Summer 2016

Student Identification Of Problem Topics In General Chemistry

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STUDENT IDENTIFICATION OF PROBLEM TOPICS IN GENERAL CHEMISTRY

A Masters Thesis

Presented to

The Graduate College of

Missouri State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science, Chemistry

By

Michelle D. H. Herridge

July 2016

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Chemistry

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ABSTRACT

Although there is a substantial, and growing, body of research in student misconceptions, there are fewer reports on students' beliefs regarding difficulty of subject matter. Eliciting these beliefs can be used to develop effective instructional tools since there is a direct connection between students' self-efficacy and their study habits. As part of a long-term goal of elucidating student perceptions regarding topics in introductory chemistry, I present the results of an in-depth qualitative and quantitative study conducted in the general chemistry courses at a large, research-intensive institution in the Midwest United States. A basic listing of topics, culled from South Carolina high school chemistry standards, was ranked by students in order to evaluate areas of weakness in teaching. A substantial number of students were surveyed using tools developed in a pilot study completed at Clemson University as a proof of concept for continuing research at Missouri State University. Following this work, 168 students completed weekly journal entries in which they were asked about the difficulty of introductory chemistry topics, both independently and compared to other topics being learned. This information delineates the difficulties students perceive rather than the difficulties expected such that chemistry education can work to reduce these problems and make the courses more enjoyable and approachable to students.

KEYWORDS: chemistry education, general chemistry, science education, secondary chemistry education, chemophobia

This abstract is approved as to form and content

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ACKNOWLEDGEMENTS

First and foremost, this thesis would not have been possible without the support, guidance, and patience of my advisor, Dr. Gautam Bhattacharyya. Thank you for your confidence in me.

Thank you also to all of the professors at both universities for perspective, suggestions, data collection. While I cannot list each one, professors of important note are Prof. Lisa Reece, Dr. Dennis Taylor, Prof. Helena Metzker, and Dr. Bryan Breyfogle. Additional thanks to my committee members, Dr. Erich Steinle and Dr. Les Dean. Without the influence of every professor I've encountered, this project and insights would not be what they are. I am also appreciative to the graduate college of Missouri State University and the financial support given throughout my graduate studies.

To my parents, Vicki and Van Herridge, my husband, Robert Bailey, and best friend, Ali Kane, thank you for your understanding and encouragement in every moment of panic and tolerance for every hour of discussion and review.

I dedicate this thesis to the teachers who encouraged me to celebrate science, individuality, philosophy, and chemistry. Without their influence, I would never have found my place.

Ms. Carole Rathbun, Ms. Libba Allen, Mr. Murray Eicher,

Mr. Bruce Newton, Ms. Linnea Wildenradt Haase, and Dr. Lina Jansson

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LIST OF TOPICS IN ORDER OF CLASS PRESENTATION

For short surveys:

A. Scientific notation, significant digits, dimensional analysis, graph reading, model development

B. Electron configurations and orbitals; Lewis dot structures

C. Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity)

D. Types of bonding (ionic and covalent)

E. Names and formulas for ionic and covalent compounds

For longer surveys:

A. Scientific notation, significant digits, dimensional analysis, & graph reading

B. Error analysis

C. Electron configurations and orbitals

D. Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity)

E. Alpha, beta and gamma radiation

F. Half-lives

G. Types of bonding (ionic and covalent)

H. Lewis dot structures

I. Oxidation numbers

J. Names and formulas for ionic and covalent compounds

K. Intermolecular forces

L. Bonding characteristics of carbon

M. Structural formulas and names of simple hydrocarbons

N. Organic chemistry/compounds

O. Balancing equations (simple synthesis, decomposition, single replacement, double replacement and combustion)

P. Predicting products of acid-base reactions

Q. Endothermic and exothermic reactions

R. The concept of moles

S. Percent yield, mass of excess and limiting reagent

T. Oxidation and reduction processes

U. Electrochemistry

V. Chemical equilibrium and Le Chatelier's principle

W. Behaviors of gas and gas laws (relationship of pressure, volume or temperature)

X. Heating and cooling curves

Y. Saturated solutions, solubility and precipitates

Z. Colligative properties of solutions (freezing point depression/boiling point elevation)

AA. Concentration of solutions in terms of molarity and percent weight/mass

BB. Properties of salts, acids and bases

CC. Strong and weak acids and bases and their properties

DD. pH and pOH

EE. Titrations

FF. Solubility curves

GG. Separating mixtures

HH. Solubility rules

Lab Category containing lab oriented skills and technology issues

App Application problems related to using and applying information generally

CHAPTER I: OVERVIEW OF THE STUDY

Rationale for the Study

Currently, chemistry teachers are faced with the problem of presenting material to students who often come with negative preconceived notions of the subject being "difficult" or "complicated". As a reflection of this perceived difficulty, US rates of students pursuing science, technology, engineering and math (STEM) fields is considerably lower than many other countries. It is reasonable to link between the conception of science as a challenging subject and the lack of student motivation to pursue said fields.

Much of chemistry education research deals with the overarching theme of chemistry and its difficulty as an entire subject rather than identifying the particular topics within the subject that cause students to withdraw from studying chemistry. This lack of understanding makes it impossible to pinpoint the problems that cause negative reactions to chemistry teaching. Only with identification of particular chemistry topics can changes be made that encourage students to pursue the subject.

Personal Background

My research is an attempt to understand why students have their particular opinions about chemistry and pinpoint the specific issues that cause the negative attitudes towards chemistry. There is sufficient research that shows that the opinion of chemistry is rather negative, but there is not enough information as to why these perceptions persist and how they can be addressed by instruction. Identifying the problems in current

chemistry teaching and curriculums would provide an important first step to propose solutions to the problem that chemistry is difficult for many students and transform teaching methods so that the subject can have a better acceptance by students. In other words, my research is an attempt at being a PR strategist for the field of chemistry. I do not think that chemistry is a topic that should scare people. I think chemistry is awesome, and I want every student who studies it to share my enthusiasm. My responsibility in this research project has mainly been surveys and journal entries that I have designed and compiled that elucidate the details about how students react to specific elements of chemistry, what prevents them from pursuing it further, and how we can help them better understand the subject.

From the beginning, I have been given amazing freedom from my research by my advisor, so I have designed, evaluated, compared, and otherwise controlled every step of this research and am proud to call it my own, though I have had extensive advice, help, and suggestions from my advisor and other mentors in the field. Since I hope to work in this field as my career, this research has been integral in my development as a young professional and has already made changes in the way that some departments are teaching. There is no other way to say it, I absolutely love my research.

CHAPTER II: REVIEW OF RELATED LITERATURE

Researchers Erdogan and Koseoglu in Turkey find that the themes of nature and knowledge of science seem to be transferred in chemistry, physics and biology classes, but that the concept of "science as a way of thinking" is rarely manifested in student behavior. Making the transition between understanding science and living science is crucial to the expansion of the scientific world, which is reflected in the greatly expanding desire to promote scientific literacy (2012).While arguments can be made about science education as a general field and the importance of scientific literacy for all subjects, this project focuses on chemistry learning and understanding. As such, this review consists of domain-specific content. Science as a whole is extensive and has many sub-disciplines, and each of these has their own challenges in expression and teaching. How chemistry is taught is often substantively different from physics or biology instruction. Since my career and work intends to investigate how to specifically teach chemistry, the context of this work focuses only in this domain.

Chemistry Education

Primary learning theories used in classrooms today are the constructivist, sociocultural and cognitive learning theories. Traditional theories gave rise to the notion of transferring knowledge from teacher to student intact. The constructivist teacher understands the individuality of every student and focuses on the scaffolding or framework necessary for a student to do their own learning (Bodner, Klobuchar & Geelan, 2001) in ways that are "universal and predictable" (Howe, 1996). Having origins

in Piagetian work, this theory bases itself on building one's own personal knowledge as your interaction with the world and testing and exploring hypotheses about your surroundings. Frequently, it is a concept of "knowledge [being] constructed in the mind of the beholder" (Bodner, Klobuchar & Geelan, 2001). As Howe comments, students may predictably build certain constructs from given information, as long as that information is first understood (1996). This brings up the question of common knowledge and the communication necessary to have scientific discourse, which is the topic of sociocultural learning theory and specifically Vygotsky's work. Sociocultural learning theories promote utilization of students as group participants, not as individuals with no reference and highly stresses the importance of language. Not only do students need to work together and each have the personal knowledge of a situation and the preemptive scaffolding, but there is also an emphasis on cross-contextual meaning – making the connection to apply a particular piece of knowledge to many different situations. Motivation of the student is extremely important in this process, as are interactive teaching methods (Howe, 1996).

According to Johnstone, sociocultural learning theory is not enough and needs to be supplemented with constructivism to form cognitive theory. Described as two vines growing towards each other, class study and world experience work together to support each other in developing understanding of a topic. These two facets of information allow students to grow into an idea, but also provide a filter for how students approach science – they use what they know previously to interpret new information, and the amount of prior information is critical to the amount of information gathered from a new situation. *A priori* information forms the basis by which all new things are learned. Much like the

sociocultural theory, one's knowledge is intertwined with new information so it is cross-contextually relevant, but is collected and understood primarily in the mind of the student, as in the constructivist theory (Johnstone, 1997).

At this point, there is a rough understanding of the possible ways to teach science; the question now comes to the methods of how to put it all together in a way that both opens the field to personal interpretations while teaching the information and encourages science without limiting methods to a strict or certain philosophy. Using creativity, students should be able to develop their own meanings of science without aligning them to the outlined philosophies of history, but rather, develop their own ideas of science first and then approach the philosophy as a summation of how they view science. Once a student has grasped the steps in a process, then his or her ability to then explain it as it may apply to other situation hinges on whether or not science is a game where you can answer all the questions or becomes a test that you feel you have failed time and time again. To see the way things grow and understand how ideas and concepts intertwine is really important in grasping science as a whole. Since science is such a broad topic, ranging from physics to psychology, there are many aspects that can be taught individually that do not really have any bearing on the rest of knowledge, and then there is that one piece of information that causes the realization that they are all interconnected. The constructivist theory builds these relationships from the beginning, making a comprehensive understanding of science that much easier to grasp, even at younger ages. This theory also develops a method of discussion and exploration that I think is critical to the success of scientists. Considering the philosophies presented, the main driving force for a lot of scientists is the pursuit of knowledge and understanding, in some way or

another, realist or antirealist, science is performed to explain. In developing the techniques and skills to question everything and evaluate everything, students have the ability to pursue science and evaluate the world from a scientific standpoint, which is the ultimate goal.

Tony Mitchell (1993) of St. Cloud State University decided to investigate the alleged goals of introductory chemistry classes. Mitchell identified four types of chemistry classes, and then decided to survey students in each of these four classes on what the goals of the classes should be. The four classes were: for majors and pre-professionals, health care majors, liberal arts majors, and a preparatory class. Using these four class types, Mitchell devised a list of twenty-two goals for a chemistry course, based on accepted standards and test materials, and surveyed students in each of the different types of classes and had them “agree” or “disagree” with the goal being relevant and/or necessary to the class. The resulting answers were divided into six response sets because the health care majors and the liberal arts majors both had options of one year or one term courses, and this difference in class length did affect the agreement rating. Data analysis from the survey showed that there was general consensus on some of the goals that particularly applied to reflection on the emphasis of developing intellectual skills. There was great variation, however, between the liberal arts majors’ classes and the other classes, especially when describing goals involving “future work” and preparation for later classes. The day-to-day usage of chemistry was also an interesting point of variation because only those classes that were not science or major related found this useful. Conversely, the preparation for future classes was most important to chemistry and science students (Mitchell, 1993).

Other studies (Obenland, Kincaid, & Hutchinson, 2014; Overman, Vermunt, Meijer, Bulte, & Brekelmans 2014), show that there may be other reasons that also deter students from chemistry, namely, lack of interest and application to “real world” settings. Osborne and Collins (2001) did a study utilizing focus groups that discussed these particular issues. It was found that a majority of students had issue with the repetition of technical material, leading to “a lack of positive interest” (pg 443). While these students agreed that science was important and valued in general society, Osborne suggests “that most of what non-scientists need to know in order to make informed public judgments about science fall under the rubric of history, philosophy, and sociology of science, rather than the technical content of scientific subjects.” (pg 441; quoted from Fuller, 1997:7) This comment suggests that content knowledge of chemistry is not useful without context. Without understanding of basic foundational information, students will be unable to build their knowledge of the subject for application later in life. Curriculums like the Common Core aim to organize student objectives and “provide clear and consistent learning goals to help prepare students for college, career, and life. The standards clearly demonstrate what students are expected to learn at each grade level, so that every parent and teacher can understand and support their learning” ("Read the Standards", 2014).

These standards were developed with the help of teachers by state leaders starting in 2009. State leaders were members in the National Governors Association Center for Best Practices (NGA Center) and the Council of Chief State School Officers (CCSSO). According to the official Common Core website (2014), the common core standards were

based on “the best state standards already in existence, the experience of teachers, content experts, states and leading thinkers, [and] feedback from the public.”

The Power of Belief

There is contention about what science is and how we should teach it, and then how teachers can or should be transferring science ideas and literacy, but a large part of science learning falls into the hands of the students. That is, student opinions and expectations have a huge influence on their performance in chemistry classes.

There have been a number of studies on the attitudes of chemistry students, but first the work of Christopher Bauer (2005) should be examined to emphasize the difference between self-concept and self-efficacy, and the problems with measuring one or the other. Self-efficacy is the “self-perception of an ability to do something very specific” (pg 1864), i.e. the ability to solve a particular equation or explain a property trend. Self-concept is the “evaluation an individual makes and customarily maintains with respect to himself or herself in general or specific areas of knowledge” (pg 1864). This is the overall perception of the student about their participation and ability to excel in the field. The difference is that, while a student may have the ability to do parts of chemistry, they may think that overall they will fail because of perceptions of difficulty (having high self-efficacy but low self-concept), or they may find that their inability to do particular aspects of chemistry prevents them from understanding any part of chemistry (having both low self-efficacy and low self-concept). As demonstrated by Osborne, Simn and Collin (2003), DeWitt, Osborne, Archer, Dillon, Willis, and Wong (2013) and others

(Potvin & Hasni, 2014), low self-concept implies a rather strong correlation to low enrollment in the sciences.

As Widanski and McCarthy (2009) point out, there exists a phenomenon of "chemophobia", or chemistry anxiety, which afflicts a great portion of students. Fear of chemistry often prevents students from pursing the field or having any interest in it. The effects of high-school chemistry classes often last through college and potentially could be passed down to the children of people who had poor experiences with the subject as students. Their study at a two-year college indicates that most students have anxiety related to chemistry learning, chemistry evaluation, and handling chemicals. From a self-reported survey on a scale of one to five, females had more anxiety than males and business and health majors had the highest levels of anxiety related to chemistry. McCarthy and Widanski conclude their article with the following: "Recognizing the existence of chemistry anxiety is the first step in reducing negative attitudes towards chemistry… improving students' attitudes about chemistry will have a positive impact" (2009), which could be considered a main impetus for my research.

