were simply too many concepts they had not mastered and they could not catch up at that point in the semester. This student did not attend another lecture and did not take the final.

Table 18 below summarizes average scores by course grade earned in the spring semester of Chem 4 for each of the contributing factors to Chem 4 students’ final grades, with the addition of the average number of absences. Trends for all contributing factors follow course grade earned, including average quiz scores, exam scores, homework scores and clicker question scores. As reported earlier, and is seen again here, absenteeism has an inverse relationship with course grade earned.

Table 18: Average scores by course grade earned

<table>
<thead>
<tr>
<th>Final grade</th>
<th>Homework</th>
<th>Clickers</th>
<th>Exam 1</th>
<th>Quiz 1</th>
<th>Exam 2</th>
<th>Quiz 2</th>
<th>Exam 3</th>
<th>Quiz 3</th>
<th>Final</th>
<th>Absences</th>
</tr>
</thead>
<tbody>
<tr>
<td>points possible</td>
<td>50.0</td>
<td>50.0</td>
<td>100.0</td>
<td>20.0</td>
<td>100.0</td>
<td>20.0</td>
<td>100.0</td>
<td>20.0</td>
<td>200.0</td>
<td>n/a</td>
</tr>
<tr>
<td>A (N=16)</td>
<td>47.4</td>
<td>45.7</td>
<td>94.6</td>
<td>19.4</td>
<td>84.3</td>
<td>19.4</td>
<td>97.2</td>
<td>19.8</td>
<td>182</td>
<td>0.6</td>
</tr>
<tr>
<td>B (N=80)</td>
<td>43.6</td>
<td>41.3</td>
<td>86.6</td>
<td>18.5</td>
<td>76.3</td>
<td>18.8</td>
<td>89.2</td>
<td>18.9</td>
<td>167</td>
<td>2.2</td>
</tr>
<tr>
<td>C (N=53)</td>
<td>38.6</td>
<td>37.2</td>
<td>78.5</td>
<td>17.9</td>
<td>65.0</td>
<td>18.2</td>
<td>80.5</td>
<td>17.5</td>
<td>152</td>
<td>4.0</td>
</tr>
<tr>
<td>Fail (N=87)</td>
<td>29.7</td>
<td>30.4</td>
<td>61.5</td>
<td>14.7</td>
<td>49.9</td>
<td>16.2</td>
<td>65.2</td>
<td>16.2</td>
<td>121</td>
<td>6.0</td>
</tr>
<tr>
<td>Class average</td>
<td>37.6</td>
<td>36.7</td>
<td>75.8</td>
<td>16.7</td>
<td>63.3</td>
<td>17.4</td>
<td>75.3</td>
<td>16.1</td>
<td>136</td>
<td>4.6</td>
</tr>
</tbody>
</table>

While these averages provide some characterization of ‘typical’ students and their performance, there are always students who do not fall within the averages; there are students who try very hard and attend every class, yet are not as successful as they would like to be, or students who do not initially perform well but are able to change their behaviors and find success. A closer look at a few of these students who fall outside the norm may provide some insights to certain behaviors that lead to success and how clickers may have played a part in their learning experience.
Case study 2 - A ‘C’ student with perfect attendance

Student #35 from the 8 am section of the spring semester attended every lecture during the semester yet earned a ‘C’ in the course. This student failed the first exam with a score of 63% and from the survey given following the first exam, the student strongly agreed that they were motivated to complete the assigned readings before class (question #8 with a response of 5), however they did not consistently correctly answer the reading questions leading up to the first exam. The student also agreed that they come to Chem 4 class more prepared than other classes that do not use clickers (question #23 with a response of 4) and that using clickers helped motivate them to keep up with the material on a daily basis (question #15 with a response of 5), however they also did not consistently correctly answer the review questions. This student performed well on the progress clicker questions, indicating they were able to grasp the concepts as they were being taught, however their low scores on the reading and review questions suggests they were not adequately preparing for the class. On the first exam, eight of the twenty-nine questions were based on clicker questions the students had seen during class; four questions were exact questions written verbatim and four questions were very similar with numbers changed in the questions. Half of the questions were conceptual in nature and the other half were algorithmic. This student answered four of these eight questions correctly, which was much lower than the class average of 6.1 on these eight questions, indicating that this student underperformed on the questions that were taken directly from lecture. Their score of 63% on the first exam supports this theory of not adequately preparing. Their clicker scores declined following the first exam, perhaps a downward spiraling effect (Jones, 1984) answering just 44% of clicker questions correctly, and this student did not pass the second exam, again scoring 63%. This student was attending every lecture, but needed some behavioral change in order to pass the course. As noted previously in the attrition section of this paper, the instructor made a deal with
the students immediately following the second exam to help prevent students from losing all hope of passing the course. The deal stated was that any student could pass the course with a “C”, regardless of final points earned, if they met four criteria; attend every lecture from that day forward, complete all homework assignments from that day forward, pass all three proficiency quizzes, and earn an 80% on the third exam and final exam. Following the second exam, this student’s scores improved on the reading clicker questions; they answered six of eight reading questions correctly. Their review clicker question scores also improved during this time period between the second and third exams, and they answered 63% of all clicker questions correctly during this time period. This student scored an 80% on the third exam and then a 72.5% on the final. On the final exam, twelve of the forty questions were identified as being similar or identical to clicker questions asked during lecture. This student scored on par with the class, answering nine of the twelve correctly while the class average was 73%. Their final homework score was 41.7 (out of 50 possible) which is a little above the class average of 39.5, but a little below the 42.8 average of those students regularly attending class. This student’s clicker points score over the course of the semester was 40.6 (out of 50), which was also a little above the class average but a little below the average of regularly attending students. This student seems to have struggled with identifying the study habits that would lead to success during the first half of the semester. It is plausible this student thought they were adequately learning the material in lecture as they were finding some success on the progress clicker questions. After failing both the first and second exams, however, this student may have realized a change was required to improve their performance on the final two exams and ultimately pass the course. After the deal was given by the instructor, this student may have had a renewed hope in passing the course and made an effort to improve their study habits. From the survey responses, it would appear this student changed their attitudes regarding the benefits of using clickers sometime during the semester.
From the post-exam 1 survey the student agreed they like using clickers in this course (question 1 with a response of 4), however, from the exit survey given at the end of the semester, this student strongly agreed that using clickers was a valuable part of the class (question #5 with a response of 5) and that the clicker questions helped reinforce the material from lecture (question #13 with a response of 5). Similarly, after the first exam this student disagreed that they would prefer having just lecture and no clickers in this course (question #16 with a response of 2), however at the end of the semester their response changed to strong disagreement (question #10 with a response of 1). Also from the end of year survey, this student thought the clicker questions helped identify whether they understood the material (question #19 with a response of 4) and found it beneficial to get instant feedback on the questions (question #21 with a response of 5). This student also strongly agreed they would like to use clickers in more of their classes (question #32 with a response of 5). From their survey responses it would seem likely that, during the semester, this student realized there was more benefit from using clickers than they originally thought. One possible explanation is that the clickers helped enable this student to identify what material they were having difficulty with in lecture, which helped motivate this student to improve their study habits and pass the course.

*Case study 3 - A student who did not perform well on clicker questions in lecture*

For those students who attended class regularly (zero or one absence during the semester), the average score from clicker questions was 43.2 points out of 50 during the spring semester, with a standard deviation of 2.7. Student #57 from the 10 am section missed just one lecture and earned 37.1 points, or over two standard deviations below the average. From the survey administered after the first exam, this student strongly agreed that they were motivated to complete the assigned reading before each class (question #8 with a response of 5) and keep up
with the material on a daily basis (question #15 with a response of 5). They performed well on the reading questions suggesting they were coming to class prepared on most days. This student indicated they regularly reviewed the clicker questions and added them to their notes after class (question #10 with a response of 5) and strongly disagreed that clickers had no benefit on their learning (question #13 with a response of 1). They performed very well on the review clicker questions suggesting they were completing the homework on time and reviewing their notes. For example, on 2/4/11 the topic of atomic mass and isotopes was introduced. The lecture concluded with the following progress check clicker question:

Silver has 2 naturally occurring isotopes. The lighter isotope, Ag-107 has a mass of 106.905 amu and an abundance of 51.84%. What is the mass of the other isotope (Ag-109)?
A) 107.87 amu
B) 52.45 amu
C) 108.97 amu
D) 55.42 amu
E) 52.49 amu
F) 108.84 amu
G) Not enough information is provided.

To correctly answer this question, students must multiply the percent abundance of each isotope by the mass and add the two components together. During lecture, 71% of the class answered correctly while this student did not. In the following lecture, the following challenge review clicker question was asked:

Gallium has two isotopes: Ga-69 (mass = 68.93 amu) and Ga-71 (mass = 70.92 amu). What is the % abundance of the heavier isotope?
A) 39.70 %
B) 39.95 %
C) 60.05 %
D) 60.30 %
E) Not enough information is provided

This is a more difficult question using the same concept and this student correctly answered the questions while only 36% of the class correctly answered, indicating this student had mastered
the calculations with this topic since the last lecture when they could not perform a simpler calculation. It would appear this student was putting forth considerable effort outside of class.

When asked what the most significant benefits from using clickers was, this student’s first choice was that it provided feedback on how well they understood the material (selection ‘B’ from 4/4/11 ad hoc question) and their second choice was that it provided practice problems while learning new material (selection ‘F’ on 4/4/11 ad hoc question). This student performed very well on the homework, earning 48.8 points from 50 possible, which was much higher than the class average of 43 points of the group of students who regularly attended classes. This is a student who was motivated to come to every class prepared and they completed all of the homework, with which they were very successful, yet they had difficulty with the questions asked in lecture. Instead of falling into complacency due to their success on the homework when they had ample time and notes available, it would appear this student used the feedback they were getting from the clicker questions asked in lecture and put in the work to learn the material. This student earned an 84% on the first exam and a 70% on the second exam, which is not a passing grade (73% is required to pass). This student then earned a perfect 100% on the third exam and a 90% on the final; one of only 27 students who earned an ‘A’ of the 213 students taking the final exam. This student, who appeared to struggle with new concepts as they were being taught, earned a ‘B+’ in the course. A conclusion that may be drawn from this case study may be that this student’s work ethic and attitude towards learning combined with the feedback they received from the clicker questions helped enable them to be successful in the course and overcome any difficulties they encountered with new concepts.
Case study 4 - A student who does not like using clickers

Student #98 from the 8 am section did not pass the first exam, earning a score of 70% (73% is required to pass) while the class average was 75.5 in the 8 am section. They attended every class up to that first exam and did well on the clicker questions, answering 32 correctly out of 37 questions during those first nine lectures. Three of the five questions this student did not answer correctly were reading questions; they performed very well on the progress and review clicker questions, missing just 2 of 32 questions. This was better than the class average by about one standard deviation; this student earned 32 clicker points while the class average was 27.6 for this time period. Of the 8 exam questions that were either identical or very similar to clicker questions, this student answered 5 correctly, which is below the class average of 6.1. From the post exam survey this student indicated they did not like using clickers in this class (question #1 with a response of 1) and strongly disagreed that the money spent on the clicker was worth the cost (question #29 with a response of 1). This student disagreed that the clickers helped keep them interested in class (question #7 with a response of 2) and that they would prefer just lecture and no clickers in this course (question #16 with a response of 4). This student agreed that sometimes they skip classes they consider boring (question #17 with a response of 4). The survey response data combined with the clicker scores may suggest this student felt like they could handle this course with a minimal effort and they did not need clickers to help them learn. This student then missed two lectures between the first exam and second exam, and they answered 66% of the clicker questions correctly on the days they attended class; they missed one reading question, four review questions and five progress questions. This student earned 19 points from clicker questions during this time period which was slightly above the class average of 17.2 for the lectures attended by about one-half of a standard deviation. After failing to pass the first exam, it does not appear that this student changed study habits or came to class more
prepared in order to improve their exam score. In fact, the student’s relative performance with the rest of the class declined on the clicker questions. They earned a 67% on the second exam, again failing to pass. This student was now halfway through the course and had not passed either of the first two exams. They did not miss the cut by much on the first two exams and if this student earned 80% on the third exam and final, they would pass the course; they did not need the special deal the instructor offered in order to pass. However, this student would need to change some aspect of their behavior in order for to pass the course. This student did not miss another lecture and their clicker scores improved, providing correct answers to 83% of the clicker questions asked. They missed two reading questions from 4/18/10 and 4/22/11, however only 58% of the students answered the reading question on 4/13 and 44% correctly answered the reading question on 4/22. This student scored a 95% on the third exam and an 80% on the final exam, giving them a final grade of a ‘B-’ in the course. From the final survey administered at the end of the semester, it appeared this student’s attitudes regarding the use of clickers in this course had shifted from their attitudes earlier in the semester. Perhaps most significantly, this student agreed that using clickers was a valuable part of this course (question #5 with a response of 4). This student learned that the clicker questions helped identify whether they understood the material or not (question #19 with a response of 4) and they found it beneficial to get instant feedback whether they could answer the questions correctly or not (question #21 with a response of 4). This student also agreed the clicker questions helped reinforce the material from lecture (question #13 with a response of 4). In answering identical questions from the post-exam 1 survey, this student’s responses did not flip-flop, however they did move towards being more open to using clickers; their final judgments were neutral, instead of being negative, in considering the cost of the clicker to be worth the expense (question #29 with a response of 3) and in preferring to have just lecture and no clickers in the course (question #10 with a response of 3). Interestingly, this
student ultimately agreed they would like to use clickers in more of their classes (question #32 with a response of 4). It would appear this student realized there were significant benefits from using clickers they had not previously recognized, and they helped him/her succeed in the course.

**Instructor perceptions**

**Question:** What were some of the challenges you encountered with using clickers?

**Response:** The biggest challenges were technological…there was a little bit of a learning curve, but mostly it was the technology. There were issues of dropped answers, dead batteries, and broken clickers. My receiver broke once and I had to get a new one. It is important for the instructor to be flexible and have back up plans…what’s your policy if a student forgets their clicker, if they don’t have batteries, or the batteries die…and so forth. Once you’ve experienced a gamut of the problems, you can develop an approach for them, and then it’s doable. You definitely have to have back-up plans. On those few occasions, they understood that we were just going to treat it as normal and were still pretty engaged. But I think if that happened once a week, then it would be a much different environment. In general, they worked though. One example of a backup plan I used was that we double-submitted answers on exams.