Further research by Eddy (2000), studied the characteristics of students with high levels of chemophobia and found that chemistry anxiety was highly correlated with math anxiety, but that a large majority of students suffered from the association of chemistry with stress and failure. Findings from other studies referenced suggest that psychological treatments designed to reduce chemical anxiety can result in higher chemistry course grades and that students who do poorly in chemistry have high levels of anxiety related to the subject. Eddy took a list of activities in chemistry courses (such as reading a formula) and surveyed students to discover the mean anxiety level related to that particular

activity. Much like McCarthy and Widanski, there were three subsets that were grouped for evaluation – learning chemistry, chemistry evaluation, and handling chemicals – and these were paired with math and trait anxiety measurements for evaluation. There was a high correlation between math anxiety and chemistry anxiety, and a finding that both do in fact exist on the college campus. Eddy suggests that chemophobia may be fought off with similar methods for math literacy as long as it is recognized as an issue to overcome in the classroom (2000).

However, chemophobia has such prevalence in our society that products are often labeled "chemical-free", as noted in Sanderson's article (2013), even though every single physical object is composed of chemicals, from air to zebras, from soup to soap. Combining this phobia with the ideas of self-concept, we arrive at a conclusion that chemistry is less pursued because students do not believe they can succeed in what they are afraid of, and they are afraid of chemistry because they do not think they can do well in the subject.

A student's decision about whether or not he or she can do well in the class can also be discussed in the context of Prochaska's transtheoretical stages of change model. The stages indicate whether or not a student will even contemplate action, in this case attendance and/or enrollment in chemistry courses. This model is critical in changing the student's beliefs regarding their ability and encouraging participation and success in class. With pre-contemplation, contemplation, and preparation, a student may find that they are capable of more than they originally expected. It is only through this system, and the following actions that result from preparation, that a student can build self-

efficacy and self-concept that results in pursuit of a difficult subject. Further maintenance is also critical for the student to stay involved in the courses (Whitelaw, 2000).

Summary

There are many opinions on what chemistry aims to do and how we should interpret what we know, or what we think we know. Chemistry curricula are constantly changing, somewhat because philosophers keep arguing about what it should be. In the meantime, the introduction of the common core and research about what students expect to happen in the chemistry classroom have given information regarding some of the learning-based goals of chemistry (Mitchell, 2013), while other research has addressed the extent to which scientific thinking is taught (Erdogan and Koseoglu, 2012). Part of the investigation in chemistry education deals with teachers' perspectives and understanding of the subject, as well as the use of learning theories to construct methods of teaching (Bell, nd; McComas, 2004; Howe, 1996). Sufficient research has taken place to assert that there is a fear of chemistry for many students (Widanski, 2009; Eddy, 2000; Sanderson, 2013), and that this fear negatively impacts enrollment, appreciation, and understanding of chemistry (Osborne, 2003; DeWitt, 2013; Bauer, 2005). What has yet to take place is an investigation of the understanding of specific topics that cause the fear for students, which is the goal of this research project.

CHAPTER III: METHODOLOGY

This research project began with pilot studies at Clemson University. I was looking for information on why students, and people in general, reacted negatively to telling them I was a chemistry major. I felt the best way to do this was to find out what was hard about chemistry from the student perspective. To do this, I designed a research project that collected data at two major universities from the students in general chemistry courses. The intention was to discover what topics students in chemistry lecture classes believe to be the most and least difficult.

Pilot Study

A pilot study was completed at Clemson University during the fall semester of 2013. This initial survey was a valuable tool in updating and altering the format for continued survey research and pointed towards new information that previously was not considered as critical elements to be studied. At this stage, I anticipated much more simplicity than arose from the data. The breadth of information gathered from this pilot study was valuable in presenting at a conference, where peer analysis sparked questions that were incorporated in the continued research. A single survey during the semester was used for the pilot study, and while this information is valuable and was used for comparison to new survey data as a method for confirming generalizability, important questions were raised about gathering data over time and comparing circumstances to understanding. The IRB approval for Clemson University was approved on November 18, 2013.

Participants and setting. For this study, I used general chemistry course participants, of which there is only one lecture, CH 1010. There were about a thousand students a semester taking this class, and there were eight professors responsible for the lecture component. At Clemson, there is a large engineering program, and most students that take this course are either engineering or hard science majors.

All professors of sections of CH 1010, General Chemistry, were approached to help with their students' participation in the survey. Some professors chose to use paper surveys, while some requested the use of iClickers, which they used regularly in class. The survey was administered by the professors during class time on a scheduled exam period, with a brief introduction and the inclusion of the consent form. Professors then returned the results of the survey to me for data analysis. All data, whether collected electronically or physically, was tabulated in excel for evaluation. The consent form and survey can be found in Appendices A and B, respectively.

Nine hundred and eleven (911) students participated in the surveys. Most students were physical and social science majors or engineers (92%). Approximately four percent were English, history, arts, humanities or language majors. The rest were a mix of agriculture, health sciences, education, packaging science or undeclared. A large majority of students were freshmen (85%), with sophomores being the second most common class standing (9%). The decision to take the class was primarily due to either a general education or major requirement, with only three percent taking the class "just for fun" or another reason. Appendix I contains demographic information in detail.

Instrument and Data Collection. The initial survey was collected during an exam period near the end of the semester, so that most students would be in attendance.

For the survey, introductory, general chemistry class students were polled with the assistance of the lecturers in two formats, depending upon the lecturer's preference. One option was through the use of iClickers, an electronic polling system that is regularly used in those particular classes. The other option was paper surveys printed and provided to the lecturers by the researcher. The surveys were completed during class time on a date of an exam in hopes that most students would be in attendance. The recruitment letter and survey for Clemson are in Appendices A and B, respectively.

The survey consisted of demographic information in addition to an option to select the one hardest and one easiest topic from a list of five. These five topics were broad summaries of the first major subjects taught in the course and aligned with SC high school standards for chemistry content. It is the assumed that these five topics are universally taught in all general chemistry courses and come at the beginning of the course.

From these surveys, the primary data considered was the selection of the hardest and easiest topics. The topics were listed with specific items that were related to the broad topic. In addition, analysis of selection based on major, grade, class standing, and enthusiasm were considered. These factors were limited in differences, so further study collected this information but was considered superfluous. Problems with this survey included their limited major selection options. This was changed in the Missouri State survey.

Current evaluations of the data are limited to the selection of hardest and easiest topic overall and by major. Overall results can be found in Table 2. However, it was found that science majors differed considerably from the liberal arts majors in selecting

topics as difficult, and this was the topic of a presentation at the Midwest Regional American Chemical Society meeting in November 2014. Data can be found in Table 3 below about the differences in these rankings. It should be noted that the topics were not ranked in order of difficulty. One topic was chosen by each student as the most difficult and one topic was chosen as most easy. This explains why the ranking of hardest topics is not inverse to the ranking of easiest topics. For the rankings based on majors, it was found that liberal arts majors selected language based concepts as easier more often than science majors, while science majors selected math and analytically based concepts as easier more often than liberal arts majors. This difference reflects that the language we use is critical to making chemistry accessible to all students. It is important to note that there was consensus about the most-chosen easiest topic, regardless of major (scientific notation, significant digits, dimensional analysis, graph reading, model development), as well as the two most-chosen hardest topics (Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity) and Electron configurations and orbitals; Lewis dot structures).

Further comparisons can be made between the rankings and grades, hours studied, or graduation year, but this is this subject for another project.

Insights from CH 1010 Surveys The use of demographics to compare majors, graduation year and hours studied in the class showed surprising results. Initially, only the ranking of the topics was going to be looked at, but the differences in the majors' selections of topics and rankings showed that there are different understandings of chemistry that may inherently lead to the understanding, or lack thereof, of the subject. More research comparing different majors and understanding should help to determine

the generalizability of this phenomenon and perhaps lead to new teaching methods that

Table 1: Selection of Hardest Topic

	Hardest topic	Students	Percent
A	Scientific notation, significant digits, dimensional analysis, graph reading, model development	60	7%
B	Electron configurations and orbitals; Lewis dot structures	202	22%
C	Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity)	391	43%
D	Types of bonding (ionic and covalent)	121	13%
E	Names and formulas for ionic and covalent compounds	105	12%

Table 2: Selection of Easiest Topic

	Easiest topic	Students	Percent
A	Scientific notation, significant digits, dimensional analysis, graph reading, model development	508	56%
B	Electron configurations and orbitals; Lewis dot structures	134	15%
C	Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity)	100	11%
D	Types of bonding (ionic and covalent)	36	4%
E	Names and formulas for ionic and covalent compounds	93	10%

Table 3: Selection of Hard and Easy Topics by Major

Science Majors			Liberal Arts Majors		
Hardest topic			Hardest topic		
A	41	10%	A	15	4%
B	100	24%	B	94	23%
C	187	46%	C	184	45%
D	55	13%	D	64	16%
E	51	12%	E	52	13%
Science Majors			Liberal Arts Majors		
Easiest topic			Easiest topic		
A	215	53%	A	271	66%
B	82	20%	B	46	11%
C	62	15%	C	36	9%
D	20	5%	D	12	3%
E	48	12%	E	42	10%

translate better to different methods of thinking. This is also a topic for further research.

Interesting questions were raised through presentation of this initial data, including the correlation between attendance and understanding, understanding of later topics based on the understanding of the former topics, rationalizing the purpose of learning certain topics, and expanding the number of topics to be more inclusive of general chemistry topics. Overall, the selection of topics proved to be a good starting point for evaluating student opinions of the subject. The questions seemed to be easily understood by students and the phrasing was clear.

The inclusion of open-ended responses allowed for some feedback about strengths and weaknesses of chemistry experience. This question was reviewed and is not included in data analysis because of the ambiguity of the responses, as well as their divergence. Topics ranged from personal historical experiences to teacher based comments to complete forfeiture of understanding. There was not enough cohesion to draw any conclusions.

Another change made because of the results of the pilot study surveys is the expansion and clarification of major selection. Initial surveys were limited to just five selections for majors because of the use of iClickers, which have five options for response. The use of paper surveys allowed for those students not involved in the listed majors to write in what major they were actually a part of. The surveys being used in the continued research use college divisions within the university to be more inclusive.

The collection and analysis of the pilot study data caused me to realize that there are more in-depth questions that I would like to ask and that I would like a larger cross-

section of students to participate in the survey in order to better understand the phenomena associated with the learning of chemistry.

Guiding Questions

The specific questions addressed are:

- Of the approximately first five major topics general chemistry, what do most students believe to be most difficult and most easy?
- What topics do general chemistry students believe to be the most difficult and most easy from week to week? How difficult/easy are these topics in their opinion?
- What topics do general chemistry students believe to be the most difficult and most easy when reflecting on a completed general chemistry course? How does this ranking compare to the weekly ranking of topics?
- How do students group and identify topics that are taught in a general chemistry course?

Theoretical Frameworks

This research project has been structured in the context of phenomenography, as individual perceptions of chemistry courses has been investigated. Furthermore, the effects of constructionism can be seen through student interpretation and stated relationships.

Phenomenography is research in the context of understanding how people interact with the world around them. As a second-order approach, phenomenography aims "to define the different ways in which people experience, interpret, understand, perceive or conceptualize a certain phenomenon or aspect of reality" (Bodner & Orgill, 2007). This research method was chosen as it is student perspectives on difficulty of topics that is being investigated. Assumptions under this framework are that there are a finite number of experiences associated with an action or procedure. At some point, the views,

experiences, and opinions expressed by participants will start being repeated. It is at this repetition point that saturation of the possible outcomes occurs. Using this framework for this project assumes that students are aware of what they have difficulties with and how to reasonably express their experiences in a way that is quantifiable and coherent.

Methods

Participants and Setting. The participants for this project were students enrolled in general chemistry courses at Missouri State University in southwest Missouri. Four hundred and fifty two students were surveyed at Missouri State University from three courses. These students completed the same surveys as the pilot study with minor corrections, mostly regarding demographics and selection of the hardest and easiest topics. Additionally, 168 students enrolled in CHM 117, which is a lab course corresponding with CHM 116, at Missouri State participated in qualitative journal assignments and an extended summative survey. The companion lecture course is a one-semester general chemistry class that covers most topics that are taught in a traditional two-semester system. A majority of these CHM 117 students are nursing majors. All of the classes are general chemistry courses that have no chemistry prerequisites. IRB approval from Missouri State University was received February 2, 2015.

Instrument and Data Collection. The primary tools were surveys and structured journal entries. Two sets of students participated. The first group were students enrolled in a chemistry lecture course, and the survey was very much like those administered at Clemson University. These were collected in much the same format as the students at Clemson, and the course codes were CHM 107 (Chemistry for the Citizen), 116

(Fundamentals of Chemistry), 160 (General Chemistry I) and 170 (General Chemistry II); all of which are freshman-level chemistry courses. The recruitment letter for these one-time survey participants and the survey are in Appendices C and D, respectively. For these surveys students were polled with the assistance of the lecturers in two formats, depending upon the lecturer's preference. One option was through the use of TurningPoint, an electronic polling system that is regularly used in those particular classes. The other option was paper surveys printed and provided to the lecturers by the researcher. The surveys were completed during class time on a date of an exam in hopes that most students would be in attendance.

The five sets of topics given on this shorter survey were organized and chosen from South Carolina state standards for high school chemistry. For example, H.S.1. states: "The student will use the science and engineering practices, including the processes and skills of scientific inquiry, to develop understandings of science content" (Zais, pg 81, 2014). It then specifies scientific notation, significant digits, graph reading and model development, which is how topic "A" on the survey was generated.

The second group of students were enrolled in CHM 117, a lab, and were asked each week to complete a journal entry describing their current chemistry learning behavior and opinions. Students used the online learning site Blackboard to type in responses via the "journal" function every week. These questions were consistent throughout the semester. In addition, there was a preliminary survey structured assignment to collect demographic information of these students.

The last journal entry was altered as a cumulative final ranking of all the topics covered during the semester. This list of thirty-four topics was organized through the use

of syllabi provided by the professors, South Carolina standards, and textbook organization. This was checked with the course instructors to ensure that the topics were comprehensive, organized by order of instruction, and terms that students would be familiar with.

The references for the letters A-E for the surveys and the letters A-AH can be found in appendices B and H, respectively, as well as in the list of topics on page x. Appendix E is the recruitment script, Appendix F is the demographic survey, Appendix G consists of the questions asked for the weekly survey, and Appendix H is the final, cumulative semester difficulty prompt.

Role of the Researcher and Researcher Bias. I was primarily responsible for participant recruitment, data collection, and analysis. Dr. Bhattacharyya participated in the participant recruitment, initial data collection, and analysis. Both of us participated in the preparation of protocols and the scholarly dissemination of research results for conferences and journal publications.

Data Analysis. Survey data was collected either electronically through the TurningPoint system, on hard copy surveys, or through completion of a scantron. All data collected was input and analyzed through the use of Excel. Data collected were multiple choice question responses that were limited to specific answers. Specific data results can be found in Appendices I and J. Sample data processing can be found in Appendix N. Histograms depicting frequencies helped to determine trends and correlations between demographic information with difficulty of subject as well as the ranking of the difficult

subjects.

Weekly journal entry topics were entered into an Excel spreadsheet and had numerical rank values that were quantitatively analyzed as well as additional qualitative information. The journal topics were grouped by emergent themes identified by repetition, by the five survey topics given on a different instrument, and by the thirty-four topics given on the end of semester ranking instrument, as can be seen in Appendix M, which lists all of the hardest topics given by students and what category they were attributed to for the ranking analysis. Once grouped, these topic rankings were averaged within the group to compare across instruments and to organize the data. For example, there were sixty-five journal responses that were categorized as topic A from the end of semester list. These sixty-five entries had sixty-five numerical rank values that were averaged. This average was used in comparisons with end of semester rankings such as those in Figures 6 and 7. As can be seen, the journals were primarily analyzed via their quantitative values, and qualitative information aided in interpretation.

The end of semester ranking of topics was evaluated through averages of given rank topics by students. Each topic was listed with every student-given rank value. These values were averaged and graphed using Excel. Every student was given the list of topics and asked to rank the difficulty on a scale of one to ten. The distribution of the responses per topic can be found in Appendix K. For each topic, the responses were then averaged for a value to compare all of the topics. This average and ranking can be found in Appendix L. These values were used for rank over time and in comparison to the weekly ranking values that are discussed in Figures 6 and 7 in the results and discussion.

Validity. Construct validity of the surveys was established by using topics as

stated in the South Carolina state standards documents as well as the course professors' syllabi. Additionally, students had opportunities to write in topics as they wished to ensure appropriate coverage of topics. Content validity was established through consultation with the course professors to confirm that the items were stated in ways that were consistent with their in-course presentations. Validity was further strengthened, along with reliability, through replication using a variety of courses and professors at two universities.

CHAPTER IV: RESULTS AND DISCUSSION

In this chapter, I present the findings of the surveys and journals. Due to the nature of the results and their flow from step to step during the data collection, the information and the discussion of results are combined for clarity. Because of the quantity of data collected from this project, only a limited amount is reviewed and discussed here. Primarily, questions concerning the hardest topic were considered. For the surveys, weekly journals, and end of semester rankings, there were questions concerning demographic information, hours studied, enthusiasm, and other information, but the limited effects of these were evaluated in the pilot study and any conclusions to be drawn from those data will have to be discussed in a different project. For the results and discussion section of this paper, I will explain the expectations and findings in a non-chronological order of data collected; first the surveys, which demonstrate validity, then the end of semester rankings for organizational reasons, and finally the weekly journal entries.

Surveys

As shown in Figures 1 and 2, the topic selected with the highest frequency by students as the most difficult of the five topics was property trends. The most difficult topic was property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity). This could be considered a broad understanding of relationships and reading the periodic table. Further research will show that relationships are in fact what students are having trouble with.

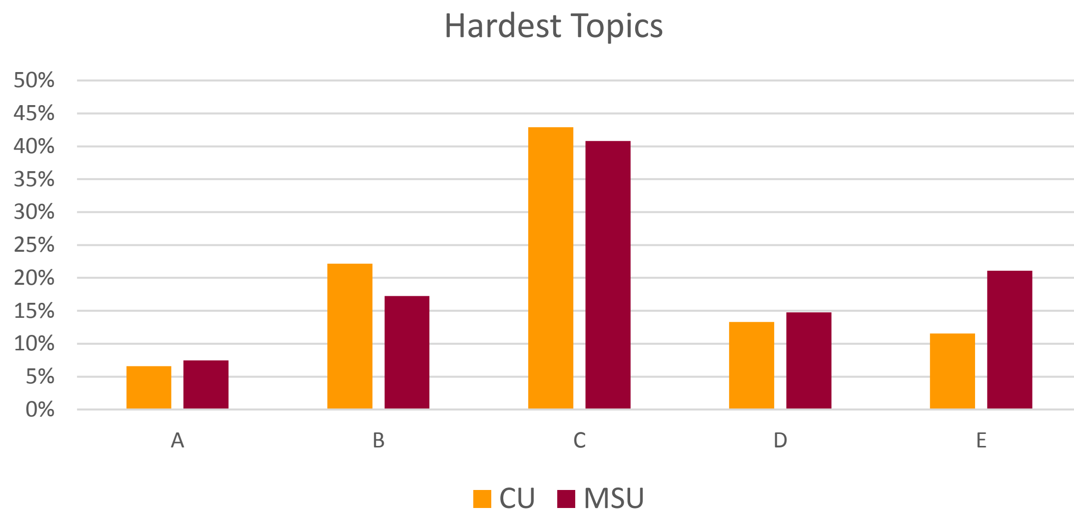

Figure 1: Selection of hardest topic from survey

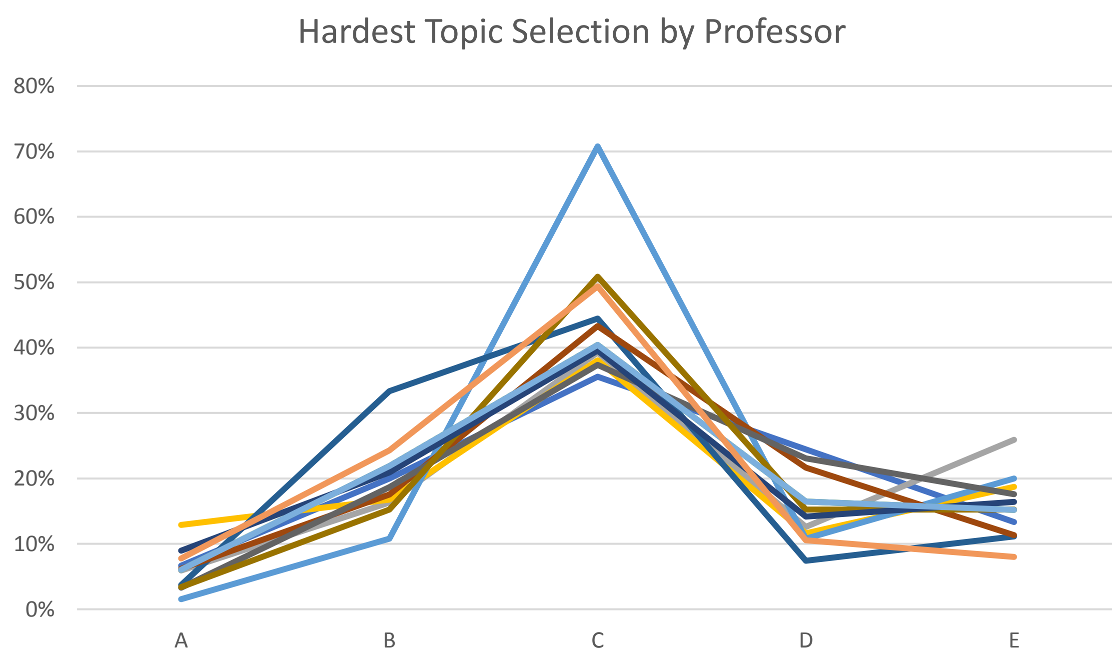

Figure 2: Selection of hardest topic by professor at all universities

The least-frequently chosen topic was scientific notation, significant digits, dimensional analysis, graph reading, and model development. It should be noted that these results reflect the students' beliefs; not their performance. As such, it is noteworthy

that students chose topic set A – containing all the basic mathematical concepts – as the least difficult considering the significant body of research indicating students' difficulties with math in chemistry courses (Eddy, 2000). This apparent discrepancy between students' beliefs in this study and their mathematical performance as previously-reported by others may be a type of expert-reversal effect, in which an individual's sense of familiarity with a topic leads to poorer-than-expected performance due to carelessness (Yeh, 2010). Further investigation is needed to shed greater insight into this disconnect.

Perhaps the most remarkable result of this research is that the "short" surveys collected at Clemson University and in all of the courses at Missouri State University yielded the same overall pattern! Despite different semesters, different schools, different levels of course, different professors, different formats (online and seated), and different textbooks and other instructional materials, the trends in the students' responses were uniform throughout. Of particular note is the agreement between professors. Figure 2

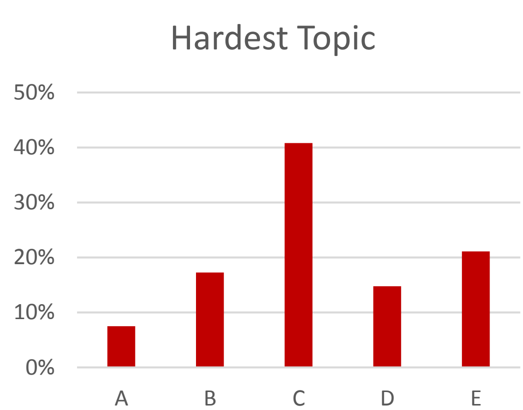

Figure 3: Selection of hardest topic at MSU

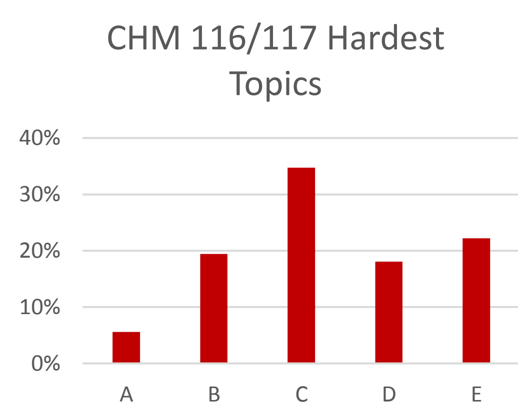

Figure 4: Selection of hardest topic among 116/117 students

Table 4: Ranking of topics from the end of the semester

Easiest – 2	3	4	4.5	5	Hardest - 6
A. Scientific notation, significant digits, dimensional analysis, and graph reading	O. Balancing equations (simple synthesis, decomposition, single replacement, double replacement and combustion) R. The concept of moles B. Error analysis G. Types of bonding (ionic and covalent) H. Lewis dot structures	W. Behaviors of gas and gas laws (relationship of pressure, volume or temperature) C. Electron configurations and orbitals S. Percent yield, mass of excess & limiting reagent Q. Endothermic and exothermic reactions AB. Properties of salts, acids and bases X. Heating and cooling curves D. Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity) AG. Separating mixtures (distillation, crystallization filtration, paper chromatography, and centrifuge) Z. Colligative properties of solutions (freezing point depression and boiling point elevation) AD. pH and pOH J. Names & formulas for ionic & covalent compounds AC. Strong & weak acids/bases & their properties AH. Solubility rules F. Half-lives	L. Bonding characteristics of carbon E. Alpha, beta and gamma radiation AF. Solubility curves M. Structural formulas and names of simple hydrocarbons	I. Oxidation numbers AA. Concentration of solutions in terms of molarity and percent weight/mass Y. Saturated solutions, solubility and precipitates P. Predicting products of acid-base reactions T. Oxidation and reduction processes N. Organic chemistry/compounds K. Intermolecular forces V. Chemical equilibrium and Le Chatelier's principle U. Electrochemistry	AE. Titrations

shows the responses from students at both Clemson University and Missouri State University with twelve different sections of classes, each with a different professor. Some of these classes are specifically engineering courses, some are just for business majors, some are honors and some are general. The responses are overwhelmingly consistent. This accounts for race, native language, gender, major, and other social and psychological differences. Even with the variety of professors and class levels, the uniformity of responses indicates that student beliefs of difficulty of topics are substantial and important, and that research should be pursued to explain these selections.

End of Semester Ranking

The second result to discuss is the difficulty of these five topics in the context of an extended list that was given to the smaller group of CHM 117 students. As seen in Table 6, these five topics align with the extended list of topics, taking the same order of difficulty, though there are interspersed topics. The least chosen topic for most hard, scientific notation, was once again the easiest, having a considerably lower ranking than any other topic. The most difficult topic was titrations. Many professors reviewing this information were surprised by this selection as the most difficult topic. This may be a result of titrations being one of the last topics in lecture and the last lab projects. Many of the comments related to this lab expressed frustration with lab materials and not having talked about the subject extensively in lecture as it is more of an application topic in the students' opinion. The end of semester ranking was collected from students who had been completing the weekly journal, so the cued responses from that process may have influenced student choices when selecting and ranking the most difficult topics.

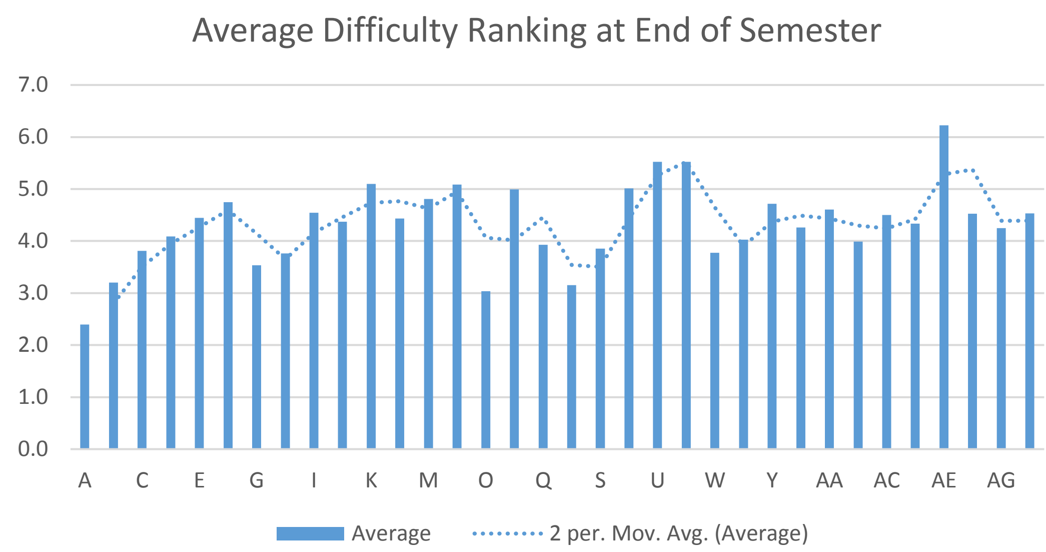

Figure 5: Ranking of topics by 117 students at the end of semester with respect to time

Looking at this list, it is interesting to note that topics that teachers may group together as similar topics for teaching are not necessarily grouped as the same difficulty for students. For example, the topics of Lewis dot structures, electron configurations, and oxidation numbers are all related in designing a lesson and in the mind of many teachers, but have varying rates of difficulty. Similarly, solubility curves, precipitates, and solubility rules are taught together, but are not similar in difficulty ranking.

The most interesting finding to come from this particular set of data can be shown through the ranking of difficulty of topics with respect to time during the semester that those topics are taught, as shown in Figure 5. Solid blue values were determined through the averaging of all responses for the topic, which can be found in Appendix L. The responses for each individual topic are also graphed and can be found in Appendix K. The dotted line shows the trend over time of the difficulty of topics. What is interesting to note is that the peaks of difficulty coincide with the exam schedule, *i.e.* exams take place after each of the peak topics F, N, V, and AA. Given that overall rankings were collected

at the end of the semester, this result seems particularly noteworthy. First, it indicates that initial beliefs about topic difficulty left strong and lingering impressions on the students. Second, at the time of the survey, at least some of the students would have been reviewing some of the topics for their final exam. Yet, even with this possibility the trend persisted in the final rankings. As such, this result shows students' beliefs about the difficulty of course content maybe as durable as their misconceptions of that content,

Finally, comparison of the end-of-term rankings with the in-term rankings offers some insight into an age-old debate about students' perceptions of difficulty as a function of time preceding an exam. These data consistently indicate that students believed that the hardest material was covered closest to the exam. As such, time to process course topics seems to supersede "fresh" topics, at least with respect to students' beliefs.