I could imagine it could be challenging for some instructors with writing the questions, but I had Stuart writing the questions, and I also have a lot of experience with science education. But even with that, it took a while to figure out the pattern of what worked best with what types of questions, how many, and the point system. But after about a year, the average instructor should have that pretty solid, and then it is just fine tuning. Even now, after several semesters, I am still editing the questions.

**Question:** What were the most significant benefits from using clickers with your teaching?
Response: It gives me a carrot and a stick to hold the students accountable. As teachers, we can say things like we value a student-centered classroom, we value students coming prepared to class, we value peer teaching, we value student engagement and participation, and we value student attendance. Teachers have lots of little tricks for dealing with some of those things, but not all. There are things like voting with cards, or turning in those note cards I did. But I could only do that about once a week…because then I had to sort and grade 300 note cards. So I was trying to do certain things that I knew would be valuable, but now I have a tool that can allow me to do all of those things all at once. I could say, “Did you come to class prepared today?” If not, here’s a question. “Did you review notes from last class…are you even here?” So now I have a tool that facilitates everything that I want to do.

Now, if you’re going in with an attitude of being very much didactic and want to lecture for 50 minutes, then the clickers won’t do anything for you. But if you value these other things like peer teaching, student-centered learning, attendance and effort during class, then you have this tool that makes it easy to reinforce those things. I could do many of the things I want to do without clickers with a small classroom, but once you get over about 30 students, I just don’t know how you do it.

I was able to reinforce student behavior consistently. I think students were there more often and more engaged, and I got this upward spiral instead of a downward spiral, using both a carrot and a stick, and using different pedagogical practices.

Question: How much did your pedagogy change while using clickers?

Response: Using clickers didn’t change my pedagogy because there were always things I valued that I knew were beneficial to my classroom, such as student-centered learning. There were things that were halfway implemented, however, because there was no easy way to implement them. For example, I would ask questions in class, just not with the clickers. But half
the students would sit there stare at me…so the pedagogy was there, but there was no good way to implement it. But now, I can say you’re either going to get 5 points today or 10 points today, depending on how you work on these problems. So they work on them! And so it’s allowed me to do the things I wanted to but couldn’t.

Before jumping on the clicker bandwagon, and saying “this is great, this semester I got 90% attendance and 70% pass rate!” I realize that it’s not the clicker doing those things. It was the contract for attendance, it was getting them to attend, it was the peer teaching, and it was those things facilitated by the clickers. So you have to be comfortable doing those other things, thinking about a more student-centric classroom. I had trouble taking it to the degree I wanted to because there was no carrot and stick that were readily available for that. But with clickers, I was able to hold them accountable for the things I wanted them to do.

I think another thing the clickers helped with was making the classroom more interactive both ways. My classroom was always very interactive one way with me giving them things to do, but the backwards feedback wasn’t there. You can have students hold up an index card, but it’s still not the same as showing the bar graph with 82% getting the question right, and seeing the wrong answers that were also selected. The students get a feeling much more clearly that I’m listening to them. So this situation just happened in a recent lecture where the vast majority of students answered the question wrong…and then I said “whoa…I must not have done a very good job of explaining this to you.” And it was me taking some responsibility for 80% of them getting it wrong, and recognizing there’s some disconnect here, so let’s work on it some more. And I think they really appreciate that.

I think the last big change is helping them engage more cognitively, reflecting more on the material with the formative assessment, which wasn’t there if students give the problems a half-hearted effort, or if I reviewed the question right afterwards and gave them the answers. But
now when students see 80% of the class answer correctly but they did not, they might think, “I have a gap here. I need help. I need to work harder. I need to come more prepared.” So we may be supporting a little more reflection on the students’ parts.

**Question:** What’s the ‘big picture’ conclusion you’ve drawn from using clickers?

**Response:** Clickers have been the closest I’ve had to a magic bullet, where I say “Holy cow”, this just allowed me to do so many things. The math worksheets helped maybe 5% of the students, the study skills worksheets helped maybe 5% of the students, or a few students do a little bit better. But the using the clickers has been the first time where I saw such a big, whole scale shift in the class. Because it tackled so many things…it helped attendance, it helped them come prepared, it helped me give them formative assessment, it gave me formative assessment, helped them be more engaged, provided peer learning opportunities, increased their attention span, and on, and on. It’s not the clickers; it’s what the clickers facilitate. If I could do all of these things without the plastic, and without having students pay for it, and without the technical issues…of course I would. But I haven’t figured out a way to do all of those things. Nobody hands you a clicker and says “This is the pedagogy”…you have to figure that out for yourself, you have to meld it with your own philosophy, you have to meld it with your students, and with the subject matter. Do you have calculations, do you have rote memorization questions…what is your content? So you have to meld it with all of those things. There is no canned pedagogy. You have to figure out how it is going to work for you. And it is that iterative process of reflecting on what the positive directions have been, what didn’t work, taking those inputs and thinking how you can capitalize on this. So it is a tool to do clever things with. You can do really boring things with it, or you can think outside the box and shoot for the moon…”what can I achieve with this new tool I have?”
**Question:** What are your recommendations for other instructors considering using clickers?

**Response:** For anyone thinking about using clickers, my recommendations would be first to observe somebody with more experience using them and see what they’re able to achieve. And have some conversations with them. You’re going to need to articulate what your goals are and what you value, beyond just traditional objectives like “I want 90% pass rate”. But how do you achieve that, and what are you values? It helps to have conversations with people who are using clickers, and who are thinking about their teaching. And look at the research literature; although there is some flawed research out there, there are also some good ideas too about how to use clickers. Carve out some time, because it will take some time shifting over and using clickers for the first time. Maybe start planning on it before you do your shift. I think it is imperative to have a student-centered classroom, and if you’re not in that direction already, then think about what small steps you can take in your classroom even before you use clickers that will move you to a student-centered classroom. Maybe for one semester or a year, you can emphasize students coming to class prepared, so you’re going to figure out without clickers what you can do that will move you in that direction that you value. But if you start looking at your teaching, and you think you can achieve all of those things you want to do….and you think attendance doesn’t have a value, or student-centered doesn’t have a value, then clickers are not a great tool for you. So it is really about understanding what your goals are and what things you are not thinking you can achieve right now with your current technology or in your current class environment.

Beyond that, take baby steps. You don’t have to have a full curriculum of clicker questions for the full semester. You could start out with say two a day, but I think you would see limited benefits, but it just makes the workload manageable. Also, I think if you do one question a week, every other week, there’s not enough reinforcement for them to say “Oh this is a good
idea; this is what I should be doing.” So you have a significant number of students who are just zoning out. So if you start out really small that first semester, you probably won’t see any benefit because you haven’t used a lot of clicker questions, but you are still fine tuning, and that whole first semester issue. Then that second semester you have most of your clicker curriculum and you are fine tuning their use…so I think three to four semesters is what you need to commit to. Even someone like me who does something like this for my research and had a full grad student working on it, we didn’t see much the first semester. So you really need to put several semesters in.

**Analysis of second semester data**

Several changes concerning the use of clickers were implemented for the second semester of this study in order to maximize the possible benefit from using the devices. Clearly, the changes made had a significant impact on student daily attendance, as was expected from the literature (Caldwell, 2007). The attendance-performance graph shown to the students at the beginning of the second semester may have had an effect on this second semester of the study, particularly in the lectures preceding the first exam while the message was still fresh in the students’ minds. Perhaps the modified clicker questions were more engaging and motivated students to attend class more regularly throughout the semester (Graham, 2007), although that is difficult to determine based solely on attendance data. It is likely, although difficult to confirm, that the change in point structure influenced student behaviors by providing additional incentive to attend class and participate with the clickers, even if not adequately prepared (Weiler, 2005). It is also very likely that the contract made with the students following the second exam influenced attendance between the second and third exam. The offer was intended to provide a way for students to pass the course who were, up to that point, not passing and at risk of losing
hope of passing the course, possibly resulting in more absenteeism (Jones, 1984). The data show a modest decline in absenteeism in the spring semester following the second exam, as opposed to an increase as was seen in the fall semester, and this deal likely had an influence on this effect.

It has been shown from both the literature and the results of the first semester that student performance is linked to attendance (Herman, 2009; Moore et al., 2003; Slem, 1983; Dobkin et al. 2010; Soto, 2009; Clump 2003; Jones, 1984; Van Blerkom, 1982; Jenne, 1973). Therefore, it would be expected that student performance in the spring 2011 semester would improve as attendance improved, and this trend was seen. On the comprehensive final exam, a record 69% of the students who took the final exam passed it, relative to a historical average pass rate of 55%. Perhaps the most impressive quantitative result from this study was seen in the relationship between student attrition and final exam score. It was historically seen that when more students remained in the class and took the final, the average score on the final exam would decrease.

While using clickers however, the opposite effect was seen. Not only did more students remain in the class to take the final, but the average score improved significantly. The agreement made with the students to offer them a chance to pass the course regardless of their scores through the second exam very likely influenced more students to stay in class. By keeping these low performing students in class, one expectation would have been to see a reduction in the average final exam score and the course completion rate. Instead, a significant improvement was seen in both. It would seem some other class dynamic changed that led to the improved test scores in spite of keeping the weaker students in class. Possible explanations include that clickers help enable valuable formative assessment opportunities (Beatty, 2004; Gormley-Heenan, 2009, Mazur, 1997), help foster greater student engagement and active learning (Graham, 2007; Graham, 2007; Kaleta and Joosten, 2007; Trees and Jackson, 2007; Gormley-Heenan, 2009), help
slow down the flow of new information, allowing students more opportunity to process new information, and a host of other proposed benefits that were described in the literature review.

In comparing the final exam scores from the two semesters of this study, there was only minor improvement in the number of students passing the final among the students who attended class regularly between the two semesters. This should be of little surprise as these highly motivated students require less external motivation and are better prepared to gauge their level of understanding in order to be successful (Weiler, 2005). Perhaps the adjustments made in the spring semester by altering the clicker questions for the spring, adding more types of clicker questions, incorporating peer collaboration, and the other adjustments made had a more profound effect on the students who were not highly motivated to have perfect attendance and perhaps did not begin with the best study habits (Greer and Heaney, 2004). It was shown at the beginning of this chapter that there was a change in the distribution of grades between semesters with more students earning “A”s and “B”s while fewer students failed to pass the final in the spring semester compared with the fall semester (Addison, et al, 2009). While there was little change in average performance on the final exam among students who missed one or fewer lectures, there was a significant gain in performance on the final exam among students missing more lectures. For example, the group of students in the fall semester who missed between two and seven lectures during the semester (N=96) earned an average score of 69.8% on the final exam while the same subset of students from the spring semester (N=78) earned an average score of 74.6%. It seems reasonable that using clickers will not have the same effect on every student and that certain groups of students may gain more from their use than others.

A compelling summative piece of evidence towards the benefits from using clickers comes from comparing student pass rates among groups of students with the same number of absences. Of little surprise, pass rates among students with perfect attendance or missing only
one class during the semester did not change between semesters. The pass rate among students missing two to three lectures, however, increased sharply from 48% (fall 2010) to 67% (spring 2011). The pass rate among students who missed four or five classes also rose sharply from 44% (fall 2010) to 63% (spring 2011). Students with similar attendance records performed much better during the second semester of the study than in the first. Controlling for attendance in this manner suggests that other changes in course design between semesters also significantly contributed to student success.

Based on the student surveys, the students believed that using clickers enhanced their education, which was consistent with the literature (Preszler et al., 2007; Gormley-Heenan, 2009; Trees and Jackson, 2007; Uhari et al., 2003). They appreciated the formative assessment opportunities and thought the devices helped keep their attention during lectures. It was also shown in the case studies that in particular situations, students changed their perceptions of using the devices during the semester, growing fonder of their use and realizing there was more benefit than originally perceived. Many authors in the literature cited noted that using clickers effectively took practice on part of the instructor (Crossgrove and Curran, 2008; Gauci et al., 2009). It might also be true that it can take time and practice for students to realize the full benefits as well. As the instructor becomes more adept at using the devices and is more convinced of their value, the students may respond to the instructor’s enthusiasm towards using the devices. As the students begin to see the advantages from using the clickers, they may increase their active participation, further enhancing the benefits from being in class.

The instructor felt that using clickers has clearly been the most useful tool to support the pedagogy he strives for in a large class environment. Historically, it has been challenging to reward (or penalize) attendance and to have a bidirectional dialogue with the students. The instructor already has taken careful steps to create an active learning environment, as well as
identify and address student deficiencies or problem areas. Low attendance and course pass rate remained a chronic problem despite these efforts, however. Using clickers offered a solution in motivating students to attend class, motivating students to participate in class, and in facilitating continuous and honest two-way dialogue to gauge their level of understanding. The enhanced dialogue led to instructional behavior changes, such as addressing misconceptions, clarifying a topic the students did not understand or moving quickly past a topic the students clearly understood to allow extra time for other topics. Student behaviors may have changed as a result of the additional dialogue by increasing their active participation in class, seeking answers to problems they did not understand when the majority of the class was successful, or altering their study habits in order to be more successful.
Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The focus of this research was to determine whether using clickers facilitates an improvement in learning with Chem 4 students and, if so, how the clickers may facilitate pedagogy that contributes to student learning. While the instructor and the students saw benefits from using the devices, there was minimal statistically significant improvement in attrition or performance during the first semester of this study. The data, however, did clearly show that performance was linked to attendance. Several changes were made as part of the iterative process of action research design, using knowledge gained from the first semester of the study. The changes were intended to motivate students to attend class more regularly, while improving the quality of clicker questions. The results from the second semester of this study showed significant improvements in both reducing attrition and improving student performance on exams and overall course completion. The published literature (Beatty, 2004; Martyn, 2007; Kaleta and Joosten, 2007) indicated that using clickers effectively was a skill that often required time and practice to fully develop, and this was found to be true in this study.

The combined results obtained after implementing clickers are truly impressive compared with the historical values because improvements in one area were not being gained due to sacrifices in other areas, as was seen in prior semesters. Prior to using clickers, average scores on the final exam decreased as more students took the final exam, and conversely, average scores increased when absenteeism increased and fewer students took the final exam. While using clickers, however, average test scores significantly increased while also keeping more students in the classroom and taking the final exam. Both are significant achievements by themselves, and particularly impressive when combined, as seen in this study. Assuming an average annual
enrollment of 500 students in Chem 4, a 5% reduction in attrition that was seen in the second semester of this study equates to an additional 25 students who would complete the course each year. An improvement of 14% over the historical average of students passing the course equates to 70 students who would not need to repeat the course and would advance to Chem 1A each year.