Weekly Journal Entries and Rankings

This end of semester ranking was also compared to the weekly ranking from the journal surveys. Rank according to the weekly journals can be found in Table 7. Not surprisingly, some topics that were given in the journals were not on the end of semester list, and some topics that were on the end of semester list were not mentioned in the journals. The full list of journal entries, with difficulty ranking and associated topic from the given list is printed in Appendix M. Even though the instrument solicited responses with respect to lecture-based content, a large portion of the comments in the journals focused on difficulties with lab specific skills. It is highly likely that this deviation from

Table 5: Ranking of topics according to weekly journal entries

Easiest – 4	5	5.5	6	Hardest - 8
Application of theory	Lab Skills	A. Scientific notation, significant digits, dimensional analysis, and graph reading	K. Intermolecular forces	AH. Solubility rules
Misc introductory topics	S. Percent yield, mass of excess and limiting reagent	D. Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity)	Q. Endothermic and exothermic reactions	T. Oxidation and reduction processes
B. Error analysis	W. Behaviors of gas and gas laws (relationship of pressure, volume or temperature)	C. Electron configurations and orbitals	AE. Titrations	
AB. Properties of salts, acids and bases	H. Lewis dot structures	X. Heating and cooling curves	Z. Colligative properties of solutions (freezing point depression and boiling point elevation)	
P. Predicting products of acid-base reactions	I. Oxidation numbers	O. Balancing equations (simple synthesis, decomposition, single replacement, double replacement and combustion)	R. The concept of moles	
		AA. Concentration of solutions in terms of molarity and percent weight/mass	J. Names and formulas for ionic and covalent compounds	
		AC. Strong and weak acids and bases and their properties	G. Types of bonding (ionic and covalent)	
			AD. pH and pOH	

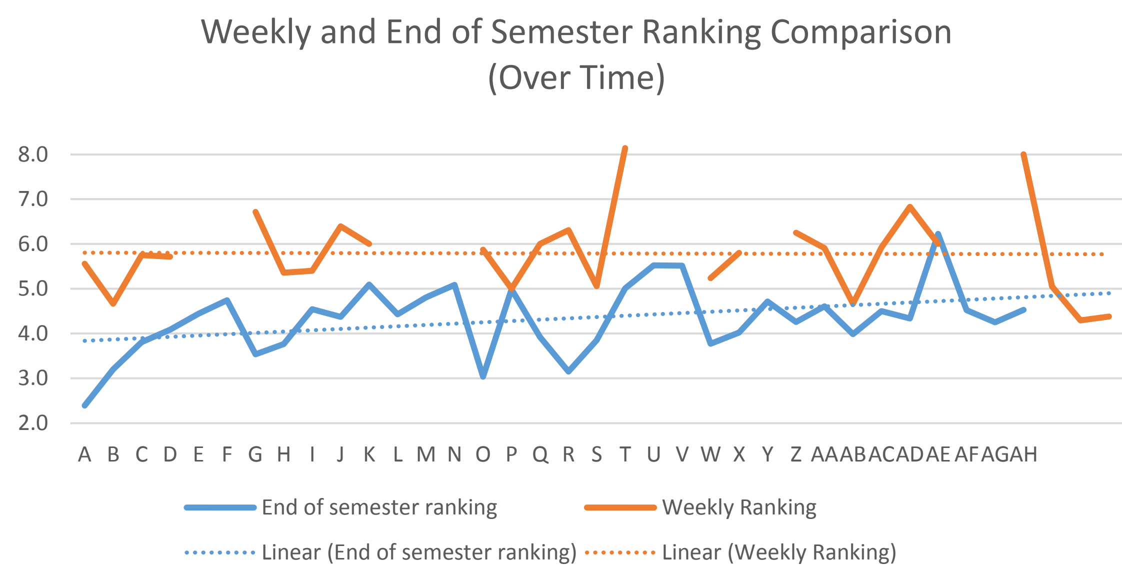

Figure 6: Comparison over time between end of semester ranking and weekly ranking of difficulty (Refer to list of topics on page x.)

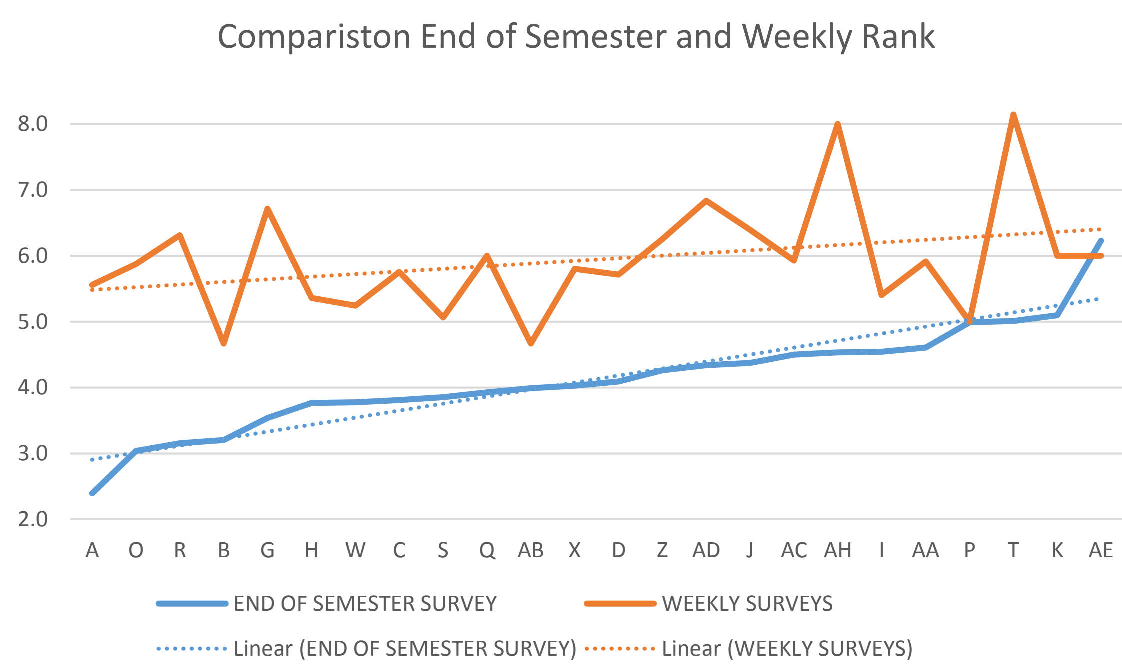

Figure 7: Comparison between end of semester ranking and weekly ranking of difficulty (Refer to list of topics on page x.)

the requested data was an artifact of collecting the data during the lab sections. With respect to lecture-based topics, the most common topic of difficulty was the completion and understanding of word problems and applications of information. Nearly every student mentioned at least one of the following topics related to solving word problems: identifying and/or recalling information for a question, reading a periodic table, setting up problems, and vocabulary were referenced The students' comments indicates that knowing information does not necessarily imply the ability to apply it. According to the data, it may seem that there are a disproportionate number of responses related to significant figures and conversions. I posit that the volume of these responses are more related to the fact that it is the first topic to be taught and is therefore taught without much context. As can be seen in Figure 6, the difference between the difficulty ranking during the semester and the ranking at the end of the semester are noticeable but not drastic. Specifically, the blue line in Figure 6 is the averaged ranking value from the end of the semester data, which has a slight difficulty increase towards the end of the semester. This line is simply a different representation of the graph in Figure 5. The orange line is the average rank of topics according to the weekly journal entries, evaluated by grouping the entries by topic and finding the average of selected difficulty. These topics have a trend line showing that the perceived difficulty throughout the semester does not change, with a slope of 0.0004. While the lasting perceptions shift with contextual information of the semester, making the first topics easier in retrospect. The difference in difficulty would also be a result of comparison – the weekly rankings not having any other topics for reference while the end of semester rankings did.

The gaps in Figure 6 are a result of students not mentioning those topics in their journals. The missing topics that are listed in the end of the semester ranking but are not in the weekly journals are: E. Alpha, beta and gamma radiation; F. Half-lives; L. Bonding characteristics of carbon; M. Structural formulas and names of simple hydrocarbons; N. Organic chemistry/compounds; U. Electrochemistry; V. Chemical equilibrium and Le Chatelier's principle; Z. Colligative properties of solutions (freezing point depression and boiling point elevation); FF. Solubility curves; and GG. Separating mixtures (distillation, crystallization filtration, paper chromatography, and centrifuge). The likely reason for these topics not being included in weekly journals is because they are topics that may be mentioned as only part of a lecture instead of a full day, or may be paired with other topics that are considered more difficult.

The interesting difference is better recognized by referencing Figure 7, where topics on the x-axis are ordered by the difficulty ranking given by the end of the semester. In this graph, you can see the convergence of the most difficult topics having the same difficulty ranking. In addition, the nearly level slope of the weekly survey trend line indicates that students believe every subject to be of similar difficulty while they are learning the material, and it is only at the end of the semester when they have contextual evidence that differences in difficulty are actually demonstrated through data. This figure indicates that the more difficult topics are in fact more difficult whether they are evaluated in the moment of learning or when reflecting on the semester of work.

The difference between the end of semester survey ranking and the weekly journal rank is greatest for the following topics (ranked in order of largest difference): A (Scientific notation, significant digits, dimensional analysis, and graph reading), G

(Scientific notation, significant digits, dimensional analysis, and graph reading), R (The concept of moles), T (Oxidation and reduction processes), and HH (Solubility rules). These topics are generally low ranking in difficulty for the end of semester ranking, but rather high during the weekly journals. This difference in ranking between the weekly ranking when learning the topic and the end of the semester when reflecting may indicate that these are the topics that most rely on context to be understood.

Summary

The final figure (Figure 8) shows a simple summary of the difficulty of the five topics that were evaluated on the surveys at Clemson University and the surveys at Missouri State University, in the end of semester ranking, and the weekly ranking. The easiest topic for three of four instruments was scientific notation, which was second easiest for the fourth. The most difficult topics are naming and trends. Overall, this data has shown that the hardest topics are those that require context and application and the easiest topic is the math that is taught first in the semester.

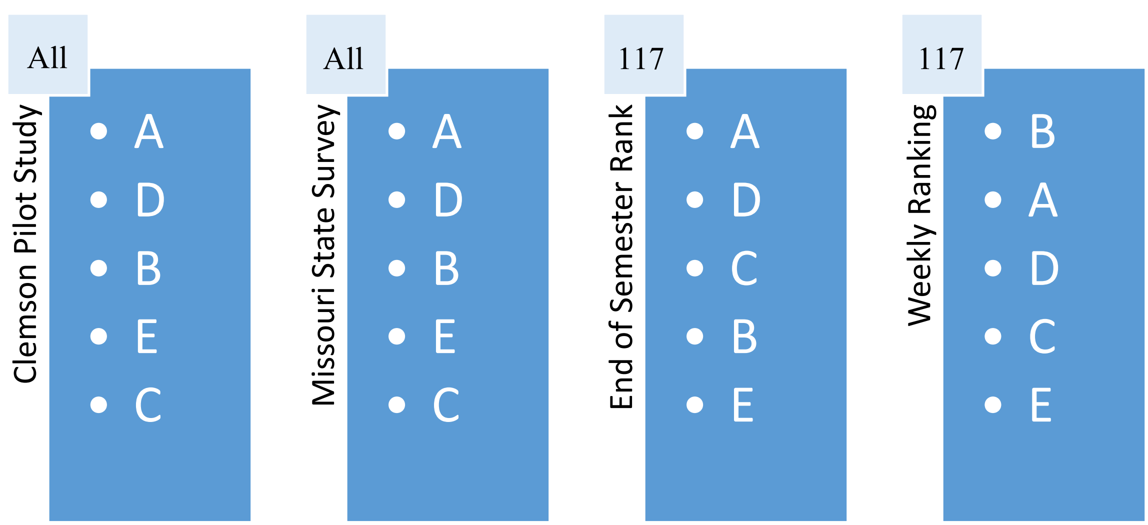

Figure 8: Comparison of difficulty of five surveyed topics, hardest at bottom

CHAPTER V: CONCLUSIONS

The findings of this research project could provide a good foundation for future work on chemistry curriculum and what chemistry educators may need to pay attention to in expressing information for student consumption. The data shows that it does not matter where a student takes chemistry, who teaches the course, or the level of the course, some topics are always chosen as more difficult. This proliferation of agreement indicates that there is much work to be done that can help nearly every student, regardless of location and demographic specificities. No matter the instructor, trends were the perceived hardest topic for students – understanding information in relation to other information, understanding relationships, and making connections. This is what seems hardest to most students.

While chemophobia is related to math for many anecdotally, it seems that students believe that the hardest topics in chemistry are in fact those that are contextual and deal with application of concepts or relationships between them. The least difficult topic across the board is scientific notation, significant digits, dimensional analysis, and graph reading, which is what most students think of as math in chemistry. While learning the topic, it has a higher difficulty rating, however the difficulty drops at the end of the semester when other topics give the math relevancy. Takeaways from this research project would primarily be that students believe topics are easier when they have references and contextual information.

The results of this research offer a second significant insight into students' beliefs about topic difficulty. As the plot in Figure 5 of the previous chapter demonstrated, the

peaks occurred just before each exam. This tendency of topics to peak in difficulty immediately before an exam indicates that a longer time to work with a concept is more important for students' self-efficacy than the "freshness" of the topic. That the trend in these peaks hold even at the end of the term, merits further investigation. One possibility is – at least according to the students' beliefs – they did not encounter that "most difficult" topic again once they finished the exam. Please note that this point does not mean that they did not receive instruction incorporating the topic in question, just that the students may not have recognized it as such.

As with all studies, this one some limitations. The surveys were administered based on several assumptions. Chief among them was that the students know and understand the topics in the survey. Another implicit assumption that was made was that the students could see an underlying connection between the topics that were grouped together on the surveys. The other significant assumption of this study was that were self-aware enough to identify their problem areas and rank them. Other than these assumptions, a major limitation was the gender distribution of the CHM 117 sample, in which there were only two men out of 168 students.

In future work concerning student perceptions, it will be important to account for assumptions of educators, as the listed topics and the student identified topics differed enough to affect rankings of some. Working to identify the details of what makes these topics difficult, and not just the generic title will also be a next step in the evaluation of current chemistry curriculum. Collecting more surveys as more institutions with different curriculum styles, comparing textbook orders and content, and trying new teaching methods that focus on contextual and relational understanding are the next steps in

further work. Additionally, pinpointing what about the difficult topics is causing students to think it is difficult is a goal of further research. With this information, restructuring courses and writing to explain things more clearly will help to encourage student learning. As mentioned earlier, when student are no longer afraid of chemistry, perhaps they will enjoy it as much as I do.

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APPENDICES

Appendix A: Clemson University student recruitment script

PROJECT TITLE: Determining influence of teacher's opinion of the nature of science on teaching methods and perceived understanding
PRINCIPAL INVESTIGATOR: Gautam Bhattacharyya

Ladies and Gentlemen,

Greetings! I am a chemistry major and would appreciate your participation in my research study the general chemistry topics which students find most difficult. The information I gather will go towards further investigation and understanding of the current ideas and practices of the chemistry field as presented in the high school and college classrooms.

To help with this research project, I would request for you to take an anonymous survey lasting about 10 to 15 minutes. Although there are no direct benefits to you, your participation is likely to help improve introductory chemistry education.

If there are any questions, please feel free to contact me at mherrid@g.clemson.edu or the project Principal Investigator, Dr. Gautam Bhattacharyya of Clemson University at 864-656-1356. If you have any questions or concerns about your rights in this research study, please contact the Clemson University Office of Research Compliance (ORC) at 864-656-6460 or irb@clemson.edu. If you are outside of the Upstate South Carolina area, please use the ORC’s toll-free number, 866-297-3071.

If you are able to participate, please click tear this page off and keep it for your records and continue on to the survey. Please note that by continuing on to the survey, you consent to participating in it. Thank you kindly for your time and efforts.