This study confirmed that students who attend class more regularly perform, on average, better than students who attend class less frequently. Achieving higher attendance rates is one key aspect to student performance, and this aspect can be influenced by the use of clickers, using a penalty or reward system affecting student grades. Instructor pedagogy and student engagement are also critical elements that affect student learning. While the instructor in this course historically has used a student-centric pedagogy, it was typically one-way communication. The use of clickers allows a two-way dialogue which promotes active participation from the students. Instead of posing questions to the class and having many students sit idly by until the answer is provided, using clickers can help reward students to participate and put forth their best effort. The students are better able to construct their own mental framework of knowledge by being more actively engaged in lecture, having fewer chunks of information to process in between breaks in the lecture, being given appropriately challenging questions to apply new information or skills while receiving formative assessment concerning their learning, and having adequate time to recall the new information in order to answer those questions.

As opposed to a downward spiral that was presented in the literature and also seen in this study, many students likely experienced an upward spiral when clickers were used. The students were encouraged to attend class and participate, and were then rewarded with good test scores. With that positive reinforcement, they continued to attend class regularly and participate, followed by continued positive performance. The instructor’s excitement from seeing improved
attendance and test scores from the first semester is likely brought into class for the second semester. This positive energy likely influences student perceptions of the clickers as well as their overall attitude toward the class in a positive spiral of classroom energy and participation.

Data from the student surveys indicate that the students were overwhelmingly in favor of using clickers. Many students who were skeptical of their use at the beginning of the semester changed their views and were in favor of using clickers by the end of the semester. Students saw many benefits from using clickers, but one common theme was a more engaging class lecture which helped maintain their attention levels while also recognizing that having a portion of their grade tied to their attendance and participation provided motivation for coming to class.

While the results clearly show an improvement in student performance while using clickers, it is again reiterated that the clickers are a tool to support a pedagogy the instructor wishes to implement. According to the instructor, clickers have been the best tool he has seen that enables him to easily address several known deficiencies in his class, all at one time. Chem 4 is a large enrollment class where taking attendance and encouraging a dialogue with the students has historically been difficult. Using clickers enables a method to monitor and reward attendance in addition to getting honest feedback from nearly all of the students regarding their understanding of the topics being presented and discussed in class. Being able to collect and store the data from clicker responses for further analysis enables the instructor to more clearly identify student misconceptions and areas of difficulty so as to alter future content delivery in an effort to better teach the students. One clear example of this application from this study concerns the topic of significant figures. After placing additional focus over prior semesters on significant figures during the second semester of this study by offering more wrong answers to clicker questions due to significant figures, there was only minimal improvement made when students were asked to identify the correct number of significant figures after performing a calculation.
with mixed functions; using addition/subtraction and multiplication/division in the same calculation. This topic was known to be challenging for students in Chem 4 and students clearly were not learning some key aspect of this topic. It was learned from this study that simply doing more of the same (i.e. more practice and more questions) did not help them learn the topic of using and applying significant figures. It seems a different approach needs to be taken to help students overcome this hurdle. This is just one particular topic that was targeted during this research, however it shows that the task of improving student performance in Chem 4 is far from over and requires a continuous effort. Using the backwards design approach, a clear understanding of what the students need to know has already been identified for this topic and the challenge now is to define a new method of teaching the material that will help the students learn. The students likely are not aware of what will help them and cannot directly communicate what they need. By continuing to use clickers, however, new methods of instruction can be attempted while getting real-time, honest feedback from the students. The instructor can use the formative assessment data to alter instruction real-time, especially when knowing what to look for.

Improved attendance, reduced attrition, heightened student engagement, improved exam scores, increased course pass rate, positive student feelings about using clickers, and the instructor’s positive feedback are all taken together as part of a triangulation approach to evaluate the efficacy of using clickers in Chem 4. All inputs suggest that using clickers has had a positive impact on student learning by aiding the instructor to create a more engaging classroom, rewarding attendance, and utilizing a more effective method of instruction for this introductory chemistry course.
Recommendations

It is apparent from the study that using clickers does provide the instructor with an additional tool to motivate and engage the students in active learning, and students do respond to having their grades impacted by attendance and participation. Students also recognize and appreciate the effort to improve instruction, and they see the benefit from being able to give the instructor feedback, as well as receiving the feedback themselves as to how well they understand a topic. After analyzing the results and reflecting what has yet to be accomplished, there are three focus areas that need to be further developed.

The first recommendation from this study is to continue using clickers in Chem 4 and strive for continued improvement in student learning while continuing to find best practices for using clickers. While improvement has been realized in both attrition and performance, additional gains can still be achieved. One suggestion would be to increase the impact on the students’ final course grades from the clicker points and identify whether this has a positive impact on student performance. During this study, 7.5% of the students’ final grades were attributed to clicker points. It might be beneficial to create more incentive for students to come to class prepared as well as take the time to learn from their mistakes so as not to lose additional points on future questions. There were cases where it seemed many students were not coming to class prepared and increasing the reward, or penalty, might change their behaviors. One benefit Mazur (1997) found as important to his success with using clickers was in having students come to class prepared and ready to learn new material. The instructor from this study also noted the benefit of students doing the reading prior to class and thus not needing to cover the basics that students could get from the textbook. These “are you prepared” questions provide excellent opportunity to quickly reward the students and identify any possible misconceptions from the reading. Clearly there is a group of highly motivated students who do not need the external
rewards and will be successful under most any circumstance. There is a large student population, however, that does need some external motivation to help them develop the necessary study habits and learn how to be successful in a college science course. By combining the “are you prepared” with the “are you learning” types of questions, instructors can motivate students to come to class and keep students’ attention throughout a lecture period while challenging and assessing student learning.

In addition to modifying the point structure from using clickers, it would be beneficial to identify specific topics students are having difficulty with, such as significant figures that has been discussed previously, and modify instruction in those areas in order to help students overcome those hurdles. As opposed to waiting for exams to assess student learning, which require long periods of time before trying new strategies, instructors can try new approaches and assess learning on a real-time basis using clickers. Instructors can also ask the students which strategies are most helpful to them during individual lectures by posing appropriate clicker questions during those lectures. It would be interesting to try different types of attitudinal questions to better elicit student responses concerning their perceptions as to what is most effective in helping them understand the lecture material. While there are many suggestions from the published literature, only a handful were used in this research and there are surely many new approaches yet to be discovered that are effective in this area. Since it requires such little class time to ask a clicker question, it could be beneficial to try new types of questions, both instructional and attitudinal, in order to find those that work most effectively. This process can enable instructors to alter their teaching based on what the students are saying they need on a real-time basis, as opposed to what the instructor assumes the students need in order to learn the more difficult topics in the course.
A second possible future research area in studying the effectiveness of using clickers might include studies with other chemistry courses at CSUS. Chem 1A, for example, is a large enrollment course where attendance is not taken, has attrition problems, and has student pass rates that are less than ideal. Students are required to learn more concepts and at a faster pace in Chem 1A compared with Chem 4, and students who fall behind have a very challenging task of catching up, often dropping or failing the course. Higher level chemistry courses may also benefit from using clickers for all of the aforementioned benefits of active learning and formative assessment, and it would be interesting to study the effectiveness of using clickers in courses such as organic chemistry, physical chemistry and inorganic chemistry, as just a few examples. While instructors may not have concerns with motivation or attendance in these higher level courses, there could be benefits to motivating students to come to class more prepared and actively participating in class. By actively applying the concepts they are being taught students may be able to build a more extensive framework of knowledge in their minds than might otherwise be built by listening to a didactic or pedantic lecture.

While it would be very interesting to expand this research to other courses, it is likely a daunting task for many instructors. The thought of redesigning their courses and incorporating an unknown element (clickers) to their classroom may deter many instructors from embracing the idea of using clickers for the first time. Thus, the third potential focus area is to create a forum for using clickers at CSUS, across academic disciplines. Instructors who have used clickers can share challenges they have encountered, solutions they have found and actual clicker questions they have used and found to be beneficial to student learning. There is no need to re-invent how to successfully use clickers and there is a tremendous amount of existing knowledge that can be shared. In addition, it could be very helpful for instructors considering using clickers for the first time to have a resource at their campus from which to gather information. In addition to the
pedagogical advantages of sharing information, instructors can also help each other overcome any technical difficulties, as well as unite their voice when working with companies selling the clickers and clicker software. From the two semesters of research during this study, there were several occasions when the clicker responses were not being received and the instructor had to alter his planned lecture material. It would be understandable for first time users, who have not yet seen any direct impact on student learning, to abandon using clickers if they encounter too many of these inconveniences from the clickers. If instructors are sharing information and teaming up as a single user group to the manufacturer, however, they would be likely to overcome any technological hurdles more quickly than if acting alone. Also, many instructors who have used clickers in their classrooms at one time have stopped and it would be enlightening to understand why. Thus it could be beneficial to interview instructors at CSUS who have used clickers in order to understand what has worked well and what has not to identify best practices or pitfalls to avoid for new users considering the technology. While there is a vast amount of published research, it could be beneficial to have a more focused study from CSUS instructors using clickers with CSUS students; some instructors might find the data more relevant or trustworthy. They would benefit from having access to the instructors to talk with and further discuss their experiences of using clickers. Thus, organizing a community of clicker users on campus and publishing knowledge gained from experienced users would be beneficial on multiple levels.
APPENDIX A

List of content clicker questions used

Class period 1

Clicker question #1 (reading check): Based on your reading for today, which of the following statements is FALSE?
A) In amorphous solids, the atoms/molecules do not have long-range order.
B) Liquids have indefinite shape and definite volume.
C) Compounds are substances composed of two or more elements in fixed proportions.
D) Heterogeneous mixtures have the same composition throughout.
E) Physical properties are those that a substance displays without changing its composition.
F) Melting is an example of a physical change since the process results in a new form of the same substance.

Clicker question #2 (progress check): Based on what you have just learned, which of the following is not an example of matter?
A) Books  D) Rocks
B) Water  E) Thoughts
C) Air   F) People

Clicker question #3 (progress check): Based on what you have just learned, which of the following is an example of a chemical property of a sample of hydrogen gas?
A) Boiling point  D) Mass
B) Compressible  E) Colorless
C) Flammable  F) Density

Class period 2

Clicker question #1 (review from last class): Based on what you have learned last class, identify the mistake in the following concept map:

![Concept Map Diagram]
A) “Reaction with acid” should be listed under “physical properties”.
B) “Light” should be listed under “examples” of matter.
C) The terms describing “physical properties” and “chemical properties” are switched.
D) The arrow between “matter” and “submicroscopic properties” should be pointing in the other direction.
E) It was “Socrates” who coined the term “atoms” to refer to “submicroscopic particles”.

Clicker question #2 (reading check): Based on your reading for today, which of the following statements is TRUE?
A) Dmitry Medvedev is credited with developing the first periodic table.
B) The original periodic table was used to predict the existence of undiscovered elements.
C) The properties of the “transition elements” tend to be more predictable based on their position in the PT than the “main-group elements”.
D) Metalloids are the best conductors of electricity.
E) The original periodic table was based on a theoretical understanding.
F) The “noble gases” are the most expensive elements, so historically, only nobility could afford them.

Class period 3

Clicker question #1 (review from last class): Based on what we have learned so far this semester, which of the following drawings is not an appropriate room temperature representation of the element listed? Note: the box is the container for that sample and each circle represents 1 atom of that element. Feel free to use the periodic table.

A. iron                 B. helium     C. hydrogen

D. oxygen               E. copper     F. argon
Clicker question #2 (reading check): Based on your reading for today, which of the following statements is FALSE?
A) The number of protons in an atom’s nucleus defines which element it is.
B) Based on his “gold foil experiment” Rutherford first proposed the nuclear theory of the atom.
C) The protons and neutrons which make up an atom’s nucleus account for the majority of the atom’s mass (> 99.9%), but only a small fraction of its volume.
D) Protons and neutrons have equal and opposite charge.
E) The mass of one proton is approximately equal to one atomic mass unit (amu).
F) Thomson first discovered the electron, changing the common view that the atom was the smallest unit of matter.
G) An atom’s atomic number, Z, represents the number of protons in the atom’s nucleus.

Clicker question #3 (progress check): A given carbon nucleus is found to contain 6 protons and 8 neutrons. How many electrons (rounded to the nearest whole number) would be required to equal the mass of the carbon nucleus?
A) 14    D) 25,656
B) 25,661    E) 25,455
C) 3,665    F) 87,273

Clicker question #4 (progress check): Based on what you have learned today, which of the following statements is true with regards to the element with Z = 16? Feel free to check the periodic table.
A) The element is oxygen. Oxygen must have 16 neutrons in the nucleus.
B) The element is oxygen. Oxygen has a total of 16 protons and neutrons.
C) The element is oxygen. A neutral atom of oxygen must have 16 electrons.
D) The element is sulfur. Sulfur must have 16 neutrons in the nucleus.
E) The element is sulfur. Sulfur has a total of 16 protons and neutrons.
F) The element is sulfur. A neutral atom of sulfur must have 16 electrons.

Class period 4

Clicker Question #1 (review from last class): Which of the following statements concerning the element Be is TRUE? [Feel free to use a periodic table.]
A) Its melting point is an example of a chemical property.
B) Be is a diatomic element.
C) An atom of Be has 4 neutrons.
D) Be is the atomic symbol for Berkelium.
E) Be is an example of an alkaline earth metal.
F) Its nucleus accounts for most of the volume of a Be atom.

Clicker Question #2 (reading check): Which letter corresponds to the main topic you were asked to read about for today’s class?
A) “Forming ions”    D) “Metric system”
B) “Compounds”    E) “Chemical formulas”
C) “Isotopes”    F) “Conversion factors”

Clicker Question #3 (reading check): Based on your reading for today, which of the following statements is false?
A) An atom’s “mass number” is the sum of the number of its protons and neutrons.  
B) Different isotopes of the same atom have different numbers of protons.  
C) It is possible to determine the number of neutrons in the nucleus of an atom given that atom’s “mass number” and “atomic number”.  
D) An atom’s “atomic number” indicates the number of protons in its nucleus. 
E) Different isotopes of a given element have different masses.  
F) All of the above statements are true.