Sincerely,
Michelle Herridge
Clemson University
Department of Chemistry

PLEASE NOTE THAT THIS RECRUITMENT SCRIPT AND INFORMATIONAL LETTER REQUESTING CONSENT WILL CONSTITUTE THE FIRST PAGE OF THE ANONYMOUS STUDENT SURVEY. THANK YOU.

Appendix B: Clemson University student survey

What chemistry classes are you currently enrolled in?

A. CH 1010 and lab only
B. Multiple chemistry classes

What year was your high school graduation?

A. 2013
B. 2012
C. 2011
D. 2010
E. 2009 or prior

Why did you decide to take this class?

A. General Education requirement
B. Major requirement
C. Just for fun
D. Other

What is your major?

A. Physical sciences – biology, chemistry, physics, biochemistry, genetics, etc
B. Social science - sociology, psychology, political science, anthropology, etc
C. Engineering
D. English and Languages – English, literature, foreign language, etc
E. History and Humanities – business, history, philosophy, etc
F. Arts – music, theater, etc

What grade did you expect to get in this chemistry course at the beginning of the semester?

A. A
B. B
C. C
D. D
E. F

What is your current midterm grade?

A. A
B. B
C. C
D. D
E. F

How many hours a week outside of class do you spend working on this course, (e.g. studying or doing homework)?

A. 0-2.99 hours
B. 3.0-5.99 hours

C. 6.0-8.99 hours
D. 9.0-11.99 hours
E. 12+ hours

What chemistry topic was most difficult for you to understand?

A. Scientific notation, significant digits, dimensional analysis, graph reading, model development
B. Electron configurations and orbitals; Lewis dot structures
C. Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity)
D. Types of bonding (ionic and covalent)
E. Names and formulas for ionic and covalent compounds

What chemistry topic was easiest for you to understand?

A. Scientific notation, significant digits, dimensional analysis, graph reading, model development
B. Electron configurations and orbitals; Lewis dot structures
C. Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity)
D. Types of bonding (ionic and covalent)
E. Names and formulas for ionic and covalent compounds

What do you see as the greatest strengths and the greatest weaknesses of your chemistry education up to this point?

Appendix C: MSU semester student recruitment script

PROJECT TITLE: Identifying problem topics in teaching chemistry
PRINCIPAL INVESTIGATOR: Gautam Bhattacharyya

Ladies and Gentlemen,

Greetings! I am a chemistry major and would appreciate your participation in my research study the general chemistry topics which students find most difficult. The information I gather will go towards further investigation and understanding of the current ideas and practices of the chemistry field as presented in the high school and college classrooms.

To help with this research project, I would request for you to take an anonymous survey lasting about 10 to 15 minutes. Although there are no direct benefits to you, your participation is likely to help improve introductory chemistry education.

If there are any questions, please feel free to contact me at herridge00@live.missouristate.edu or the project Principal Investigator, Dr. Gautam Bhattacharyya of Missouri State University at 417-836-4487. If you have any questions or concerns about your rights in this research study, please contact the Missouri State University Office of Research Administration (ORA) at 417- 836-5972 or ora@missouristate.edu.

If you are able to participate, please tear this page off and keep it for your records and continue on to the survey. Please note that by continuing on to the survey, you consent to participating in it. This survey is completely voluntary and you may withdraw at any point. Not participating in this survey will have no repercussions. Thank you kindly for your time and efforts.

Sincerely,
Michelle Herridge
Missouri State University
Department of Chemistry

PLEASE NOTE THAT THIS RECRUITMENT SCRIPT AND INFORMATIONAL LETTER REQUESTING CONSENT WILL CONSTITUTE THE FIRST PAGE OF THE ANONYMOUS STUDENT SURVEY. THANK YOU.

Appendix D: MSU general student survey

What chemistry lecture classes are you currently enrolled in?

A. CHM 107
B. CHM 116
C. CHM 160
D. CHM 170
E. Multiple chemistry classes

What year was your high school graduation?

A. 2014
B. 2013
C. 2012
D. 2011
E. 2010 or prior

Why did you decide to take this class?

A. General Education requirement
B. Major requirement
C. Just for fun
D. Other

What is your college?

A. Natural and Applied Sciences –
(Biology; Chemistry; Computer Science; Geography, Geology, & Planning; Hospitality & Restaurant Administration; Mathematics; Physics, Astronomy, & Materials Science)
B. Health and Human Services –
(Biomedical Sciences; Communication Sciences & Disorders; Health, Physical Education & Recreation; Nursing; Physical Therapy; Physician Assistant Studies; Psychology; School of Social Work; Sports Medicine & Athletic Training)
C. Education –
(Childhood Education & Family Studies; Counseling, Leadership, & Special Education; Greenwood Laboratory School; Reading, Foundations, & Technology)
D. Humanities and Public Affairs OR Business –
(Defense & Strategic Studies; Economics; History; Military Science; Philosophy; Political Science; Religious Studies; Sociology, Anthropology, & Criminology; School of Accountancy; Computer Information Systems; Fashion & Interior Design; Finance & General Business; Management; Marketing; Technology & Construction Management)
E. Arts and Letters–
(Art & Design; Communication; English; Media, Journalism & Film; Modern & Classical Languages; Music; Theatre & Dance)

What grade did you expect to get in this chemistry course at the beginning of the semester?

A. A
B. B

C. C
D. D
E. F

What is your current midterm grade?

A. A
B. B
C. C
D. D
E. F

How many hours a week outside of class do you spend working on this course, (e.g. studying or doing homework)?

A. 0-2.99 hours
B. 3.0-5.99 hours
C. 6.0-8.99 hours
D. 9.0-11.99 hours
E. 12+ hours

What chemistry topic was most difficult for you to understand?

A. Scientific notation, significant digits, dimensional analysis, graph reading, model development
B. Electron configurations and orbitals; Lewis dot structures
C. Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity)
D. Types of bonding (ionic and covalent)
E. Names and formulas for ionic and covalent compounds

What chemistry topic was easiest for you to understand?

A. Scientific notation, significant digits, dimensional analysis, graph reading, model development
B. Electron configurations and orbitals; Lewis dot structures
C. Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity)
D. Types of bonding (ionic and covalent)
E. Names and formulas for ionic and covalent compounds

Appendix E: MSU weekly survey student recruitment script

PROJECT TITLE: Identifying problem topics in teaching chemistry
PRINCIPAL INVESTIGATOR: Gautam Bhattacharyya

Ladies and Gentlemen,

Greetings! I am a chemistry major and would appreciate your participation in my research study the general chemistry topics which students find most difficult. The information I gather will go towards further investigation and understanding of the current ideas and practices of the chemistry field as presented in the high school and college classrooms.

To help with this research project, I would request for you to take an anonymous survey lasting about 5 to 10 minutes once a week during lab time and participate in a verbal interview at the end of the semester after grades have been submitted. Although there are no direct benefits to you, your participation is likely to help improve introductory chemistry education.

If there are any questions, please feel free to contact me at herridge00@live.missouristate.edu or the project Principal Investigator, Dr. Gautam Bhattacharyya of Missouri State University at 417-836-4487. If you have any questions or concerns about your rights in this research study, please contact the Missouri State University Office of Research Administration (ORA) at 417- 836-5972 or ora@missouristate.edu.

If you are able to participate, please tear this page off and keep it for your records and continue on to the survey. Please note that by continuing on to the survey, you consent to participating in it. This survey is completely voluntary and you may withdraw at any point. Not participating in this survey will have no repercussions. Thank you kindly for your time and efforts.

Sincerely,
Michelle Herridge
Missouri State University
Department of Chemistry

PLEASE NOTE THAT THIS RECRUITMENT SCRIPT AND INFORMATIONAL LETTER REQUESTING CONSENT WILL CONSTITUTE THE FIRST PAGE OF THE ANONYMOUS STUDENT SURVEY. THANK YOU.

Appendix F: MSU demographic information for weekly journal participants

What year was your high school graduation?

A. 2014
B. 2013
C. 2012
D. 2011
E. 2010 or prior

Why did you decide to take this class?

A. General Education requirement
B. Major requirement
C. Just for fun
D. Other

What grade do you expect to get in CHM 116?

A. A
B. B
C. C
D. D
E. F

What is your college?

A. Natural and Applied Sciences
B. Health and Human Services
C. Education
D. Humanities and Public Affairs
E. Arts and Letters

How would you rank your enthusiasm towards chemistry as a subject? (1-6, 1 being your most favorite subject and 6 being your most hated subject)

How would you rank your enthusiasm towards your chemistry classes? (1-6, 1 being your most favorite subject and 6 being your most hated subject)

What do you see as the greatest strengths and the greatest weaknesses of your chemistry education up to this point?

Appendix G: MSU weekly journal prompt

Thank you for participating in this research project! Your input is valuable and much appreciated!

Please answer the following questions as honestly as possible. These questions will be the same each week, but your feedback about each week's lesson is important and will help us to improve chemistry teaching in the future. Please title each journal entry with the date.

How would you rank your enthusiasm towards chemistry as a subject on a scale of 1-6, 1 being your most favorite and 6 being your least?

How would you rank your enthusiasm towards your chemistry classes on a scale of 1-6, 1 being your most favorite and 6 being your least?

What topics did you learn this week?

How many hours this week outside of class did you spend working on this course, (e.g. studying or doing homework)?

What was the most difficult topic for you this week? How would you rank its difficulty? (1-10, 1 being extremely easy and 10 being extremely difficult)

What was the easiest topic for you this week? How would you rank its ease? (1-10, 1 being extremely easy and 10 being extremely difficult)

Appendix H: MSU end of semester journal entry

Thank you for participating in this research project! Your input is valuable and much appreciated!

If you have not completed the student demographic survey, please do. It can be found under Lab 0 assignments – Student Demographics for Research

First, what lecture section were you in?

Please rank these topics from easiest to hardest. For each one, please rank the difficulty on a scale of 1-10. If you did not discuss a topic in class, you can skip it. If there is a topic you discussed in class that is not on this list, feel free to add it. After ranking, please write at least one sentence about the five most difficult topics and WHY they were difficult.

A. Scientific notation, significant digits, dimensional analysis, and graph reading
B. Error analysis
C. Electron configurations and orbitals
D. Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity)
E. Alpha, beta and gamma radiation
F. Half-lives
G. Types of bonding (ionic and covalent)
H. Lewis dot structures
I. Oxidation numbers
J. Names and formulas for ionic and covalent compounds
K. Intermolecular forces
L. Bonding characteristics of carbon
M. Structural formulas and names of simple hydrocarbons
N. Organic chemistry/compounds
O. Balancing equations (simple synthesis, decomposition, single replacement, double replacement and combustion)
P. Predicting products of acid-base reactions
Q. Endothermic and exothermic reactions
R. The concept of moles
S. Percent yield, mass of excess and limiting reagent
T. Oxidation and reduction processes
U. Electrochemistry
V. Chemical equilibrium and Le Chatelier's principle
W. Behaviors of gas and gas laws (relationship of pressure, volume or temperature)
X. Heating and cooling curves
Y. Saturated solutions, solubility and precipitates

Z. Colligative properties of solutions (freezing point depression and boiling point elevation)
AA. Concentration of solutions in terms of molarity and percent weight/mass
BB. Properties of salts, acids and bases
CC. Strong and weak acids and bases and their properties
DD. pH and pOH
EE. Titrations
FF. Solubility curves
GG. Separating mixtures (distillation, crystallization filtration, paper chromatography, and centrifuge)
HH. Solubility rules

What do you see as the greatest strengths and the greatest weaknesses of your chemistry education up to this point?

How would you rank your enthusiasm towards the subject of chemistry?

Having taken this class, do you like chemistry more or less? Has it changed your opinion of science?

Appendix I: Clemson Survey Response Data

Major				
A	Physical Sciences		405	44%
B	Social Sciences		45	5%
C	Engineering		390	43%
D	English and languages		4	0%
E	History and humanities		31	3%
F	Arts		1	0%
G	Packaging Science		2	0%
H	Agricultural		12	1%
I	Food science and Nutrition		5	1%
J	Nursing/Health Science		4	0%
K	Education		1	0%
L	Undeclared		11	1%
				911

Graduation Year				
A		2013	777	85%
B		2012	83	9%
C		2011	20	2%
D		2010	11	1%
E	2009 or earlier		10	1%

Decision to take class			
A	General Education Requirement	161	18%
B	Major requirement	711	78%
C	Just for fun	9	1%
D	Other	14	2%

Grade			
	A	273	30%
	B	360	40%
	C	196	22%
	D	56	6%
	F	12	1%

Hours studied per week			
A	0-2.99	306	34%
B	3.0-5.99	435	48%
C	6.0-8.99	127	14%
D	9.0-11.99	22	2%
E	12+	16	2%

Understanding of the topic			
A	Outstanding	216	24%
B	good	185	20%
C	reasonable	61	7%
D	vague	5	1%
E	none	32	4%

Hardest topic			
A	sci note, sig fig, dim analysis	60	7%
B	electron config, lewis dots	202	22%
C	property trends	391	43%
D	types of bonding	121	13%
E	names and formulas	105	12%

Easiest topic			
A	sci note, sig fig, dim analysis	508	56%
B	electron config, lewis dots	134	15%
C	property trends	100	11%
D	types of bonding	36	4%
E	names and formulas	93	10%

Appendix J: Missouri State Survey Response Data

School			
A	Natural and Applied Sciences	132	30%
B	Health and Human Services	259	59%
C	Education	21	5%
D	Humanities and Public Affairs	2	0%
E	Business	21	5%
F	Arts and Letters	6	1%
			441

Class			
A	CHM 107	4	1%
B	CHM 116	216	49%
C	CHM 160	231	52%
D	CHM 170	0	0%

Graduation Year			
A	2014	282	64%
B	2013	62	14%
C	2012	32	7%
D	2011	16	4%
E	2010 or earlier	50	11%

Decision to take class			
A	General Education Requirement	112	25.4%
B	Major requirement	297	67.3%
C	Just for fun	5	1.1%
D	Other	29	6.6%