Clicker Question #4 (progress check): Which answer lists, in the correct order, the # of protons, the # of neutrons, the atomic number, and the mass number for the isotope, 
A) 235, 143, 92, 235  
B) 143, 92, 235, 92  
C) 235, 92, 143, 92  
D) 143, 92, 92, 235  
E) 92, 143, 92, 235  
F) 92, 143, 235, 92  

Class period 5

Clicker Question #1 (review from last class): Based on what we learned last class, which of the following isotopes has the greatest number of neutrons? 
A) Cu-65  
B) Ga-69  
C) Ge-76  
D) Se-77  
E) Not enough information is provided.

Clicker Question #2 (reading check): Based on your reading for today, which of the following statements is false? 
A) The atomic mass is an average mass for an element, accounting for the masses of its isotopes and their abundances. 
B) Any given element may have many different isotopes, but only 1 atomic number. 
C) Some isotopes are not stable and can transform into other elements. 
D) Looking at the periodic table, the atomic mass for carbon is 12.01 g. 
E) For an element having 2 different isotopes, its atomic mass will be closer to the most commonly occurring isotope.

Clicker Question #3 (progress check): Chlorine has two naturally occurring isotopes. One has a mass of 34.969 amu and a 75.78% natural abundance. The other isotope has a mass of 36.966 amu and a 24.22% natural abundance. Without looking at the periodic table, what is the atomic mass of chlorine? 
A) 36.95 amu  
B) 35.95 amu  
C) 36.50 amu  
D) 35.45 amu  
E) 37.20 amu

Clicker question #4 (progress check): Silver has 2 naturally occurring isotopes. The lighter isotope, Ag-107 has a mass of 106.905 amu and an abundance of 51.84%. What is the mass of the other isotope (Ag-109)? 
A) 107.87 amu
Clicker question #5 (challenge homework question): Gallium has two naturally occurring isotopes: Ga-69 (mass = 68.93 amu) and Ga-71 (mass = 70.92 amu). Using only the information available on the periodic table, determine the % abundance of the heavier isotope? Hint: what do you know about the sum of the two abundances?
A) 39.70 %
B) 39.95 %
C) 60.05 %
D) 60.30 %
E) Not enough information is provided

Class period 6

Clicker Question #1 (review from last class): Over the weekend, Jeff created a new element (Z = 130) and named it jeffrium (symbol = Jf). A sample of 10 atoms of Jf indicating the percent abundance of its 2 isotopes is shown in the box below. What atomic mass should be written on the periodic table for Jf?

KEY
○ Jf-235 (334.9 amu)
● Jf-238 (337.9 amu)

A) 130 amu
B) 335.8 amu
C) 336.7 amu
D) 337.0 amu
E) 337.4 amu
F) 338.2 amu

Clicker question #2 (challenge homework question): Question #5 from class period 5.

Clicker question #3 (reading check): Based on your reading for today, which of the following statements is false?
A) Compounds are substances composed of 2 or more elements in fixed, definite proportions.
B) Compounds retain the properties of the elements from which they were formed.
C) The law of constant composition states that every sample of a given compound will have the same proportions of their constituent elements.
D) Chemical formulas indicate the elements present in the compound as well as the relative number of atoms of each.
E) Any sample of rust (iron oxide, Fe2O3) will contain 3 oxygen atoms for every 2 iron atoms.

Clicker question #4 (progress check): What is the mass % of N and O in a 5.50 g sample of HNO3?
A) 15.8% N and 82.6% O  D) 22.2% N and 76.2% O
B) 18.0% N and 80.4% O  E) 26.4% N and 72.0% O
C) 20.1% N and 78.3% O

Clicker question #5 (progress check): What masses of N and O can be isolated from 1.66 g of HNO3?
A) 0.369 g N and 1.26 g O  D) 0.553 g N and 1.08 g O
B) 0.451 g N and 1.18 g O  E) 0.618 g N and 1.01 g O
C) 0.502 g N and 1.13 g O

Clicker question #6 (progress check): A sample of HNO3 contains 6.02 g of N. What is the mass of the sample?
A) 5.13 g HNO3  D) 20.4 g HNO3
B) 11.0 g HNO3  E) 27.1 g HNO3
C) 18.8 g HNO3

Clicker Question #7 (challenge homework question): If one sample of rust (Fe2O3) contains 13.5 g Fe and 5.80 g O, how many grams of Fe can be recovered from a second sample of rust containing 13.1 g O?
A) 30.5 g  
B) 5.98 g  
C) 20.8 g  
D) 5.63 g  
E) 32.4 g  
F) None of these

Class period 7

Clicker question #1 (review from last class): Pure water is 88.8% oxygen by mass. What mass of hydrogen can be isolated from 95.0 g of water?
A) 8.6 g  D) 85.4 g
B) 13.8 g  E) 21.2 g
C) 84.4 g  F) None of these answers is correct

Clicker Question #2 - homework from last class period

Clicker Question #3 (independent learning): How many total atoms are in one unit of: Al2(C2O4)3 ("oxalate", see naming handout)
A) 3  B) 8  C) 16  D) 20  E) 24
Clicker question #4 (reading check): Based on your reading for today, which of the following statements is false?

A) Losing one or more electrons results in the formation of a positively charged ion.
B) Molecular compounds are formed from two or more non-metals.
C) Positively charged ions are called cations; negatively charged ions are called anions.
D) Ionic compounds are formed from one metal and one or more non-metals.
E) Oxygen is an example of an atomic element.
F) Ionic compounds always contain cations and anions in a ratio that cancels out their charges.

Clicker question #5 (progress check): Which of the following chlorine containing compounds are ionic: CaCl₂, HCl, CCl₄, CuCl₂, AlCl₃, NH₄Cl, PCl₅

A) HCl, CCl₄, NH₄Cl, PCl₅
B) CaCl₂, CuCl₂, AlCl₃
C) CuCl₂, AlCl₃
D) CaCl₂, HCl, CuCl₂, AlCl₃
E) CaCl₂, CuCl₂, AlCl₃, NH₄Cl
F) CuCl₂, AlCl₃, PCl₅

Clicker question #6 (progress check): Which of the following statements is False? Feel free to use a periodic table.

A) The typical ion of lithium contains 3 p+ and 2 e-.
B) During chemical reactions, metals tend to lose e-.
C) The F⁻ ion has one extra e- than a neutral F atom.
D) Argon is the nearest noble gas to magnesium.
E) Selenium typically has a +2 charge when it becomes an ion.

Class period 8

Clicker question #1 (review from last class): Which of the boxed terms (A-J) is correctly used in the following paragraph? Feel free to use a periodic table.

“When reacting with sulfur, the compound strontium will gain electrons to form the Sr²⁺ ion. Sulfur, a typical metal, will gladly accept electrons from strontium resulting in the formation of the S⁻ cation. At this point the two ions repel each other to form the molecular compound Sr₂S.”

Clicker question #2 (reading check): Based on your reading for today, which of the following statements is false?

A) Oxyanions are negatively charged ions containing oxygen.
B) Type I metals always form their cations with the same charge.
C) Transition metals are typically Type II metals
D) When naming ionic compounds, the cation name comes first, followed by the name of the anion.
E) Polyatomic ions are groups of atoms with an overall net charge.
F) Metals in group 1A and 2A are all Type II metals.

G) When naming a Type II ionic compound, it is necessary to identify the charge on the cation in parenthesis.

Clicker question #3: What is the formula for zinc nitride?
A) ZnN  B) ZnN₂  C) Zn₃N  
D) Zn₂N₃  E) Zn₅N₂  F) ZnN₃

Clicker question #4: What is the name for Co₃N₂?
A) cobalt(I) nitrogen  B) cobalt(II) nitrogen  C) cobalt(I) nitride  
D) cobalt(II) nitride  E) cobalt(III) nitride  F) none of the above

Class period 9

Clicker question #1 (review from last class): What is the name of Pb₃N₄?
A) lead(III) nitride  B) potassium(III) nitride  C) prebium(IV) nitride  
D) lead nitride  E) lead(III) nitrate  F) potassium nitrate  G) lead(IV) nitride

Clicker question #2 (Prepared for today?): Which of the following does not give the correct name for the ion shown?
A) BrO⁻, hypobromite  B) C₂H₃O₂⁻, acetate  C) PO₄³⁻, phosphate  
D) S²⁻, sulfide  E) OH⁻, hydroxide  F) NO₂⁻, nitrate  G) CrO₄²⁻, chromate

Clicker question #3: What is the name of Cu₃(BO₃)₂?
A) copper(I) perborate  B) copper borite  C) copper(I) bromated  
D) copper(II) borate  E) copper(II) bromite  F) copper borate  G) copper(II) perborite

Clicker question #4: What is the formula for cobalt(III) chromate?
A) Co₃(CrO₄)₂  B) CoCrO₄  C) Co₂(Cr₂O₇)₃  
D) Co₃(CrO₃)₂  E) Co₂(CrO₄)₃  F) Co(CrO4)₃  G) Co₃Cr₂O₇

Class period 10

Clicker question #1 (review from last class): Ferric sulfate is a yellowish solid and has been used as pigments, or dyes…what is its chemical formula?
A) Fe₂(SO₄)₃  B) FeSO₄  C) Fe(III)(SO₄)₂  
D) Fe(SO₄)₃  E) Fe₃(SO₄)₂
Clicker question #2 (Concept check): What is the common formula for Dihydrogen sulfide?
A) H(II)S
B) H₂S
C) HS⁻
D) H⁺S²⁻
E) None of these

Clicker question #3 (progress check): What is the most accurate name for N₂O₃?
A) Nitrogen(III) oxide
B) Dinitrogen oxide
C) Dinitrogen trioxide
D) Nitrogen(III) oxide(II)
E) Dinitrogen trioxygen
F) None of these

Class period 11

Clicker questions #1-4 (review from last class). Run as "self-paced mini-quiz".
1) What is the name of CuBrO₄?
A) copper(I) perbromate     D) cesium perbromite
B) cesium bromite     E) copper(II) perbromate
C) copper monobromine tetroxide     F) copper(I) bromate

2) What is the name of SO₃?
A) sulfite     D) sulfur(VI) trioxide
B) monosulfur trioxide     E) sulfate
C) sulfur(VI) oxide     F) sulfur trioxide

3) What is the formula for magnesium arsenate?
A) Mn₂(AsO₃)₃     D) Mg₃ArO₃
B) Mn₃(AsO₄)₂     E) Mn₃ArO₂
C) Mg₃(AsO₄)₂     F) MgAsO₃

4) What is the formula for nonachlorine heptaiodide?
A) Cl₆I₁₀     D) Cl₁₁I₉
B) Cl₈I₇     E) Cl₉I₇
C) Cl₉I₁₀     F) Cl₁₁I₈

Class period 11(a) – Review session for exam
Clicker questions #1-4 (review from last class). Run as "self-paced mini-quiz".
1) What is the name of K₃N?
A) tripotassium mononitride     D) krypton(I) nitrite
B) krypton nitride     E) potassium(I) nitride
C) potassium(III) nitrite     F) potassium nitride
2) What is the name of H₂C₂O₄ (aq)?
A) carbonic acid  D) oxalous acid
B) oxalic acid  E) acetic acid
C) dihyrodgen dicarbonate  F) carbonous acid

3) What is the formula for hydrosulfuric acid?
A) H₂SO₄ (aq)  D) HS (aq)
B) H₃SO₃ (aq)  E) H₂S (aq)
C) H₂S (aq)  F) H₂SO₄ (aq)

4) What is the formula for manganese(II) dihydrogen phosphate?
A) Mn₃(H₂PO₄)₂  D) Mn(H₂PO₄)₃
B) Mg(H₂PO₄)₂  E) Mn₂(H₂PO₄)₃
C) Mn(H₂PO₄)₂  F) MgH₂PO₃

Class period 12

Clicker Question #1 (reading check): Based on your reading for today, which of the following statements is false?
A) Scientific notation is used to convert very large and very small numbers to more compact numbers.
B) Significant figures represent the precision of a measured quantity.
C) Zeros are always treated as significant figures.
D) A value with fewer significant figures is less precise than a value with more significant figures.
E) An exact number has an unlimited number of significant figures.
F) The formula mass of a molecule or compound is typically expressed in terms of atomic mass units.

Clicker Question #2 (Concept Check): Your thermometer has markings every 0.1 °C. Your sample temperature reads between the 22.3 °C and 22.4 °C markings as seen in the picture. Which reading is reasonable to record in your lab notebook?
A) About 22 °C
B) 22 °C
C) 22.3 °C
D) 22.4 °C
E) 22.33 °C
F) 22.36 °C
G) 22.337 °C

Clicker Question #3 (Concept Check): Which of the following measurements has the greatest number of significant figures?
A) 605000  C) 0.06050  E) 0.0000605
B) 0.605  D) 6.0500  F) 605.0

Clicker Question #4 (Concept Check): A sample is found to weigh 0.0003025 g. Express this mass in scientific notation with 3 significant figures.
A) $3.025 \times 10^{-4}$ g  E) $3.025 \times 10^4$ g
B) $3.03 \times 10^{-4}$ g  F) $3.02 \times 10^4$ g
C) $0.302 \times 10^{-3}$ g  G) $3.03 \times 10^2$ g
D) $3.02 \times 10^4$ g  H) None of these are correct

Class period 13

Clicker Question #1 (Concept Check): Determine the answer to the following calculation using the correct number of sig figs.

\[
\frac{(13.001 \times 64)}{2.1}
\]

A) 400  C) 396.22  E) $4.0 \times 10^2$
B) $4.0 \times 10^1$  D) $3.9 \times 10^2$  F) 390

Clicker Question #2 (Concept Check): Calculate the formula mass of lithium perbromate.

A) 150.841 amu  D) 151 amu
B) 150.84 amu  E) 150 amu
C) 150.8 amu  F) $1.5 \times 10^2$ amu

Clicker Question #3 (Concept Check): Which of the following problems is not shown with its correct answer?

A) $7.410 \times 14 = 1.0 \times 10^2$  C) $3.87 - 1.07 = 2.8$
B) $0.003 + 0.008 = 0.011$  D) $4 + 302 = 306$

Clicker Question #4 (Concept Check): Calculate the answer with the correct number of sig figs:

\[0.2350 \times (10.35 - 3.564)\]

A) -1.182  D) 1.596  G) 1.60
B) 1.597  E) 1.59471  H) $1.6 \times 10^2$
C) 1.594  F) 1.59565

Class period 14

Clicker Question #1 (review from last class): Without looking at the periodic table, calculate the atomic mass of antimony with the correct sig figs, given: Sb-121 (120.904 amu, 57.21%) and Sb-123 (122.904 amu, 42.79%).

A) 121.9 amu  C) 122 amu  E) 121.76 amu
B) 121.91 amu  D) 121.8 amu  F) 121.760 amu

Clicker Question #2 (review from last class): Calculate the answer with the correct number of sig figs:

\[0.2350 \times (10.35 - 3.564)\]

A) -1.182  D) 1.596  G) 1.60
B) 1.597  E) 1.59471  H) $1.6 \times 10^2$
C) 1.594  F) 1.59565

Clicker Question #3 – attitudinal question

Clicker Question #4 (review from last class): What is the formula for hydrobromic acid?

A) H$_2$BrO$_3$ (aq)  B) HBrO (aq)  C) HBrO$_3$ (aq)
Clicker Question #5 (reading check): Which of the following statements is not true?

A) SI units are a set of standard units so scientists from around the world can “speak the same language.”

B) The meter, kilogram, kelvin, liter and second are SI units for length, mass, temperature, volume and time, respectively.

C) Prefix multipliers (kilo, centi, nano, etc.) used with SI units of measurement change the value by powers of 10.

D) Conversion factors are fractions that are always equal to 1

E) Conversion factors are used to convert from one unit of measurement to another.

F) When using conversion factors, it is best to leave out the units to keep the calculations simpler.

G) All are true statements.

Clicker Question #6 (progress check): How many meters is $5.24 \times 10^8$ $\mu$m?

A) 524 m  
B) 5.24 m  
C) 524 m  
D) $5.24 \times 10^{14}$ m

Class period 15

Clicker Question #1 (review from last class): A sample of manganese weighs 6 kg. What is the mass of the sample in nanograms?

A) $6 \times 10^9$ ng  
B) $6.0 \times 10^{12}$ ng  
C) $6 \times 10^{12}$ ng  
D) $6 \times 10^{12}$ ng  
E) $6.0 \times 10^{12}$ ng  
F) $6 \times 10^3$ ng  
G) $6.0 \times 10^3$ ng  
H) $6 \times 10^9$

Clicker Question #2 and #3 (review from last class): What volume (in cL) would you get if you added the following: $760 \mu$L + 1 mL?

A) 0.176 cL  
B) 0.2 cL  
C) 770 cL  
D) 0.8 cL  
E) 1.8 cL  
F) 0.1 cL  
G) 0.0770 cL  
H) 0.18 cL

Clicker Question #4 (Corrected Quiz?): What is the formula for rubidium arsenate?

A) RbAsO$_3$  
B) Rb$_2$AsO$_3$  
C) Rb$_3$AsO$_3$  
D) Rb$_2$AsO$_4$  
E) Rb$_3$AsO$_4$

Clicker Question #5 (progress check): How many inches are equivalent to 63 $\mu$m?

A) 2.5 in.  
B) $1.6 \times 10^6$ in.  
C) $2.48 \times 10^3$ in.  
D) $0.0025$ in.  
E) $2.5 \times 10^{10}$ in.  
F) $6.2 \times 10^{-7}$ in.
Class period 16

Clicker Question #1 (review from last class):  A proton has a mass of 1.673 x 10^-27 g. How many protons are in a 1.59 lb sample of hydrogen? Assume the total mass of hydrogen is due to protons.

A) $4.31 \times 10^{29}$ protons  
B) $1.7 \times 10^{29}$ protons  
C) $4.3 \times 10^{29}$ protons  
D) $2.3 \times 10^{30}$ protons  
E) $2.1 \times 10^{34}$ protons  
F) $4.34 \times 10^{29}$ protons  
G) $1.21 \times 10^{24}$ protons  
H) $4.31 \times 10^{-25}$ protons

Clicker Question #2 (reading check): Based on your reading for today, identify the true statement:

A) Since 1 km = 10^3 m, it is also true that 1 km^3 = 10^9 m^3.
B) Density is an example of a chemical property.
C) Two objects with the same density will have the same mass.
D) Both “g/mL” and “lb/in^2” are possible units of density.
E) Given two objects, the one that is heavier will also be more dense.
F) Density can be used as a conversion factor when relating mass and distance.

Clicker Question #3 (progress check): A large crystal of potassium permanganate has a volume of 10.8 in^3. What is the volume of the crystal in pL?

A) $2.74 \times 10^{10}$ pL  
B) $2.74 \times 10^{-14}$ pL  
C) $1.77 \times 10^{11}$ pL  
D) $1.77 \times 10^{-13}$ pL  
E) $4.25 \times 10^9$ pL  
F) $4.25 \times 10^{-15}$ pL  
G) $6.59 \times 10^8$ pL  
H) $6.59 \times 10^{-16}$ pL

Clicker Question #4 (progress check): Imagine you are asked to determine the mass (in kg) of a Zn cube that has a volume of 15.00 in^3. Plan out the flowchart for the calculation. Which of the following conversion factors is not needed for the calculation?

A) 1 in/2.54 cm  
B) 103 g/1 kg  
C) 7.14 g/mL (density of Zn)  
D) 1 kg/2.205 lb  
E) 1000 cm^3/1 L  
F) $10^{-3}$ L/1 mL

Clicker Question #5 (progress check): Calculate the mass (in kg) of a Zn cube having a volume of 15.00 in^3.

A) 0.0344 kg  
B) 0.03443 kg  
C) 0.272 kg  
D) 0.2720 kg  
E) 1.76 kg  
F) 1.755 kg  
G) $6.54 \times 10^{-3}$ kg  
H) $6.536 \times 10^{-3}$ kg

Clicker Question #6 (attitudes): How confident do you feel about your answer to the previous question?

A) 100% confident  
B) pretty confident (< 100%, but more than 50%)  
C) not too confident (<50%, but more than 0%)  
D) I guessed (0%)
Class period 17

Clicker question #1 (review from last class): Extremely fuel efficient automobiles (those getting around 80 mpg) are expected to save the average driver around 500 gallons of gas each year. How many tons of gas is this each year? The density of gas is 0.67 g/mL.

A) 3 tons       E) 2 tons
B) 3.1 tons     F) 3.114 tons
C) 1.398 tons   G) 1 x 10^3 tons
D) 1 ton        H) 1.4 tons

Clicker question #2 – attitudinal

Clicker question #3– attitudinal

Clicker Question #4 (review from last class): Which of the following perfect cubes has the highest density? A cube that...
A) weighs 10 g and is 1 cm on each side.
B) weighs 100 g and is 10 cm on each side.
C) weighs 0.1 g and is 0.1 cm on each side.
D) weighs 10,000 g and is 10 cm on each side.

Clicker Question #5 (review from last class): A car gets 35.0 mpg (miles per gallon). Calculate this fuel efficiency in metric units.
A) 82.3 km/L  E) 14 km/qt
B) 4.9 x 10^4 ft/L  F) 14.9 km/L
C) 4.6 x 10^4 ft/qt  G) 4.88 x 10^4 ft/L
D) 15 km/L  H) 82 km/L

Clicker Question #6 (review from last class): A farm has an area of 4.0 km^2. How many acres is the farm? (Note: 1 acre = 43,560 ft^2)
A) 9.90 x 10^2 acres  E) 1.60 x 10^2 acres
B) 9.9 x 10^2 acres  F) 988.84 acres
C) 1590 acres  G) 989 acres
D) 490 acres  H) 1.6 x 10^3 acres

Clicker Question #7 (review from last class): Gold is currently selling at a price of $989.54 dollars an ounce (oz). What volume of gold (in cm^3) will have a value of $2000. dollars? Note: density, gold = 19.32 g/cm^3.
A) 1.377 cm^3  E) 674.4 cm^3
B) 2.966 cm^3  F) 1 cm^3
C) 21.06 cm^3  G) 7 x 10^2 cm^3
D) 3 cm^3  H) 2 x 10^3 cm^3
Class period 18

Clicker Question #1 (review from last class): An 18.02 g sample of pure ice contains $6.022 \times 10^{23}$ water molecules. How many water molecules are there in an ice cube with a volume of 27.0 in$^3$? Density, ice = 0.92 g/cm$^3$
A) $2.1 \times 10^{24}$ molecules  
B) $2.11 \times 10^{24}$ molecules  
C) $1.4 \times 10^{25}$ molecules  
D) $1.36 \times 10^{25}$ molecules
E) $3.80 \times 10^{25}$ molecules  
F) $3.80 \times 10^{25}$ molecules  
G) $2.5 \times 10^{26}$ molecules  
H) $2.45 \times 10^{26}$ molecules

Clicker Question #2 (reading check): Which of the following statements is incorrect?
A) A substance’s temperature is related to the motion of its atoms.  
B) The joule (J) is the SI unit of energy  
C) An exothermic chemical reaction releases energy  
D) A temperature change of one Kelvin is the same as one degree Celsius.  
E) Melting ice is an endothermic process.  
F) The products of a chemical reaction are lower in energy than the reactants.  
G) Absolute zero (defined as 0 K) is the coldest possible temperature.  
H) None of the above – all these statements are true.

Clicker Question #3 (progress check): If Mary burns 2.5 MJ each hour while riding her bike along the American River trail, how many minutes will it take her to burn off that Venti Latte from breakfast? Remember: it had 345 Cal
A) 2.0 min  
B) 35 min  
C) 0.58 min  
D) $5.8 \times 10^2$ min
E) 34.6 min  
F) 90. min  
G) $3.5 \times 10^{13}$ min  
H) 87 min

Class period 19

Clicker Question #1 (review from last class): An endothermic chemical reaction performed in a water bath results in a 10 K temperature change in the water. If the initial temperature of the water was 72°F, what is the final temperature of the water? (you should have conversion formulas in your notes!)
A) 54°F  
B) 62°F  
C) 66°F  
D) 78°F
E) 82°F  
F) 90°F  
G) None of these

Clicker Question #2 (reading check): Which of the following statements is false?
A) Specific heat capacity is the amount of energy required to raise the temperature of 1 g of a substance by 1°C.  
B) The higher a substance’s specific heat capacity, the more energy required to raise its temperature.  
C) Water has an unusually low specific heat capacity.  
D) Units of specific heat capacity are typically J/g°C  
E) Water’s specific heat capacity plays an important role in weather patterns.
F) \( q = m \times C \times DT \) represents the relationship between heat energy, mass, specific heat and change in temperature for a substance.

G) None of these (all statements are true)

Clicker Question #3 (progress check): Two samples of water at room temperature are heated. After heating the 3 g sample, the temperature of the water had increased by 6°C. After heating the 9 g sample, the temperature of the water had increased by 3°C. Which of the following statements is true?

- A) Both samples absorbed the same amount of energy
- B) The 3 g sample absorbed three times as much energy as the 9 g sample
- C) The 9 g sample absorbed three times as much energy as the 3 g sample
- D) The 3 g sample absorbed 2 times as much energy as the 9 g sample
- E) The 9 g sample absorbed 2 times as much energy as the 3 g sample
- F) The 3 g sample absorbed 6 times as much energy as the 9 g sample
- G) The 9 g sample absorbed 6 times as much energy as the 3 g sample
- H) None of these

Clicker Question #4 – re-vote on clicker question #3

Clicker Question #5 (progress check): The temperature of a 10.00 g sample of copper is 25.00°C. What is the temperature of the copper after absorbing 225.0 J? The specific heat capacity of copper is 0.385 J/g°C.

- A) 58.44°C
- B) 8.66°C
- C) 83.4°C
- D) -33.4°C
- E) 83.44°C
- F) 58.4°C
- G) -33.4°C
- H) None of these

Class period 20

Clicker Question #1 (review from last class): 4 people bring drinks to pack in a cooler for a picnic. Which one will require the most ice to cool to 5°C? The heat capacity of soda is 4.18 J/g°C and the density of soda is 1.13 g/mL.

- A) 1.0-L soda at 20°C
- B) 2.0-L soda at 15°C
- C) 0.50-L soda at 45°C
- D) 4-pack of 0.50L sodas at 20°C
Clicker question #2 (review from last class): After playing hoops, a 209.5 lb player’s body temperature is 100.0°F. Roughly how much water should he drink to replace the water lost as sweat in cooling his body down to 98.6°F? Specific heat capacity of his body is 4.00 J/g°C. Sweat evaporation cools the body by absorbing 2.44 kJ/mL of water evaporated.

A) 125 mL   D) 350 mL
B) 150 mL   E) 5.75 L
C) 275 mL   F) 6.00 L

Clicker question #3 (progress check): A 20.0 g sample of copper (specific heat = 0.384 J/g°C) is heated to 203°C and dropped into 80.0 g of water (specific heat = 4.18 J/g°C) at 25.0°C. What is the final temperature of the water? …think \( q_{\text{copper}} = -q_{\text{water}} \)

A) 19.9°C   D) 29.0°C
B) 20.9°C   E) 43.5°C
C) 155°C   F) 30.4°C
G) None of these

Class period 20(a) – review session for exam
Clicker question #1 (review from last class): Digitalis is used to control fibrillation in some heart patients and is administered in doses of 20. \( \mu \)g/kg of body weight. What dose (in mg) should be given to a 165 lb patient?

A) 1.5 x 10⁻⁶ mg   D) 1.50 x 10⁻⁶ mg
B) 1.5 mg   E) 1.50 mg
C) 1.5 x 10¹² mg   F) 1.5 x 10¹² mg

Clicker question #2 (review from last class): While panning for gold, you find a shiny piece of metal (weighing 415 g). You decide to determine the specific heat of the metal to see if it might be gold. You heat the metal to 164°C and drop it into 200.0 g of water at 22.0°C. The final temperature of the water is 46.2°C. Is it possible that your find is really gold? The specific heat of gold = 0.128 J/g°C.

A) Yaah…it’s gold! I’m rich!
B) Darn…it’s not gold.
C) I know how to do these calculations and not enough information is provided to tell if it is gold.
D) I don’t know how to do these calculations.

Class period 21

Clicker question #1 (exam correction): What distance (in m) would you get if you added the following: 0.00510 km + 608 cm?

A) 1 x 10¹ m   B) 11.1 m   C) 11.2 m
D) 11 m   E) 1.0 x 10¹ m   F) 11.18 m

Clicker question #2 (reading check): Which statement is false?
A) A “mole” represents a quantity…just like a “dozen”
B) Avogadro’s number, \( 6.022 \times 10^{23} \), is another name for the mole.
C) Avogadro’s number converts between the mass of a substance and the number of atoms.
D) The mole can specify Avogadro’s number of anything.
E) The numerical value of the mole is equal to the number of atoms in exactly 12 g of pure carbon-12.
F) The molar mass is the mass of 1 mole of atoms of an element.
G) Molar mass can be used to convert between the mass of a sample and the number of moles of atoms present in the sample.