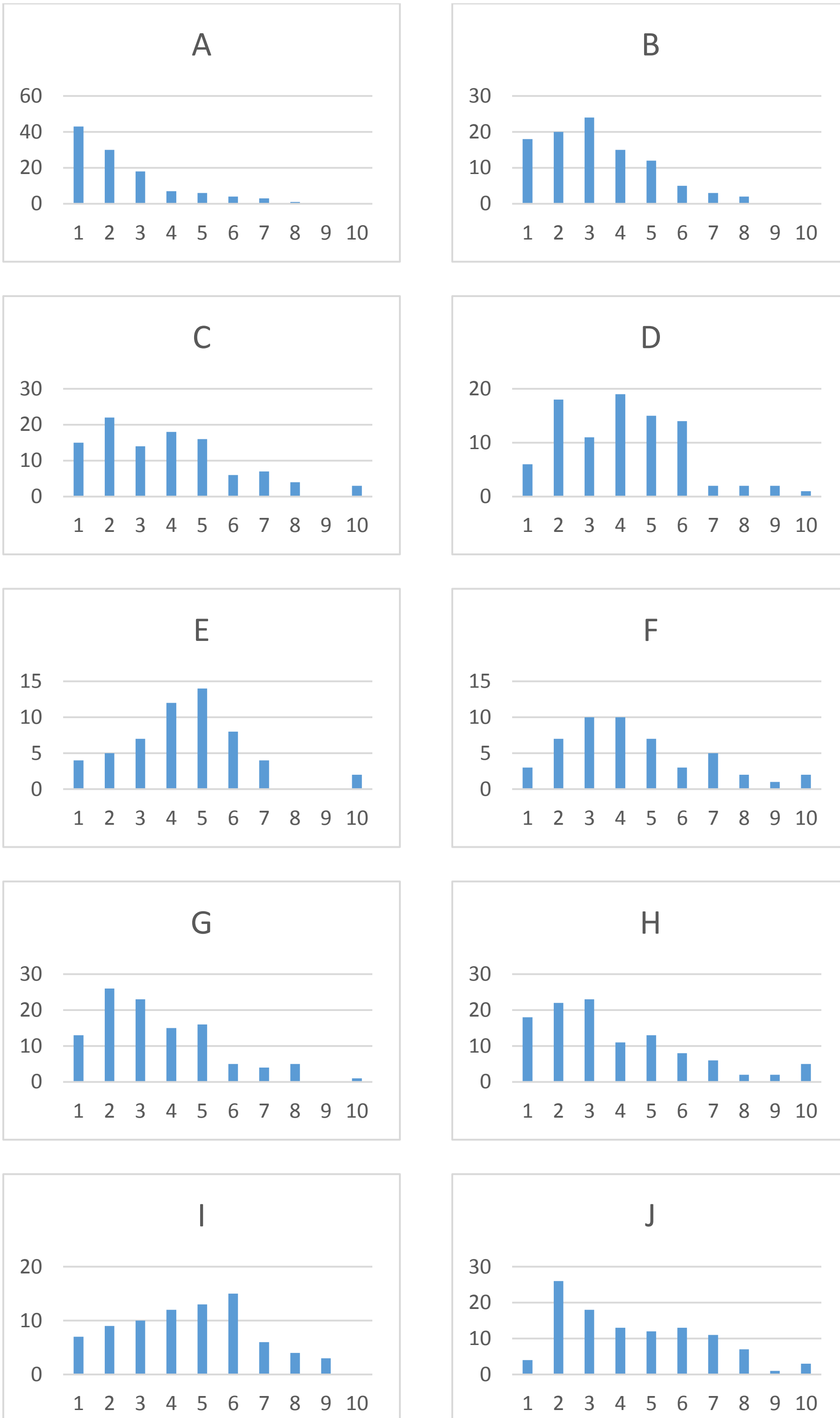
Grade			
	A	146	33%
	B	160	36%
	C	92	21%
	D	34	8%
	F	7	2%

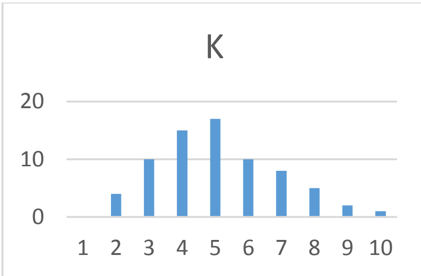
Hours studied per week			
A	0-2.99	121	27%
B	3.0-5.99	211	48%
C	6.0-8.99	88	20%
D	9.0-11.99	20	5%
E	12+	6	1%

Understanding of the topic			
A	Outstanding	30	7%
B	good	216	49%
C	reasonable	153	35%
D	vague	46	10%
E	none	2	0%
Enthusiasm			
A	Most Favorite	19	4%
B	favored	99	22%
C	middle	138	31%
D	not favored	91	21%
E	Least favorite	100	23%
Hardest topic			
A	sci note, sig fig, dim analysis	33	7%
B	electron config, lewis dots	76	17%
C	property trends	180	41%
D	types of bonding	65	15%
E	names and formulas	93	21%
Easiest topic			
A	sci note, sig fig, dim analysis	96	22%
B	electron config, lewis dots	86	20%
C	property trends	129	29%
D	types of bonding	56	13%
E	names and formulas	80	18%

Appendix K: Missouri State End of Semester Ranking Distribution by Topic

The key for the topic descriptions are found in the list of topics on page x.

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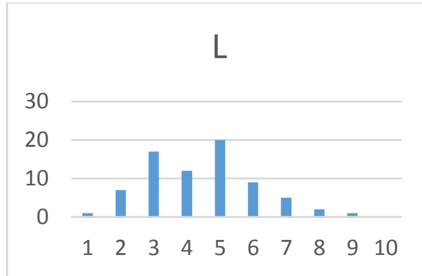
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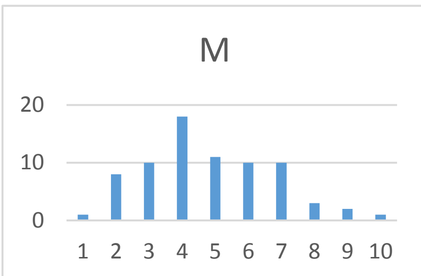
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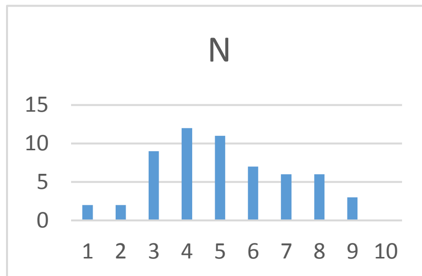
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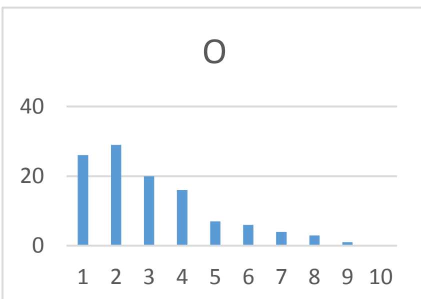
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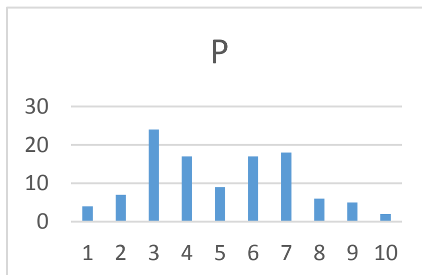
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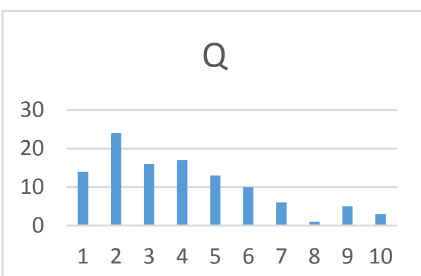
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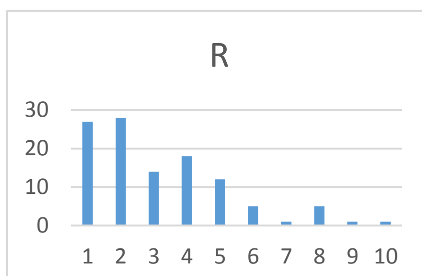
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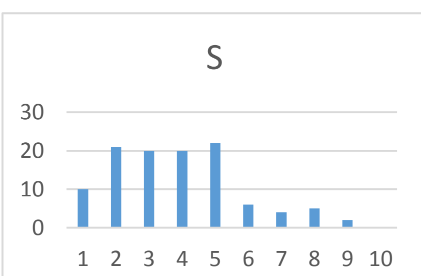
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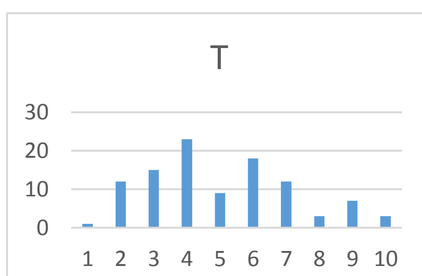
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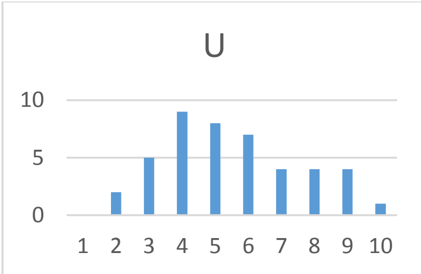
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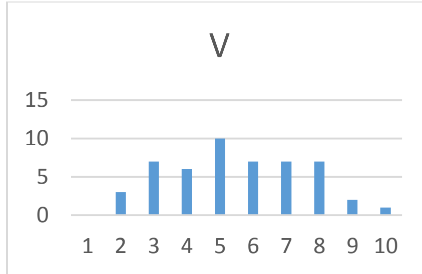
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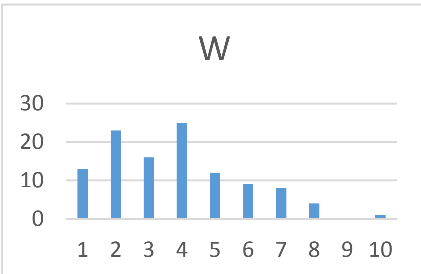
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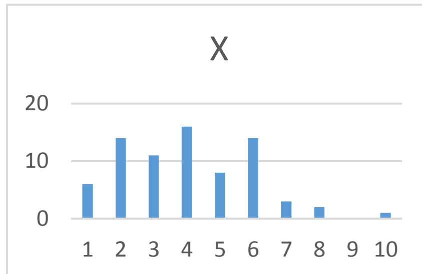
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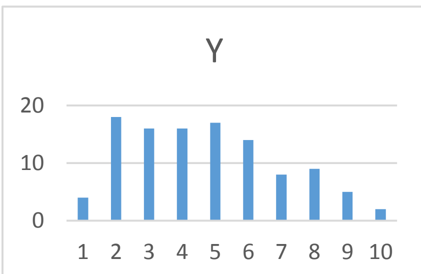
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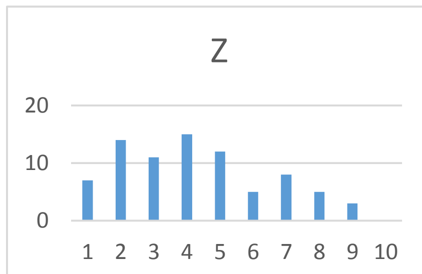
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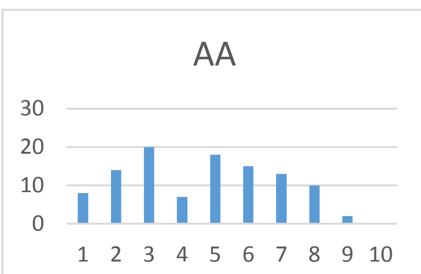
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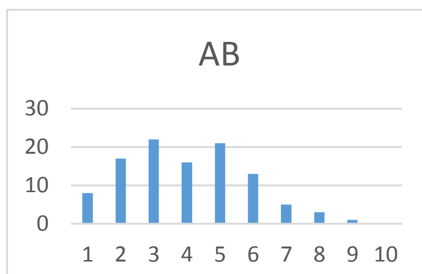
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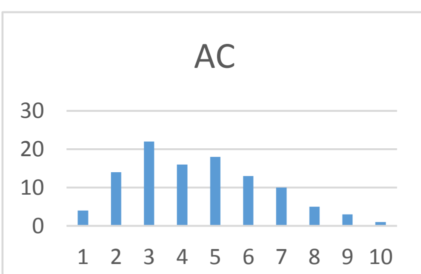
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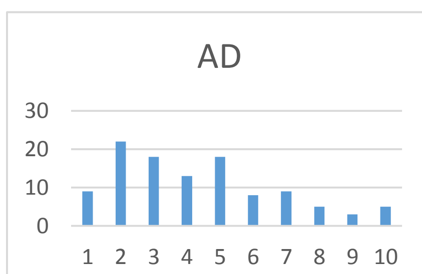
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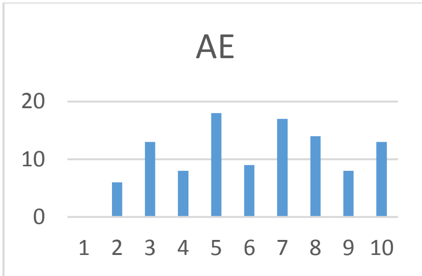
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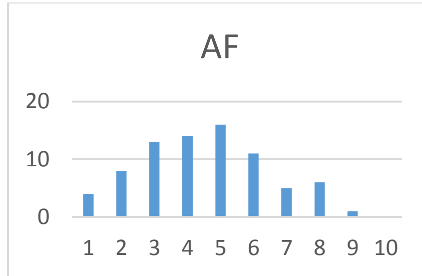
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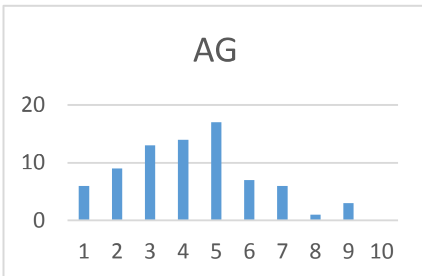
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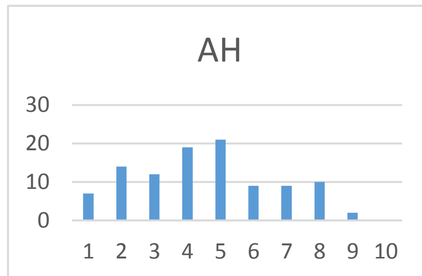
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Appendix L: End of Semester Difficulty Rankings

Topic	AVERAGE	Stdev	Median	Mode	Responses
A	2.4	1.6	2	1	112
B	3.2	1.7	3	3	90
C	3.8	2.2	4	2	110
D	4.1	2.0	4	4	74
E	4.4	1.9	4.5	5	50
F	4.7	3.3	4	4	103
G	3.5	2.0	3	2	56
H	3.8	2.4	3	3	50
I	4.5	2.1	5	6	109
J	4.4	2.3	4	2	109
K	5.1	1.8	5	5	106
L	4.4	1.6	4.5	5	44
M	4.8	1.9	4.5	4	75
N	5.1	2.0	5	4	110
O	3.0	1.9	3	2	99
P	5.0	2.2	5	3	106
Q	3.9	2.3	4	2	108
R	3.2	2.1	3	2	105
S	3.9	1.9	4	5	79
T	5.0	2.2	5	4	106
U	5.5	2.1	5	4	76
V	5.5	2.0	5	5	78
W	3.8	2.0	4	4	108
X	4.0	1.9	4	4	74
Y	4.7	2.3	5	2	107
Z	4.3	2.2	4	4	112
AA	4.6	2.2	5	3	80
AB	4.0	1.8	4	3	72
AC	4.5	2.0	4	3	112
AD	4.3	2.4	4	2	109
AE	6.2	2.4	6	5	103
AF	4.5	1.9	4.5	5	111
AG	4.3	2.0	4	5	58
AH	4.5	2.1	4	5	110

Appendix M: Weekly Journal Difficulty Rankings

STUDENT LISTED TOPIC	RANK	TOPIC
conversion factors	1	A
converting density within SI units	2	A
graphing	2	A
graphing	2	A
graphing	2	A
sig figs	2	A
sig figs	2	A
simple math	2	A
calculating class average	2	A
math problems	2	A
conversion factors	3	A
conversion factors	3	A
conversions	3	A
conversions	3	A
conversions	3	A
conversions	3	A
Conversions: how to set up the equations and converting to the correct units	3	A
conversions: multi-step conversions	3	A
conversions: multi-step conversions	3	A
converting both the top and bottom numbers	3	A
graphing	3	A
metric conversions	3	A
metric conversions	3	A
sig figs	3	A
slope of a line	3	A
math problems	3	A
calculations	3	A
using logarithms	3	A
calculating standard deviation	4	A
conversion factors	4	A
conversions	4	A
conversions	4	A
conversions	4	A
conversions	4	A
conversions	4	A
conversions	4	A
conversions of Si units to English units	4	A
conversions: multi-step conversions	4	A
conversions: multi-step conversions	4	A