Clicker question #3 (progress check): A local grocer pays $15.00 for one gross of eggs. How many eggs does the grocer get when he buys 3 gross for $45.00? [Note: 1 gross = 12 dozen.]
A) 16 eggs   D) 432 eggs
B) 144 eggs   E) 540 eggs
C) 400 eggs   F) 6,480 eggs

Clicker question #4 (progress check): Assuming it is made of pure carbon, how many carbon atoms are in a pencil lead that has a mass of 41 mg. [Actually there are additives in the pencil]
A) 2.06 x 10^{21} C atoms   D) 3.0 x 10^{24} C atoms
B) 2.1 x 10^{23} C atoms   E) 2.96 x 10^{23} C atoms
C) 2.5 x 10^{22} C atoms   F) 2.1 x 10^{24} C atoms
D) 3.0 x 10^{23} C atoms   G) 2.1 x 10^{24} C atoms

Class period 22

Clicker question #1 (review from last class): A sample of iron has a volume of 3.5 in^3. How many iron atoms are in the cube? The density of iron is 7.86 g/cm^3.
A) 3.0 x 10^{23} Fe atoms   E) 7.57 x 10^{24} Fe atoms
B) 4.86 x 10^{24} Fe atoms   F) 5.95 x 10^{25} Fe atoms
C) 7.5 x 10^{23} Fe atoms   G) 7.9 x 10^{24} Fe atoms
D) 4.9 x 10^{24} Fe atoms   H) None of the above

Clicker question #2 – attitudinal question

Clicker question #3 – attitudinal question

Clicker question #4 (progress): What is the molar mass of tin(II) permanganate?
A) 339.3 g/mol   E) 356.6 g/mol
B) 356.58 g/mol   F) 237.64 g/mol
C) 189.64 g/mol   G) 237.6 g/mol
D) 406.2 g/mol   H) None of the above

Clicker question #5 (progress): How many formula units are there in 5.85 x 10^{-2} µg of tin(II) permanganate?
A) 9.88 x 10^{16} units   E) 9.9 x 10^{16} units
B) 3.52 x 10^{16} units   F) 1.26 x 10^{19} units
C) 9.88 x 10^{22} units   G) 9.88 x 10^{19} units
D) 9.9 x 10^{15} units   H) None of the above

Class period 23

Clicker question #1 (review from last class): Calculate the molar mass of calcium nitrate.
Clicker question #2 (reading check): Based on your reading for today, which of the following conversion factors would be appropriate for calcium nitrate?

A) \( \frac{3 \text{ mol O}}{1 \text{ mol Ca(NO}_3)_2} \)  
B) \( \frac{1 \text{ mol Ca(NO}_3)_2}{2 \text{ mol Ca}} \)  
C) \( \frac{1 \text{ mol O}}{6 \text{ mol Ca(NO}_3)_2} \)  
D) \( \frac{6 \text{ mol O}}{1 \text{ mol Ca(NO}_3)_2} \)  
E) \( \frac{1 \text{ mol Ca(NO}_3)_2}{1 \text{ mol N}} \)  
F) \( \frac{2 \text{ mol Ca(NO}_3)_2}{1 \text{ mol N}} \)

Clicker question #3 (progress check): How many ng of C can be isolated from 0.0015 mg of nickel(III) carbonate?

A) 181.7 ng C  
B) 60.6 ng C  
C) \( 2.3 \times 10^{2} \) ng C  
D) 182 ng C  
E) 61 ng C  
F) \( 1.8 \times 10^{-16} \) ng C  
G) 226 ng C  
H) None of these is correct

Clicker question #4 (progress check): A sample of potassium chromate has \( 4.55 \times 10^{24} \) O atoms. What is the mass (in g) of Cr in the sample?

A) 9.822 g Cr  
B) 393 g Cr  
C) \( 9.82 \times 10^{47} \) g Cr  
D) \( 1.3 \times 10^{3} \) g Cr  
E) 98.2 g Cr  
F) 131 g Cr  
G) \( 1.57 \times 10^{3} \) g Cr  
H) None of these is correct
Clicker Question #4 (progress check): Calculate the mass % of H in a 32.0 g sample of ammonium sulfate.

A) 6.102% H  E) 6.10% H
B) 5.01% H      F) 1.32% H
C) 1.320% H     G) None of the above
D) 0.7628

Class period 25

Clicker question #1 (review from last class): Which of the following compounds has the highest percent mass of manganese?

A) Mn₂O₃  D) MnO
B) MnO₂  E) Mn₂O₇
C) Mn₃O₄  F) Not enough information is given

Clicker question #2 (reading check): Which of the following statements about empirical and molecular formulas is true?

A) An empirical formula is only for ionic compounds.
B) The molecular formula is never identical to the empirical formula.
C) The empirical formula gives the specific number of each type of atom in a compound.
D) The molecular formula gives the smallest whole-number ratio of each atom in the compound.
E) Different compounds can have the same empirical formula.

Clicker question #3 (progress check): A fuel contains 92.24% carbon by mass (the remainder is hydrogen). If one molecule of the fuel weighs \(1.30 \times 10^{-22}\) g, what is the molecular formula of the compound?

A) C₅H₁₈  E) C₂H₃
B) CH  F) C₂H₁₅
C) C₃H₂  G) CH₂
D) C₆H₆  H) C₄H₃₀

Clicker question #4 (challenge homework question): Acetylsalicylic acid (aspirin) is 60.0% C, 4.48% H, and 35.5% O. If the molar mass of this substance is around 180. g/mol, what is the molecular formula of aspirin?

A) C₈H₈O₄  E) C₃H₂O
B) C₆H₁₂O₆  F) C₁₂H₄O₂
C) CH₂O  G) C₃H₄O₄
D) C₁₀H₁₂O₃  H) C₃H₁₆O₈
Class period 26

Clicker question #1 (review from last class): Combining formaldehyde and pyrrole produces solid purple crystals. Elemental analysis shows that the crystals are 77.38% C, 4.56% H and 18.06% N by mass. The molar mass of the product is 310.38 g/mol. What is the molecular formula of the crystals?

A) $C_{18}H_{34}N_5$  
B) $C_{22}H_{4}N_3$  
C) $C_{19}H_{12}N_5$  
D) $C_{19}H_{12}N_5$  
E) $C_{21}H_{16}N_3$  
F) $C_{20}H_{14}N_4$  
G) $C_{22}H_{18}N_2$  
H) None of these is correct

Clicker question #2: homework question from previous lecture

Clicker question #3 (reading check): Which of the following does NOT represent evidence suggesting a chemical reaction has occurred?

A) A solution changes color from clear to red  
B) A solution changes color from red to clear  
C) A solid forms when two liquids are mixed  
D) A solid turns into a liquid  
E) Gas bubble form when two reactants are mixed  
F) Heat is produced when two liquids are mixed

Clicker question #4 (reading check): Sugar ($C_6H_{12}O_6$) can be fermented to generate carbon dioxide and ethanol ($C_2H_6O$) as represented by the equation below. Which statement about this equation is FALSE?

$$ C_6H_{12}O_6(aq) \rightarrow 2 \text{CO}_2(g) + 2 \text{C}_2\text{H}_6\text{O}(l) $$

A) The carbon dioxide is produced as a gas  
B) Writing “2 CO$_2$” is different than writing “C$_2$O$_4$”  
C) The total number of C atoms is the same before and after the reaction  
D) Every molecule of sugar can produce 2 molecules of products  
E) The sugar in this reaction has been dissolved in water  
F) This reaction is balanced

Clicker question #5 (progress check): What is the coefficient in front of the NaNO$_3$ when the following reaction is balanced?

$$ _\text{___} \text{Al(NO}_3)_3 \text{ (aq) + ___Na}_2\text{CO}_3 \text{ (aq) \rightarrow ___NaNO}_3 \text{ (aq) + ___Al}_2\text{(CO}_3)_3 \text{ (s)} $$

A) 1  
B) 2  
C) 3  
D) 4  
E) 5  
F) 6  
G) 7  
H) 8

Clicker question #6 (progress check): The combustion of butane produces water and carbon dioxide. What is the coefficient in front of the O$_2$ when the reaction is balanced?

$$ _\text{___} \text{C}_4\text{H}_{10} \text{ + ___O}_2 \rightarrow _\text{___} \text{CO}_2 \text{ + ___H}_2\text{O} $$

A) 2.5  
B) 4  
C) 5  
D) 6  
E) 9.5  
F) 13  
G) 18
Class period 27

Clicker Question #1 (review from last class): In solid rocket boosters for spacecrafts, solid ammonium perchlorate and solid aluminum react to form solid aluminum oxide, solid aluminum chloride, gaseous nitrogen monoxide and water vapor. What is the coefficient in front of the aluminum chloride when the reaction is balanced?

A) 1  E) 5
B) 2  F) 6
C) 3  G) 7
D) 4  H) 8

Clicker Question #2 (review from last class): What is the coefficient in front of the H\textsubscript{2} when following reaction is balanced?

\[ \text{NH}_3 (g) + \_\text{H}_2\text{O} (g) + \_\text{CH}_4 (g) \rightarrow \_\text{NH}_2\text{CHCH}_3\text{COOH} (l) + \_\text{H}_2 (g) \]

A) 2  E) 6
B) 3  F) 9
C) 4  G) 12
D) 5

Clicker Question #3 (reading check): Which of the following statements is false?

A) Making an aqueous solution involves dissolving a substance in water.
B) Solutions of strong electrolytes can conduct electricity.
C) Compounds that are insoluble do not dissolve in water.
D) A precipitation reaction is when two aqueous solutions mix to form a solid.
E) Solubility rules can be used to predict if a compound will dissolve in water.
F) All ionic compounds dissolve in water.
G) A homogeneous mixture has the same composition throughout.

Clicker Question #4 (progress check): Using the solubility guidelines, which of the following compounds would be expected to be insoluble in water?

A) Sr(OH)\textsubscript{2}  E) BaSO\textsubscript{4}
B) CaS  F) Pb(NO\textsubscript{3})\textsubscript{2}
C) Na\textsubscript{2}SO\textsubscript{4}  G) Li\textsubscript{2}CO\textsubscript{3}
D) K\textsubscript{3}PO\textsubscript{4}  H) None of these is insoluble.

Clicker Question #5 (challenge homework question): What is/are the product(s) in NIE when aqueous solutions of calcium hydroxide and tin(IV)nitrate are combined?

A) 2Ca(NO\textsubscript{3})\textsubscript{2}(aq) + Sn(OH)\textsubscript{4}(s)
B) 2Ca\textsuperscript{2+}(aq) + 4NO\textsubscript{3}\textsuperscript{-}(aq) + Sn(OH)\textsubscript{4}(s)
C) Sn(OH)\textsubscript{4}(s)
D) 2Ca(NO\textsubscript{3})\textsubscript{2}(s) + Sn(OH)\textsubscript{4}(aq)
E) 2Ca(NO\textsubscript{3})\textsubscript{2}(s) + Sn\textsuperscript{4+}(aq) + 4OH\textsuperscript{-}(aq)
F) Ca(NO\textsubscript{3})\textsubscript{2}(s)
Class period 28

Clicker Question #1 (review from last class): What is on the product side of the balanced net ionic equation (NIE) when solutions of ammonium phosphate and lead(II) nitrate are combined?
A) $2 \text{Pb}_3(\text{PO}_4)_2(s)$
B) $6 \text{NH}_4\text{NO}_3(s) + 3\text{Pb}^{2+}(aq) + 2\text{PO}_4^{3-}(aq)$
C) $6 \text{NH}_4\text{NO}_3(s)$
D) $6 \text{NH}_4^+(aq) + 6 \text{NO}_3^-(aq) + \text{Pb}_3(\text{PO}_4)_2(s)$
E) $\text{Pb}_3(\text{PO}_4)_2(s)$
F) $4 \text{NH}_4\text{NO}_3(s)$
G) “No Reaction” (all the ions are spectators)

Clicker Question #2: homework from previous lecture

Clicker Question #3 (reading check): Which of the following statements is false?
A) Acids taste sour and can dissolve some metals
B) Lemons, limes, and vinegars contain acids
C) Bases taste sweet and smell flowery
D) Acids generate H$^+$ ions when added to water
E) Neutralization reactions generally form water and a salt
F) $\text{HClO}_4(aq)$ is called perchloric acid
G) Bases generate OH$^-$ ions when added to water
H) Soap, coffee, and milk of magnesia contain bases

Clicker Question #4 (progress check): What is on the product side of the balanced NIE that occurs after mixing aqueous solutions of acetic acid (a weak acid) and potassium hydroxide?
A) $2 \text{H}_2\text{O}(l)$
B) $\text{H}_2\text{O}(l) + \text{C}_2\text{H}_5\text{O}_2^-(aq)$
C) $\text{H}_2\text{O}(l) + \text{K}_2\text{C}_2\text{H}_5\text{O}_2(s)$
D) $\text{H}_2\text{O}(l)$
E) $2 \text{H}_2\text{O}(l) + \text{C}_2\text{H}_5\text{O}_2^-(aq)$
F) $\text{H}_2\text{O}(l) + \text{K}_2\text{C}_2\text{H}_5\text{O}_2(aq)$
G) “No Reaction” (all the ions are spectators)

Class period 29

Clicker Question #1 (review from last class): Which of the following reactions is not expected to produce a gas as one of the products?
A) $\text{Na}_2\text{S}(aq) + \text{HClO}_4(aq)$
B) $\text{NaOH}(aq) + \text{NH}_4\text{I}(aq)$
C) $\text{HBr}(aq) + \text{Na}_2\text{SO}_4(aq)$
D) $\text{NaHSO}_3(aq) + \text{HNO}_3(aq)$
E) $\text{HCl}_2\text{H}_2\text{O}_2(aq) + \text{Na}_2\text{CO}_3(aq)$
F) They all produce gas

Clicker Question #2 (review from last class): Acetic is a weak acid. Which drawing of a beaker of water below is the best representation of how acetic acid exists in water?
Clicker Question #3 (reading check): Which of the following statements about oxidation-reduction reactions is false?
A) If one substance is oxidized, then another substance must be reduced
B) Oxidation-reduction reactions are also called redox reactions
C) Reduction is the gain of electrons
D) Oxidation-reduction reactions involve the transfer of electrons from one substance to another
E) Oxidation-reduction reactions require oxygen as a reactant
F) Oxidation is the loss of electrons
G) Combustion reactions are a type of oxidation-reduction reaction

Clicker Question #4 (progress check): Which of the following reactions is not a redox reaction?
A) \( \text{H}_2(g) + \text{S}(s) \rightarrow \text{H}_2\text{S}(g) \)
B) \( \text{C}_3\text{H}_8(g) + 5 \text{O}_2 \rightarrow 3 \text{CO}_2(g) + 4 \text{H}_2\text{O}(l) \)
C) \( \text{H}_2(g) + \text{F}_2(g) \rightarrow 2 \text{HF}(g) \)
D) \( \text{HCl}(aq) + \text{NaOH}(aq) \rightarrow \text{H}_2\text{O}(l) + \text{NaCl}(aq) \)
E) \( \text{Zn}(s) + 2 \text{H}_2\text{O}(l) \rightarrow \text{Zn(OH)}_2(s) \)
F) \( 2 \text{Fe}(s) + 3 \text{Cl}_2(g) \rightarrow 2 \text{FeCl}_3(s) \)

Clicker Question #5 (progress check): Which of the redox reactions from the last question would also be classified as a combustion reaction?
A) \( \text{H}_2(g) + \text{S}(s) \rightarrow \text{H}_2\text{S}(g) \)
B) \( \text{C}_3\text{H}_8(g) + 5 \text{O}_2 \rightarrow 3 \text{CO}_2(g) + 4 \text{H}_2\text{O}(l) \)
C) \( \text{H}_2(g) + \text{F}_2(g) \rightarrow 2 \text{HF}(g) \)
D) \( \text{HCl}(aq) + \text{NaOH}(aq) \rightarrow \text{H}_2\text{O}(l) + \text{NaCl}(aq) \)
E) \( \text{Zn}(s) + 2 \text{H}_2\text{O}(l) \rightarrow \text{Zn(OH)}_2(s) \)
F) \( 2 \text{Fe}(s) + 3 \text{Cl}_2(g) \rightarrow 2 \text{FeCl}_3(s) \)
Clicker Question #6 (progress check): Dodecane \((\text{C}_{12}\text{H}_{26})\) is a heavy alkane present as an oily liquid that can be burned. For every 1 mole of dodecane burned, how many moles of oxygen are also consumed?

A) 12  
B) 13.5  
C) 18  
D) 18.5  
E) 25  
F) 37

Clicker Question #7 (progress): Which of these reactions is not correctly classified (use the codes below)

<table>
<thead>
<tr>
<th>Classification Scheme I</th>
<th>Classification Scheme II</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2) acid-base</td>
<td>7) decomposition</td>
</tr>
<tr>
<td>3) gas evolution</td>
<td>8) displacement</td>
</tr>
<tr>
<td>4) oxidation-reduction</td>
<td>9) double displacement</td>
</tr>
<tr>
<td>5) combustion</td>
<td></td>
</tr>
</tbody>
</table>

A) \(2 \text{HNO}_3\text{(aq)} + \text{Ca(OH)}_2\text{(aq)} \rightarrow 2 \text{H}_2\text{O(l)} + \text{Ca(NO}_3)_2\text{(aq)}\)  
B) \(2 \text{HNO}_3\text{(aq)} + \text{SrS(aq)} \rightarrow \text{H}_2\text{S(g)} + \text{Sr(NO}_3)_2\text{(aq)}\)  
C) \(\text{N}_2\text{(g)} + 3 \text{H}_2\text{(g)} \rightarrow 2 \text{NH}_3\text{(g)}\)  
D) \(\text{Li}_2\text{SO}_4\text{(aq)} + \text{SrCl}_2\text{(aq)} \rightarrow \text{SrSO}_4\text{(s)} + 2\text{LiCl(aq)}\)  
E) \(2 \text{C}_8\text{H}_{18}\text{(l)} + 25 \text{O}_2\text{(g)} \rightarrow 16 \text{CO}_2\text{(g)} + 18 \text{H}_2\text{O(g)}\)  
F) \(\text{Fe(s)} + \text{Ni(NO}_3)_2\text{(aq)} \rightarrow \text{Ni(s)} + \text{Fe(NO}_3)_2\text{(aq)}\)

Class period 29a (review session)

Clicker Question #1 (review from last class): How many atoms are in 8.50 g of dinitrogen tetroxide?

A) \(5.56 \times 10^{22}\) atoms  
B) \(3.34 \times 10^{23}\) atoms  
C) \(4.71 \times 10^{26}\) atoms  
D) \(9.27 \times 10^{21}\) atoms  
E) \(2.83 \times 10^{27}\) atoms  
F) None of the above

Clicker Question #2 (review from last class): Which of these reactions is not correctly classified (use the codes below)

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<td>4) oxidation-reduction</td>
<td>9) double displacement</td>
</tr>
<tr>
<td>5) combustion</td>
<td></td>
</tr>
</tbody>
</table>

A) \(\text{H}_2\text{CO}_3\text{(aq)} \rightarrow \text{H}_2\text{O(l)} + \text{CO}_2\text{(g)}\)  
B) \(\text{Sr(OH)}_2\text{(s)} + 2\text{HCl(aq)} \rightarrow \text{SrCl}_2\text{(aq)} + 2\text{H}_2\text{O(l)}\)  
C) \(\text{Fe(s)} + \text{Ni(NO}_3)_2\text{(aq)} \rightarrow \text{Ni(s)} + \text{Fe(NO}_3)_2\text{(aq)}\)  
D) \(2\text{H}_2\text{(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{H}_2\text{O(g)}\)  
E) \(\text{BaCl}_2\text{(aq)} + \text{K}_2\text{SO}_4\text{(aq)} \rightarrow \text{BaSO}_4\text{(s)} + 2\text{KCl(aq)}\)  
F) None of the above
They are all correctly classified.

Class period #30

Clicker Question #1 (reading check): After balancing the following equation, which of the following would be an appropriate conversion factor:

\[ \text{NO(g)} + \text{H}_2(g) \rightarrow \text{NH}_3(g) + \text{H}_2O(g) \]

A) \[ \frac{2 \text{ mol } \text{H}_2}{5 \text{ mol } \text{NH}_3} \]  
B) \[ \frac{5 \text{ g } \text{H}_2}{2 \text{ g } \text{H}_2O} \]  
C) \[ \frac{3 \text{ mol NO}}{5 \text{ mol } \text{H}_2} \]  
D) \[ \frac{3 \text{ g } \text{H}_2}{2 \text{ g } \text{NH}_3} \]  
E) \[ \frac{2 \text{ mol } \text{H}_2O}{5 \text{ mol } \text{H}_2} \]  
F) \[ \frac{2 \text{ g NO}}{2 \text{ g } \text{H}_2O} \]

Clicker Question #2 (progress check): Using the previous equation, how many mmol of water can form from 0.030 mol of hydrogen gas?

A) 75 mmol H\(_2\)O  
B) 12 mmol H\(_2\)O  
C) 6 mmol H\(_2\)O  
D) \(7.5 \times 10^{-5}\) mmol H\(_2\)O  
E) 15 mmol H\(_2\)O  
F) 30. mmol H\(_2\)O  
G) 1.2 x 10\(^5\) mmol H\(_2\)O  
H) 60. mmol H\(_2\)O

Clicker Question #3 (progress check): Using the previous equation, how many g of H\(_2\)O can be made from 23.0 g of H\(_2\)?

A) 164 g H\(_2\)O  
B) 6.43 g H\(_2\)O  
C) 514 g H\(_2\)O  
D) 82.2 g H\(_2\)O  
E) 0.515 g H\(_2\)O  
F) 3.22 g H\(_2\)O  
G) 1.03 x 10\(^7\) g H\(_2\)O  
H) 1.03 g H\(_2\)O

Clicker Question #4 – attitudinal question

Clicker Question #5 – attitudinal question

Clicker Question #6 (progress check): The Haber process is commercially used for the production of ammonia from nitrogen and hydrogen. Assuming you have excess hydrogen gas, how many grams of ammonia can be produced from 100.0 g of nitrogen gas?

A) \(3.291 \times 10^8\) g NH\(_3\)  
B) \(82.22\) g NH\(_3\)  
C) \(6.078 \times 10^{-4}\) g NH\(_3\)  
D) \(6.078 \times 10^7\) g NH\(_3\)  
E) \(3.291 \times 10^{-4}\) g NH\(_3\)  
F) None of these

Clicker Question #7 (challenge homework question): Assuming gasoline is pure octane (C\(_8\)H\(_{18}\)), how many kg of carbon dioxide are produced (and injected into our atmosphere) from the combustion of one 15-L tank of gas? The density of octane is 0.703g/mL.

A) 33 kg CO\(_2\)  
B) 66 kg CO\(_2\)  
C) 4.1 kg CO\(_2\)  
D) \(66 \times 10^4\) kg CO\(_2\)  
E) 16 kg CO\(_2\)  
F) \(3.3 \times 10^4\) kg CO\(_2\)
Clicker Question #1 (review from last class): What is the maximum mass (in g) of precipitate that can form when 10.0 grams of sodium chloride is dissolved in water and then added to aqueous lead(II) nitrate?
A) 9.05 g PbCl₂
B) 14.5 g PbCl₂
C) 23.8 g PbCl₂
D) 47.6 g PbCl₂
E) 9.05 g NaNO₃
F) 14.5 g NaNO₃
G) 23.8 g NaNO₃
H) 47.6 g NaNO₃

Clicker Question #2 (review from last class): Li(s) reacts with water to produce lithium hydroxide and hydrogen gas. How many hydrogen molecules can be made from 6.23 g of Li?
A) 1.35 x 10²⁴ H₂ molecules
B) 5.40 x 10²³ H₂ molecules
C) 2.70 x 10²⁴ H₂ molecules
D) 1.35 x 10²³ H₂ molecules
E) 8.10 x 10²³ H₂ molecules
F) 2.70 x 10²³ H₂ molecules

Clicker Question #3 – homework from previous lecture

Clicker Question #4 (reading check): Which of the following statements is true based on your reading for today and the following equation:
2 H₂(g) + O₂(g) \rightarrow 2 H₂O(l)
A) The “actual yield” is the maximum amount of H₂O that can be made
B) O₂ is always the limiting reactant in this equation
C) The “percent yield” of H₂O should come out to be 100%
D) 1.0 g H₂ and 1.0 g O₂ can produce a maximum of 1.0 g H₂O
E) 1.0 mol H₂ and 1.0 mol O₂ can produce a maximum of 1.0 mol H₂O
F) 1.0 g H₂ and 1.0 g O₂ can produce a maximum of 2.0 g H₂O
G) 1.0 mol H₂ and 1.0 mol O₂ can produce a maximum of 2.0 mol H₂O

Clicker question #5 (challenge homework question): Find the limiting reactant, the theoretical yield of H₂O, and the percent yield if you make 9.15 g of H₂O when starting with 5.00 g H₂ and 10.0 g O₂.
2 H₂(g) + O₂ (g) \rightarrow 2 H₂O(l)
A) H₂ is limiting; 11.3 g H₂O; 81.0 % yield
B) H₂ is limiting; 11.3 g H₂O; 123% yield
C) H₂ is limiting; 44.7 g H₂O; 20.5% yield
D) H₂ is limiting; 44.7 g H₂O; 48.9% yield
E) O₂ is limiting; 11.3 g H₂O; 81.0% yield
F) O₂ is limiting; 11.3 g H₂O; 123% yield
G) O₂ is limiting; 44.7 g H₂O; 20.5% yield
H) O₂ is limiting; 44.7 g H₂O; 48.9% yield
Class period #32

Clicker Question #1 (review from last class): If the yield for the following reaction is 72.0%, how many grams of Al should be used to produce 15.0 g of Al₂(SO₄)₃?

\[ \text{Al(s)} + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{Al}_2(\text{SO}_4)_3(\text{aq}) + \text{H}_2(\text{g}) \]

A) 1.18 g  
B) 6.56 g  
C) 1.64 g  
D) 2.37 g  
E) 3.28 g

Clicker Question #2 (review from quiz): How many atoms are in 26 g of Mg(NO₃)₂?

A) \(1.1 \times 10^{23}\)  
B) \(5.9 \times 10^{22}\)  
C) \(9.5 \times 10^{23}\)  
D) \(1.0 \times 10^{24}\)  
E) \(8.4 \times 10^{23}\)

Clicker Question #3 – homework from previous lecture

Clicker Question #4 (review from last class): Photosynthesis involves the formation of glucose and oxygen gas from carbon dioxide and water (think of the reverse of a combustion reaction). What are the limiting reactant and the percent yield of glucose (C₆H₁₂O₆) assuming that 0.575 g of glucose are made from 1.00 g H₂O and 0.500 L CO₂? The density of CO₂ is 1.977 g/L.

A) H₂O is limiting; 0.674 g  
B) H₂O is limiting; 1.67 g  
C) H₂O is limiting; 34.4 %  
D) H₂O is limiting; 85.3 %  
E) CO₂ is limiting; 0.674 g  
F) CO₂ is limiting; 1.67 g  
G) CO₂ is limiting; 34.4 %  
H) CO₂ is limiting; 85.3 %

Clicker Question #5 (review from last class): A mixture of 4.00 moles of hydrogen and 3.00 moles of oxygen is ignited, forming water. What is the composition of the system by mass (each in grams) after the reaction is complete?

A) 108 g H₂O; 4.03 g H₂; 0.00 g O₂  
B) 72.1 g H₂O; 0.00 g H₂; 64.0 g O₂  
C) 72.1 g H₂O; 0.00 g H₂; 0.00 g O₂  
D) 108 g H₂O; 0.00 g H₂; 0.00 g O₂  
E) 72.1 g H₂O; 0.00 g H₂; 32.0 g O₂  
F) 108 g H₂O; 8.06 g H₂; 0.00 g O₂
APPENDIX B

List of attitudinal clicker questions used

Which of the following provides the most incentive for coming to CHM4 classes?
A) I am on campus anyways and have nothing better to do.
B) To earn points from clicker questions.
C) Hearing the lecture will help me learn the material.
D) To see friends.
E) I believe missing classes will lower my chances for passing the next test.
F) To see how well I understand the material on the clicker questions.
G) I’m paying for the class so it would be a waste of money not to attend.
H) I enjoy the class.
I) My strongest incentive is not listed above.