STUDENT LISTED TOPIC	RANK	TOPIC
conversions: multi-step conversions	4	A
conversions: multi-step conversions	4	A
conversions: using conversion factors to switch between different units	4	A
converting equations and balancing them	4	A
converting units	4	A
graphing	4	A
math: analyzing graphs	4	A
sig figs	4	A
sig figs	4	A
sig figs	4	A
sig figs	4	A
sig figs	4	A
sig figs	4	A
sig figs, specifically zeros	4	A
standard deviation	4	A
understand what the conversions were	4	A
mathematic equations and different formulas	4	A
metric to English conversions	4	A
comparing slopes and graphs	4	A
calculating density	4	A
calculations	4	A
calculations	4	A
conversion factors	5	A
conversion factors	5	A
conversion factors	5	A
conversion factors	5	A
conversion factors	5	A
conversion factors in lab	5	A
conversions	5	A
conversions	5	A
conversions	5	A
conversions	5	A
Conversions: how to convert the problems	5	A
Conversions: knowing the conversion factors	5	A
conversions: using measuring instruments unaccustomed to	5	A
conversions: what conversions I had to make and where I needed to go	5	A
converting grams to molecules	5	A
converting mass to volume	5	A
converting metric units	5	A
graphing	5	A

STUDENT LISTED TOPIC	RANK	TOPIC
sig figs	5	A
sig figs	5	A
sig figs	5	A
sig figs	5	A
sig figs	5	A
sig figs	5	A
sig figs	5	A
sig figs and conversions	5	A
sig figs and equations	5	A
significant figures	5	A
standard deviation	5	A
standard deviation	5	A
standard deviation	5	A
starting conversions	5	A
math	5	A
calculations	5	A
calculations	5	A
memorize the different conversion factors	5	A
conversions in the metric system	5.5	A
conversion factors	6	A
conversions	6	A
conversions	6	A
conversions	6	A
conversions	6	A
conversions	6	A
conversions	6	A
conversions	6	A
conversions	6	A
conversions (not knowing units)	6	A
conversions and math	6	A
conversions with moles	6	A
conversions: putting the conversion together	6	A
conversions: word problem to conversion factors	6	A
convert answers to sig figs	6	A
convert equations and relation to conductivity	6	A
converting different measurements	6	A
converting grams to molecules	6	A
converting measures	6	A
converting units	6	A
graphing questions	6	A
metric conversions	6	A
remembering conversion factors	6	A

STUDENT LISTED TOPIC	RANK	TOPIC
setting up conversion factors	6	A
sig figs	6	A
sig figs	6	A
sig figs	6	A
sig figs	6	A
significant figures	6	A
significant figures	6	A
significant figures	6	A
standard deviation	6	A
standard deviation	6	A
mathematical equations for determining slope of a graph	6	A
molecular conversions	6	A
calculations	6	A
calculations	6	A
conversion factors	6.5	A
conversion equations	7	A
conversion factors	7	A
conversions	7	A
conversions	7	A
conversions	7	A
conversions	7	A
conversions	7	A
conversions	7	A
conversions	7	A
conversions with the 10 to a n power	7	A
conversions: figuring out the conversions and finding out how to set them up based on word problems	7	A
Conversions: how to convert the problems	7	A
conversions: what conversion factors to use	7	A
conversions: wordy conversion problems	7	A
converting molarity to grams needed	7	A
graphing	7	A
sig figs	7	A
significant figures	7	A
significant figures	7	A
standard deviation	7	A
math - figuring out concentration from absorbance and such	7	A
math problems	7	A
calculating molar mass	7	A
calculations	7	A
conversion factors	7.5	A
conversion factors	8	A

STUDENT LISTED TOPIC	RANK	TOPIC
conversion factors	8	A
conversion factors	8	A
conversions	8	A
conversions	8	A
conversions	8	A
conversions between moles/grams/molecules	8	A
conversions: multi-step conversions	8	A
conversions: unit conversions	8	A
convert like three different things at once	8	A
converting moles, molecules, and atoms	8	A
setting up conversion factors	8	A
sig figs	8	A
sig figs	8	A
sig figs	8	A
sig figs	8	A
sig figs	8	A
sig figs in calculations	8	A
significant figure usage	8	A
standard deviation	8	A
calculations	8	A
calculations	8	A
numerical ratios	8	A
percentages	8	A
conversions	9	A
conversions	9	A
conversions: changing from moles to grams or volume	9	A
conversions: unit conversions	9	A
conversions: unit conversions	9	A
sig figs	9	A
math problems	9	A
conversion factors	10	A
conversions of formulas to names	10	A
conversions: unit conversions	10	A
sig figs	10	A
conversion equations		A
conversion factors with sig figs		A
conversions		A
conversions		A
conversions		A
conversions		A
conversions		A
conversions		A

STUDENT LISTED TOPIC	RANK	TOPIC
conversions with new units		A
conversions with new units		A
conversions: multi-step conversions		A
conversions: multi-step conversions		A
conversions: understanding the correct processes and conversions		A
converting moles to atoms and grams to atoms		A
converting units		A
graphing		A
graphing		A
making the graph and equations		A
metric conversions		A
sig figs		A
sig figs		A
sig figs		A
sig figs and conversions		A
standard deviation		A
math		A
math problems		A
calculations		
error analysis	5	B
errors and sig figs	6	B
calculating errors	3	B
electron configurations	4	C
electron configurations	7	C
electron configurations	9	C
orbitals	6	C
quantum-mechanical orbitals	6	C
remembering exceptions to octet rule		C
valence electrons	4	C
valence electrons and sharing electrons		C
isotopes	4	C
isotopes	5	C
isotopes	5	C
isotopes	5	C
isotopes	7	C
isotopes	7	C
isotopes		C
isotopes		C
identify what categories elements fall into	5	D
identifying chemicals	5	D
memorizing the periodic table	5	D
solving for atomic mass	5	D

STUDENT LISTED TOPIC	RANK	TOPIC
Atomic Mass: finding atomic mass	5	D
elements: figuring out the elements	2	D
memorizing element names and symbols	7	D
memorizing elements	9	D
memorizing more elements	6	D
memorizing the elements	6	D
periodic table	6	D
qualities of metals or metalloids	7	D
relation of element, symbol, atomic number, atomic mass, etc	5	D
characteristics of neutrons/protons/electrons	7	D
talking about why certain elements bond together		G
understanding binary elements	7	G
understanding how molecules work	7	G
understanding the difference between molecular compounds, ionic compounds and acidic compounds	6	G
compounds: difference between ionic compound, molecular compound, and formula unit	8	G
memorizing compounds	6	G
memorizing polyatomic ions	6	G
memorizing polyatomic ions	7	G
memorizing the common polyatomic ions		G
memorizing the polyatomic ions		G
learning where to put the bonds	3	H
Lewis Dot structure: break down of molecules	2	H
Lewis dot structures	5	H
Lewis dot structures		H
Lewis structure	6	H
Lewis structures	3	H
Lewis structures	4	H
Lewis structures	4	H
Lewis structures	4	H
Lewis structures	5	H
Lewis structures	5	H
Lewis structures	7	H
Lewis structures	7	H
Lewis structures		H
Lewis structures		H
Lewis structures and molecular geometry	7	H
Lewis structures: drawing dot structures	6	H
Lewis Structures: drawing Lewis structures	6	H
molecular geometries	3	H
molecular geometry	6	H

STUDENT LISTED TOPIC	RANK	TOPIC
molecular geometry	6	H
molecular geometry	10	H
molecular geometry		H
molecular geometry: atom modeling	4	H
molecular geometry: building the models and identifying the geometrical shape	6	H
molecular geometry: building the molecular models	9	H
molecular geometry: configurations for each of the atoms	4	H
molecular geometry: constructing molecular models and resonance	5	H
molecular geometry: determine the name of the shape	4	H
molecular geometry: determining the differences between the names of the shapes	6	H
molecular geometry: determining the structure of the atom	5	H
molecular geometry: difference between trigonal and pyramidal	6	H
molecular geometry: double bonding and figuring out the different types of 3d structures	5	H
molecular geometry: figuring out how to draw the Lewis structure based on the number of valence electrons	4	H
molecular geometry: figuring out how atoms bond together		H
Molecular Geometry: figuring out the shape of the molecules	6	H
molecular geometry: finding the shapes of the molecules	5	H
Molecular Geometry: how the bonds would form between the atoms	3	H
Molecular geometry: identifying shapes	4	H
molecular geometry: learning how to do the 3d design of shapes		H
molecular geometry: what kind of shape the molecule was	4	H
molecular modeling	5	H
molecular modeling	5	H
molecular modeling	5	H
molecular modeling	6	H
molecular modeling	7	H
molecular modeling	8	H
molecular models exceptions to shape	5	H
molecular shape of each molecule	8.5	H
molecular structure	6	H
molecular structure	7	H
resonance	5	H
ions	3	I
ions	6	I
ions and isotopes	6	I
Ions: dealing with ions	5	I
Ions: finding charges on an ion	4	I
Ions: finding ions in balanced equations	7	I

STUDENT LISTED TOPIC	RANK	TOPIC
Ions: how atoms gain and lose electrons	8	I
Ions: how ions dissociate	3	I
knowing the number of "have" electrons and the number of "need" electrons	5	I
learning the different ions	7	I
empirical formula	3	J
empirical formula	6	J
empirical formula	5	J
Empirical formula: getting the correct empirical formula	9	J
Empirical formula: how to calculate empirical formula	5	J
empirical formulas	3	J
empirical formulas	4	J
empirical formulas	5	J
empirical formulas	5	J
empirical formulas	6	J
empirical formulas	6	J
empirical formulas	7	J
Empirical Formulas: amount of moles needed from chemical formula	9	J
Empirical Formulas: creating empirical formulas from percents of elements	4	J
Empirical formulas: finding formulas from mass percents	7	J
empirical formulas: knowing how much HCl to react with Mg and find how much Cl it made	5	J
Formula: finding the amount of moles in a formula	10	J
formulas	5	J
formulas for compounds	7	J
formulas for converting problems	7	J
formulas for errors and accuracy of measurement	7	J
formulas for the gas laws	7	J
formulas on the lab questions	6	J
Formulas: finding the chemical formulas for ionic and molecular compounds	8	J
Formulas: how to read the periodic table to create a chemical equation	9	J
ionic compound naming	7	J
ionic compounds	4	J
ionic compounds	6	J
ionic compounds	7	J
ionic compounds	8	J
ionic compounds	8	J
ionic compounds vs molecular compounds	8	J
making empirical formula from data	6	J

STUDENT LISTED TOPIC	RANK	TOPIC
molecular formula	5	J
molecular formula		J
molecular formulas	6	J
names of ionic bonds	6	J
naming	8	J
naming		J
naming	10	J
naming acids	9	J
naming acids	6	J
naming acids and compounds	5	J
naming and formulas	8	J
naming chemicals ad figuring out what type of ion or molecule they are	8	J
naming compounds	5	J
naming compounds	6	J
naming compounds	7	J
naming compounds	7	J
naming compounds	7	J
naming compounds	9	J
naming compounds		J
naming compounds		J
naming compounds and how they transform from one thing to the other and how to notate everything	7	J
naming compounds and nomenclature		J
naming compound	10	J
naming conjugates	3	J
naming ionic compounds	3	J
naming ionic compounds	8	J
naming isotopes and compounds	6	J
naming lab tools	3	J
naming models	4.5	J
naming molecular equations	7	J
naming molecular geometry and their characteristics	8	J
naming molecular geometry of a compound	8	J
naming some formulas	8	J
naming the compounds	7	J
naming the powders	6	J
naming the structures	2	J
naming the types of reactions	5	J
naming: describing and naming compounds with no explanation of the differences between the electron geometries	7	J
Naming: how to write compound names		J

STUDENT LISTED TOPIC	RANK	TOPIC
Naming: identifying the type of compound	6	J
polyatomic ions	2	J
polyatomic ions	5	J
polyatomic ions	6	J
polyatomic ions	7	J
polyatomic ions	8	J
polyatomic ions	9	J
writing formulas	6	J
writing formulas for ionic compounds	7	J
intermolecular forces	4	K
intermolecular forces	5	K
intermolecular forces	7	K
intermolecular forces	8	K
polar/nonpolar	4	K
polarity	8	K
balanced chemical equations	7	O
balancing chemical equations	8	O
balancing equations	2	O
balancing equations	3	O
balancing equations	3	O
balancing equations	5	O
balancing equations	5	O
balancing equations	5	O
balancing equations	6	O
balancing equations	6	O
balancing equations	7	O
balancing equations	7	O
balancing equations	9	O
balancing equations		O
balancing equations		O
balancing equations and mass conversions	7	O
balancing equations: deciphering what the equations were looking for and how to set them up and solve them	7	O
balancing some equations		O
balancing the equations	4	O
balancing the equations	5	O
equations	4	O
equations	2	O
equations	5	O
equations	7	O
equations		O
equations: determining when to use what equation	4	O

STUDENT LISTED TOPIC	RANK	TOPIC
equations: figuring out which equations to use and how to properly plug in the missing values	4	O
equations: figuring out the different ways to solve the equations given		O
equations: figuring out the product of an equation	8	O
Equations: figuring out the product of an equation	8	O
Equations: finding equations to match findings	8	O
Equations: knowing how to do the equations correctly	6	O
Equations: knowing how to write compounds in an equation	9	O
learning about no reaction	9	O
learning the different reactions	6	O
making an equation and finding the product and balancing	8	O
net ionic equations	4	O
net ionic equations	7	O
net ionic equations	8	O
net ionic equations		O
Reactions: determining the type of chemical reactions		O
Seeing what kind of equations are what (double replacement, etc.)		O
setting up the equations		O
setting up the equations		O
stoichiometry	3	O
stoichiometry	4	O
stoichiometry	7	O
stoichiometry		O
trying to come up with the balanced equation	5	O
types of reactions	4	O
calculating net ionic equations	5	O
calculations for the empirical formula	6	O
combustion, redox, and chemical quantities	10	O
writing equations	2	O
writing equations	7	O
writing net ionic chemical reactions	7	O
writing net ionic equations	7	O
writing out solutions	4	O
combustion	8	O
predicting products and solubility	5	P
endo/exothermic reactions		Q
endothermic vs exothermic reactions	6	Q
calculating the number of molecules in a compound	8	R
molar mass	7	R
molar mass	7	R
molar mass	9	R

STUDENT LISTED TOPIC	RANK	TOPIC
molar mass and understanding the equation	9	R
molar mass		R
mole calculations	3	R
mole calculations		R
mole calculations	9	R
mole calculations		R
mole conversions	4	R
mole conversions	6	R
mole to mole conversions		R
mole-gram conversions	3	R
moles	6	R
moles	6	R
moles	7	R
moles	8	R
moles	8	R
moles and grams	5	R
moles conversions	6	R
moles homework	9	R
moles to grams to atoms and moles to atoms	4	R
moles to grams to balance equations	5	R
using the equation for finding moles		R
calculating how many moles in an equation	6	R
calculating moles	3	R
calculating moles	4	R
calculating moles/grams	7	R
calculating the amount of atoms	9	R
working with the number of atoms and molecules	6	R
limiting reactant	7	S
limiting reactants	4	S
limiting reactants	5	S
limiting reactants	8	S
mass percent/volume percent	7	S
molar calculations	5	S
molar conversions	3	S
molar conversions	3	S
percent composition	4	S
percent error	3	S
percent error	4	S
percent error	5	S
percent recovered	6	S
percent yield	6	S
percent yield: figuring out percent yield	6	S