Which of the following do you believe is the most important contributor to student success in CHM 4?
A) Taking good notes during lecture
B) Reviewing lecture notes before the exam
C) Working on practice exams before the exam
D) Reviewing clicker questions before the exam
E) Doing homework problems every week
F) Reviewing lecture notes regularly every week
G) Reading the assigned textbook each day before class
H) Being in class every day
I) Other

Based on your personal experience in this class, what do you feel is the most significant benefit from using the clickers?
A) Tells the instructor how well students are doing or if they are getting the new material.
B) Tells you, the student, how well you are doing on questions important to the instructor.
C) Helps keep you awake during class.
D) The points earned from clicker questions provide motivation for coming to class.
E) Using the clickers makes the class more personal and engaging.
F) Provides practice problems to solve while learning new material.
G) Stimulates discussion with classmates when you are allowed to work together on questions.
H) Other

This semester, points from clicker questions are worth about 7.5% of your total grade. Select the answer that you agree with most.
A) I think clicker points should not count towards my final grade.
B) I think clicker points should count, but be less than the current 7.5% of my final grade.
C) I think clicker points are just right at 7.5% of my final grade.
D) I think the clicker points should be 10% of my final grade.
E) I think clicker points should be 15% of my final grade.
F) I think clicker points should be 20% or more of my final grade.
G) I don’t think we should be using clickers in this class.
H) Other

In terms of earning points for clicker questions…
   A) I like getting 1 point for effort and 2 points for a correct answer.
   B) I think there should be no points for effort; 1 point for correct and 0 points for incorrect responses.
   C) I think there should only be 1 point for effort and no penalty for wrong answers.
   D) I don’t think there should be any points for clicker question.
   E) None of these reflects my opinion.

How confident do you feel about your answer to the previous question?
   A) 100% confident
   B) pretty confident (< 100%, but more than 50%)
   C) not too confident (<50%, but more than 0%)
   D) I guessed (0%)
APPENDIX C

Student exit survey fall semester

NSM-21, F’10  Study Skills Plus (3S): Student Survey  Name:

The questions on this survey refer to the Study Skills and Strategies Program (i.e. the 3S-program) that you were asked to complete. This survey is due in class on Monday, December 6th. Your actual answers will not impact your grade in the course, though completing the survey will count as your next 10 point writing assignment and will provide useful feedback as I consider whether to recommend or possibly require the 3S-program for all CHM 4 students.

Ranked questions: Please read each prompt carefully. Then circle the most appropriate answer based on your first reaction to each prompt. Responses are based on the following 5-point scale: 1 = strongly disagree (SD); 2 = disagree (D); 3 = neutral (N); 4 = agree (A); 5 = strongly agree (SA)

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<tbody>
<tr>
<td>1</td>
<td>The clickers are easy to use.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>2</td>
<td>The clickers worked properly during lectures.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>The clickers worked properly during exams.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>4</td>
<td>The clicker questions provided additional incentive to attend every class.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>5</td>
<td>I thought using the clickers was a valuable part of this class.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>6</td>
<td>I thought working in groups during clicker questions was beneficial.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>7</td>
<td>I went backed and added the clicker questions to my notes after class.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>8</td>
<td>I paid more attention to the lecture knowing clicker questions would be asked.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>9</td>
<td>I would have preferred to just have lecture and not any clicker questions.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>10</td>
<td>I felt the clicker questions were generally too hard.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>11</td>
<td>The points from clicker questions were not enough to motivate me to prepare for class (text reading prior to class and reviewing previous lecture material).</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>12</td>
<td>The clicker questions helped reinforce the material from the lecture.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>13</td>
<td>I would recommend clickers for future Chem 4 classes.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>14</td>
<td>I realized I needed to do the homework after missing clicker questions.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>15</td>
<td>The grades I earned on the quizzes and exams accurately reflected the amount of effort I spent preparing for them.</td>
<td>SD</td>
<td>D</td>
<td>N</td>
<td>A</td>
</tr>
</tbody>
</table>
16. The clicker questions helped identify whether I understood the lecture or not. 1 2 3 4 5
17. I felt the clicker questions were generally too easy. 1 2 3 4 5
18. I found it beneficial to get instant feedback whether I could answer the clicker questions correctly. 1 2 3 4 5
19. I did not review previous material for class and was not concerned about the review clicker questions. 1 2 3 4 5
20. I felt compelled to read the textbook prior to class knowing there would be a clicker question from the reading. 1 2 3 4 5
21. I found it useful to download and review the clicker questions and answers after lecture. 1 2 3 4 5
22. I generally did not complete the homework assignments. 1 2 3 4 5
23. I preferred to work alone during clicker questions. 1 2 3 4 5
24. The cost of the clicker was worth the expense. 1 2 3 4 5
25. When I answered the clicker questions correctly, I assumed I didn’t need to do the homework. 1 2 3 4 5
26. The clicker questions had no influence on my attendance. 1 2 3 4 5
27. I would like to use clickers in more of my classes. 1 2 3 4 5

**Free response questions:**

1. My clicker number is:

2. How many classes did you miss during the semester?
   a. 0-1
   b. 2-3
   c. 4 or more

3. Did you rent, purchase used, or purchase your clicker new?

4. Do you have any feedback or other comments which could improve the use of the clickers in this class?

Continued on back →
APPENDIX D

Student pre-survey spring semester

CHMN 4, SP’11  
Clicker Survey  
Name:

The questions on this survey refer to the “clickers” that we will be using this semester in CHM 4. Your answers will in no way impact your grade in the course.

**Ranked questions:** After reading each statement carefully, please circle the most appropriate answer based on your first reaction. Responses are based on the following 5-point scale:  
1 = strongly disagree (SD); 2 = disagree (D); 3 = neutral (N); 4 = agree (A); 5 = strongly agree (SA)

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<tbody>
<tr>
<td>1</td>
<td>I have used clickers before in my classes (circle “3” if you have never used clickers).</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>I liked using clickers in my other classes (circle “3” if you have never used clickers).</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Knowing we will have clicker questions will help motivate me to attend lecture.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>I think it will be important to attend every CHM 4 lecture.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>I often get bored during lectures.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Using clickers will motivate me to complete the assigned readings before each class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>I am more likely to attend class if it is part of my grade.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>I am not looking forward to using clickers in CHM 4.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>I prefer classes with more student interaction and discussion.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Using clickers will help motivate me to keep up with the material on a daily basis.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>I prefer classes that emphasize lecturing over student participation.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>I sometimes skip lectures in classes that are boring.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>I only complete all of the homework on time if it is worth points towards my grade.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>14</td>
<td>I like to work in small groups when working on in-class problems.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>15</td>
<td>I plan to complete the assigned textbook readings prior to each lecture.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>16</td>
<td>Missing a few classes will probably not affect my grade for this course.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>17</td>
<td>I am looking forward to using clickers in CHM 4.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>I usually don’t read the assigned textbook readings in my classes.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>19</td>
<td>I like to have practice problems during class so I can know how I</td>
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<td>20) I often have difficulty paying attention during my classes.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>21) I think I would earn a higher grade if I attended every CHM 4 lecture.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>22) I prefer to work alone when working on in-class problems.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>23) I do not think that using clickers will help motivate me to attend lecture.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>24) I typically review my notes from the previous lecture before each class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>25) I was upset about spending money to purchase/rent and register my CHM 4 clicker.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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**Free response question (continue on back as needed):**
1) If you have used clickers before, do you have any feedback on what you particularly enjoyed or did not enjoy about using them?
APPENDIX E

Student post-exam 1 survey spring semester

CHMN 4, SP’11  
Clicker Survey: Post Exam #1  
Student clicker number:

Your answers on this survey are used to improve CHM 4 and will in no way impact your grade in the course.

**Ranked questions:** After reading each statement carefully, please circle the most appropriate answer based on your first reaction. Responses are based on the following 5-point scale:

1 = strongly disagree (SD); 2 = disagree (D); 3 = neutral (N); 4 = agree (A); 5 = strongly agree (SA)

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<tbody>
<tr>
<td>1</td>
<td>I like using clickers in CHM 4.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Knowing we have clicker questions that count toward my final grade motivates me to attend lecture in CHM 4.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>I work on CHM 4 (reading, homework, reviewing notes, studying, etc.) outside of class at least 5 days each week.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Using the clickers is too complicated.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>I had to cram to prepare for Exam #1 in CHM 4.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>I would prefer to not use clickers on future exams in CHM 4.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Using clickers helps keep me interested during CHM 4 lectures.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>I am motivated to complete the assigned readings before each class because I know there will be clicker questions about the reading that will impact my grade.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>After answering a clicker question, I like seeing how the rest of the class responded to the question (when the instructor shows the bar graph results).</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>I regularly review the clicker questions from class and add them to my notes.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>I like that clicker questions count toward my overall course grade in CHM 4.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>I find it easier to pay attention in CHM 4 over my other classes.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>Using the clickers has no benefit on my learning in CHM 4.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>I prefer working on clicker questions with other people.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>Using clickers helps motivate me to keep up with the material on a daily basis.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>I would prefer just lecture and no clickers in CHM 4.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>I sometimes skip lectures in the classes that I find boring (any class, not just CHM 4).</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>18</td>
<td>I prefer to work alone when working on clicker questions.</td>
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<td>2</td>
<td>3</td>
</tr>
<tr>
<td>19</td>
<td>Missing a few classes will probably not affect my grade in CHM 4.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>Using clickers in CHM 4 makes it easier to answer questions in class (compared to raising my hand, for example).</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
21) In CHM 4, I would get a lot more clicker questions wrong if I didn’t get to use my notes/textbook.

22) I like to have practice problems during class so I can know how I am doing.

23) I come to CHM4 class more prepared than my other classes which do not use clickers.

24) I typically review my notes from the previous lecture before each class.

25) Using clickers for the exam made the exam more stressful.

26) In CHM 4, having time to discuss clicker questions with other students has helped me understand the material.

27) The clicker questions during class helped prepare me for the exam.

28) I recognized some of the exam questions from previous clicker questions.

29) I think the money to purchase/rent and register my CHM 4 clicker was worth it.

30) In CHM 4 I have been getting a lot of clicker questions correct because someone else helps me out.

<table>
<thead>
<tr>
<th>Question</th>
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<tr>
<td>21) In CHM 4, I would get a lot more clicker questions wrong if I didn’t get to use my notes/textbook.</td>
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<td>22) I like to have practice problems during class so I can know how I am doing.</td>
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<td>23) I come to CHM4 class more prepared than my other classes which do not use clickers.</td>
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<td>25) Using clickers for the exam made the exam more stressful.</td>
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<tr>
<td>26) In CHM 4, having time to discuss clicker questions with other students has helped me understand the material.</td>
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<td>27) The clicker questions during class helped prepare me for the exam.</td>
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<td>28) I recognized some of the exam questions from previous clicker questions.</td>
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<tr>
<td>29) I think the money to purchase/rent and register my CHM 4 clicker was worth it.</td>
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<tr>
<td>30) In CHM 4 I have been getting a lot of clicker questions correct because someone else helps me out.</td>
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</table>

Do you have any additional feedback about the use of clickers in CHM 4? (please write on the back)
APPENDIX F

Student exit survey spring semester

CHM 4, Spring 2011                      Student Response System “Clickers”                       Clicker

The questions on this survey refer primarily to the clickers that we have been using in class. Your actual answers will not impact your grade in the course. Your feedback is valued and is being collected to help me improve the course.

**Ranked questions:** Please read each prompt carefully. Then circle the most appropriate answer based on your first reaction to each prompt. Responses are based on the following 5-point scale: 1 = strongly disagree (SD); 2 = disagree (D); 3 = neutral (N); 4 = agree (A); 5 = strongly agree (SA)

<table>
<thead>
<tr>
<th>Question</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) The clickers are easy to use.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2) The clickers worked properly during lectures.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3) The clickers worked properly during exams.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4) The clicker questions provided additional incentive to attend every class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5) I thought using the clickers was a valuable part of this class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6) I thought working in groups during clicker questions was beneficial.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7) The clicker points should count less toward my grade.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8) I went backed and added the clicker questions to my notes after class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9) I paid more attention to the lecture knowing clicker questions would be asked.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>10) I would have preferred to just have lecture and not any clicker questions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>11) I felt the clicker questions were generally too hard.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>12) The points from clicker questions were not enough to motivate me to prepare for class (text reading prior to class and reviewing previous lecture material).</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>13) The clicker questions helped reinforce the material from the lecture.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>14) I would attend more classes if clicker points were a higher percentage of my grade.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>15) I think I would have done better in CHM 4 if I had stronger study skills.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16) I would recommend clickers for future Chem 4 classes.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>17) I realized I needed to do the homework after missing clicker questions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>18) The grades I earned on the quizzes and exams accurately reflected the amount of effort I spent preparing for them.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>19) The clicker questions helped identify whether I understood the lecture or not.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
20) I felt the clicker questions were generally too easy. & 1 & 2 & 3 & 4 & 5  
21) I found it beneficial to get instant feedback whether I could answer the clicker questions correctly. & 1 & 2 & 3 & 4 & 5  
22) I would miss more classes if there were no clicker points that affected my grade. & 1 & 2 & 3 & 4 & 5  
23) I did not review previous material for class and was not concerned about the review clicker questions. & 1 & 2 & 3 & 4 & 5  
24) I felt compelled to read the textbook prior to class knowing there would be a clicker question from the reading. & 1 & 2 & 3 & 4 & 5  
25) I found it useful to download and review the clicker questions/answers after lecture. & 1 & 2 & 3 & 4 & 5  
26) I found the time management, note taking, and exam correction worksheets that Jeff posted on the CHM 4 website to be useful. & 1 & 2 & 3 & 4 & 5  
27) I generally did not complete the homework assignments. & 1 & 2 & 3 & 4 & 5  
28) I preferred to work alone during clicker questions. & 1 & 2 & 3 & 4 & 5  
29) The cost of the clicker was worth the expense. & 1 & 2 & 3 & 4 & 5  
30) When I answered the clicker questions correctly, I assumed I didn’t need to do the homework. & 1 & 2 & 3 & 4 & 5  
31) The clicker questions had no influence on my attendance. & 1 & 2 & 3 & 4 & 5  
32) I would like to use clickers in more of my classes. & 1 & 2 & 3 & 4 & 5  

Free response questions:

5. How did you get your clicker this semester? Circle your answer:

   - Rented it
   - Bought it used
   - Bought it new

6. Do you have any feedback or other comments which could improve the use of the clickers in this class?
REFERENCES


Perez, K.E., et al. (2010). Does Displaying the Class Results Affect Student Discussion during Peer Instruction? *CBE—Life Sciences Education.* 9(1), 133-140.


Uhari, Matti et al. (2003). Experiences using an interactive audience response system in lectures. BMC Medical Education. 3(12)1-6.