STUDENT LISTED TOPIC	RANK	TOPIC
percent yields	5	S
calculating the moles and percent yield		S
learning oxidation and reduction reactions	10	T
oxidation reactions	6	T
oxidation reactions		T
oxidation, reduction and all that stuff	9	T
oxidation/reduction	7	T
oxidation/reduction	8	T
oxidation/reduction reactions	7	T
reactions: determining if the equation was oxidation-reduction or acid-base	10	T
equilibrium concentration		V
solution conductivity, gas laws	3	W
gas conversions	7	W
gas law equations	6	W
gas law equations	5	W
gas laws	2	W
gas laws	3	W
gas laws	4	W
gas laws	4	W
gas laws	5	W
gas laws	5	W
gas laws	5	W
gas laws	5	W
gas laws	5	W
gas laws	6	W
gas laws	6	W
gas laws	6	W
gas laws	7	W
gas laws	7	W
gas laws	7	W
gas laws	7	W
gas laws	8	W
gas laws	8	W
gas laws		W
Gas laws: Avogadro law	3	W
Gas laws: Boyles law	4	W
Gas Laws: Charles law	8	W
Gas Laws: Charles' law and rearranging the equation	6	W
Gas Laws: combined gas law	4	W
Gas laws: combined gas law	7	W
Gas Laws: combined gas law		W

STUDENT LISTED TOPIC	RANK	TOPIC
Gas Laws: combined gas law problems	5	W
Gas laws: combined gas laws	6	W
Gas Laws: combined gas laws	7	W
Gas laws: differentiating the gas laws	5	W
Gas Laws: differentiating the gas laws		W
gas laws: drawing a graph of pressure vs temperature	2	W
Gas laws: finding the constant in gas laws	2	W
gas laws: ideal gas law	5	W
gas laws: ideal gas law	5	W
gas laws: ideal gas law	5	W
gas laws: ideal gas law	6	W
gas laws: keeping the gas laws straight	5	W
gas laws: knowing what value to expect when the volume is increased or decreased (gas law)	5	W
gas laws: learning the different gas laws	4	W
gas laws: pv=nrt and when to use it	3	W
gas laws: pv=nrt and when to use it		W
gas laws: using gas law formulas	4	W
gas laws: using the gas law equation combined with mass	5	W
gas laws: which law definition goes with which law name	6	W
gas laws: working out ideal gas laws	6	W
gas relationships and all the formulas		W
memorizing gas laws and keeping them straight	7	W
memorizing the gas laws	7	W
calculations dealing with pressure, temperature, moles and volume	6	W
understanding ideal formula	3	W
boiling points	8	X
phase changes	3	X
phase diagrams	5	X
heat capacity	7	X
enthalpy	6	X
precipitation reactions	6	Y
solubility	4	Y
solubility	6	Y
solubility	6	Y
solubility	6	Y
solubility	7	Y
solubility	6	Y
solubility of ions	6	Y
solubility of powders	9	Y
solubility: determining whether an equation is insoluble or soluble	7	Y

STUDENT LISTED TOPIC	RANK	TOPIC
solubility: determining whether an equation is insoluble or soluble from an equation	7	Y
trying to comprehend solubility	5	Y
calculation the solution concentration	7	AA
how to do solution problems	4	AA
molarity	3	AA
molarity	5	AA
molarity	5	AA
molarity	5	AA
molarity	8	AA
molarity	8	AA
molarity and keeping formulas straight	7	AA
molarity two step problems	6	AA
solution concentration molarity	7	AA
solution equations problems	5	AA
solution stoichiometry	6	AA
solutions	7	AA
solutions	10	AA
understanding the solution concentration	6	AA
calculating molarity	3	AA
calculating percentage of formulas	5	AA
concentration	7	AA
concentration	7	AA
dilution	5	AA
dilution	5	AA
understanding mass percent	5	AA
solution conductivity	6	BB
solution conductivity	8	BB
understanding conductivity	4	BB
understanding conductivity	4	BB
calculating conductivity	5	BB
calculations for acids and bases	6	BB
conductivity	2	BB
conductivity	3	BB
conductivity	4	BB
conductivity	5	BB
conductivity	6	BB
conductivity		BB
conductivity	2	BB
conductivity: charts for conductivity	5	BB
predicting conductivity	4	BB
predicting relative slopes	6	BB

STUDENT LISTED TOPIC	RANK	TOPIC
predicting relative slopes		BB
acid and base conjugates	3	CC
acid/base concepts	8	CC
Acid/bases: Bronsted-Lowry	7	CC
acid-base neutralization and enthalpy	7	CC
acid-base reactions	5	CC
acids	7	CC
acids and bases	4	CC
acids and bases	5	CC
acids and bases/ pH=-log[concentration]	3	CC
Acids and bases: difference between acidic and basic	7	CC
Acids and bases: difference between acidic and basic	8	CC
acids/bases: Bronsted Lowry and conjugate pairs	5	CC
Acids/bases: conjugate acids and bases	9	CC
Acids/Bases: Conjugate acids/bases	7	CC
acids/bases: deciding whether a substance was basic neutral or acidic	6	CC
acids/bases: equaling acids and bases	5	CC
Acids/Bases: how to identify and balance acid-base reactions	7	CC
Acids/Bases: how to name binary acids and oxyacids	6.5	CC
Acids/Bases: identifying oxyacids and naming them	6	CC
Acids/Bases: identifying the CB and CA of acids and bases	3	CC
calculating pH	4	DD
calculating pH		DD
ph	4	DD
pH	10	DD
pH		DD
pH and stoichiometry	6	DD
pH levels	8	DD
ph poh calculations	9	DD
Math: figuring out the math with buffers	8	EE
titration equations in lab	5	EE
titration	5	EE
memorizing solubility of ions	6	HH
solubility principles	9	HH
solubility rules	9	HH
flow chart	2	Lab
flow chart	3	Lab
flow chart	3	Lab
flow chart	3	Lab
flow chart	4	Lab
flow chart	4	Lab
flow chart	4	Lab

STUDENT LISTED TOPIC	RANK	TOPIC
flow chart	4	Lab
flow chart	4	Lab
flow chart	4	Lab
flow chart	5	Lab
flow chart	5	Lab
flow chart	5	Lab
flow chart	5	Lab
flow chart	5	Lab
flow chart	5	Lab
flow chart	5	Lab
flow chart	5	Lab
flow chart	5	Lab
flow chart	5	Lab
flow chart	5	Lab
flow chart	7	Lab
flow chart	7	Lab
flow chart	7	Lab
flow chart	7	Lab
flow chart	7	Lab
flow chart	8	Lab
flow chart	8	Lab
flow chart	9	Lab
flow chart		Lab
flow chart		Lab
flow chart		Lab
flow chart		Lab
flow chart		Lab
flow chart		Lab
Flow chart: identifying the compound from the flow chart	5	Lab
flow charts		Lab
flowchart	2	Lab
flowchart	4	Lab
flowchart	4	Lab
flowchart	4	Lab
flowchart	5	Lab
flowchart	8	Lab
flowchart	8	Lab
following a flowchart	8	Lab
lab procedure	2	Lab
lab procedure	4	Lab
lab procedure	4	Lab
lab procedure	4	Lab

STUDENT LISTED TOPIC	RANK	TOPIC
lab procedure	4	Lab
lab procedure	5	Lab
lab procedure	5	Lab
lab procedure	5	Lab
lab procedure		Lab
lab quest	5	Lab
lab quest	7	Lab
lab quest machine use	6	Lab
lab reports	6	Lab
Lab Skill: figuring out the vacuum machine	4	Lab
lab skills	2	Lab
lab skills	3	Lab
lab skills	4	Lab
lab skills	5	Lab
lab skills	5	Lab
lab skills	5	Lab
lab skills	5	Lab
lab skills	6	Lab
lab skills	6	Lab
lab skills	8	Lab
lab skills		Lab
lab skills		Lab
lab skills	4	Lab
lab skills homework	2	Lab
lab skills: accurately measuring liquids	3	Lab
Lab skills: accuracy and precision	5.5	Lab
lab skills: assembling lab	6	Lab
lab skills: blackboard	6	Lab
lab skills: boring		Lab
Lab skills: buret	6	Lab
lab skills: cengage	6	Lab
lab skills: cleaning/cross contamination	6	Lab
lab skills: collecting the actual correct data	5	Lab
lab skills: conductivity probe labquest	2	Lab
lab skills: confusing directions	6	Lab
lab skills: deciding on the substance (white powders)	5	Lab
lab skills: describe the crystal shape	6	Lab
lab skills: determining crystal shape/solubility	5	Lab
lab skills: determining if a substance is completely soluble or not	6	Lab
Lab skills: determining if compounds were soluble	6	Lab
Lab skills: determining if its no reaction	3	Lab
lab skills: determining shape and crystal size of the powders	5	Lab

STUDENT LISTED TOPIC	RANK	TOPIC
lab skills: determining solubility	4	Lab
lab skills: determining solubility	6	Lab
lab skills: determining solubility of chemical equations	8.5	Lab
lab skills: determining the solubility of each solution	5	Lab
lab skills: determining what substance is listed		Lab
lab skills: determining why each substance had the characteristics it did and what it told you about the substance	5	Lab
lab skills: differentiate between slightly and completely soluble	5	Lab
lab skills: differentiating between white powders	4	Lab
lab skills: during lab figuring out numbers and formulas	5	Lab
lab skills: empirical formulas in lab	2	Lab
lab skills: equipment management	4	Lab
lab skills: experiment instructions	5	Lab
lab skills: experimental error	4.5	Lab
lab skills: figuring out how everything worked		Lab
lab skills: figuring out the conductivity of a solution	9	Lab
lab skills: figuring out the masses of the density when placed in the water at different levels	3	Lab
Lab skills: figuring out the questions on the lab	5	Lab
Lab skills: figuring out what substance was in the containers	7	Lab
lab skills: filtration	5	Lab
lab skills: finding a way to efficiently and quickly get through the lab while keeping everything clean	3	Lab
Lab skills: finding density	2	Lab
lab skills: finding density	4	Lab
Lab skills: finding estimated digit when measuring	5	Lab
Lab skills: finding pressure based on data collected	7	Lab
lab skills: finding volume	4	Lab
lab skills: finishing on time	4	Lab
lab skills: finishing the lab in time; flow chart	8	Lab
lab skills: following procedure and calculating final concentration		Lab
lab skills: following the directions	2	Lab
lab skills: getting lab supplies	2	Lab
lab skills: getting lab supplies	3	Lab
lab skills: getting the Bunsen burner to work correctly	5	Lab
lab skills: getting the equipment to work properly	4	Lab
lab skills: getting the exact number off the meniscus	6	Lab
lab skills: getting the experiment to work on time		Lab
Lab skills: getting the right amount of solution (titration)	2	Lab
lab skills: handling the syringe	4	Lab
lab skills: having enough time to complete the lab	6	Lab
Lab skills: how to do the lab		Lab

STUDENT LISTED TOPIC	RANK	TOPIC
Lab skills: how to read graduated cylinder	6	Lab
Lab skills: identifying crystal shape and solubility	5	Lab
Lab Skills: identifying differences in chemical appearance	7	Lab
lab skills: instructions	4	Lab
lab skills: instructions	4	Lab
lab skills: instructions	5	Lab
lab skills: instructions	8	Lab
lab skills: instructions		Lab
lab skills: instructions		Lab
lab skills: iodine and acid test	10	Lab
Lab skills: knowing how to find the volume of an object		Lab
lab skills: knowing how to set up equipment	5	Lab
lab skills: lab activities	2	Lab
lab skills: lab exam	7	Lab
lab skills: lab exam	9	Lab
lab skills: lab instructions	4	Lab
lab skills: lab is always confusing because it is mostly learning by doing	6	Lab
lab skills: learning how to be very precise	7	Lab
Lab skills: lighting a Bunsen burner	3	Lab
lab skills: making sure everything was done	3	Lab
lab skills: naming tools		Lab
Lab skills: not having a lab manual	6	Lab
lab skills: online lab work	9	Lab
lab skills: patience	7	Lab
lab skills: preparing for lab	2	Lab
lab skills: purpose of the lab	5	Lab
lab skills: questions at the end of lab	4	Lab
lab skills: reading assignments	6	Lab
lab skills: reading instruments	5	Lab
lab skills: reading the buret	5	Lab
lab skills: reading the graduated cylinders	8	Lab
lab skills: remembering how to use all the tools for our chemistry lab	3	Lab
lab skills: safety instructions	4	Lab
lab skills: stirring while heating the cu mixture	5	Lab
lab skills: time management in lab	7	Lab
lab skills: time management in lab	7	Lab
lab skills: time management in lab	8	Lab
lab skills: time management in lab		Lab
lab skills: using lab equipment	6	Lab
lab skills: using lab quest	4	Lab
lab skills: using the syringe	7	Lab

STUDENT LISTED TOPIC	RANK	TOPIC
lab skills: using the technology	2	Lab
lab skills: waiting for the product to separate from the precipitate after heating	2	Lab
lab skills: working alone		Lab
Lab skills: working with the sensor	4	Lab
lab skills: working with the technology in the lab	2	Lab
lab skills: working with the technology in the lab	7	Lab
lab skills: reading granulated cylinder	6	Lab
labquest	3	Lab
labquest	3	Lab
labquest	3	Lab
labquest	3	Lab
labquest	4	Lab
labquest	4	Lab
labquest	4	Lab
labquest	5	Lab
labquest	5	Lab
labquest	5	Lab
labquest	5	Lab
labquest	6	Lab
labquest	6	Lab
labquest	6	Lab
labquest	6	Lab
labquest	7	Lab
labquest		Lab
labquest		Lab
labquest		Lab
labquest		Lab
labquest		Lab
labquest		Lab
log equations	9	Lab
mass percent	5	Lab
mastering chemistry		Lab
measurement	3	Lab
measurement	7	Lab
measurement conversions and scientific notation	8	Lab
measuring conductivity	7	Lab
measuring density		Lab
measuring one gram		Lab
measuring pH levels	6	Lab
measuring the amounts correctly	2	Lab
measuring the exact ml	5	Lab

STUDENT LISTED TOPIC	RANK	TOPIC
measuring the meniscus accurately	8	Lab
number of procedures to follow in lab	4	Lab
mixing/following directions	6	Lab
setting up the experiment	2	Lab
understanding directions	5	Lab
understanding the material and what the data says	6	Lab
understanding the purpose of the lab and how to use the equipment	5	Lab
understanding what to do	5	Lab
understanding the actual lab	5	Lab
white powders	7	Lab
word problem	5	App
word problems	3	App
word problems	3	App
word problems	6	App
word problems	7	App
word problems		App
wording of problems	3	App
application word problem	2	App
application word problem	3	App
application word problem	3	App
application word problem	3	App
application word problem	3	App
application word problem	4	App
application word problem	4	App
application word problem	4	App
application word problem	4	App
application word problem	6	App
application word problem		App
application: answering practical questions about the chemical reaction	8	App
application: critical thinking questions	4	App
Application: figuring out why one had a greater conductivity	3	App
Application: how to apply information	7	App
Application: identifying information in word problems	5	App
Application: incorporating math	4	App
keeping all the information straight	4	App
knowing what formula to use	6	App
deciding the formula to use	3	App
abstract topics in class		App
analysis of chemicals	5	App
remembering how to identify the substances on our own without the sheet telling us how to	4	App

STUDENT LISTED TOPIC	RANK	TOPIC
remembering the different terms that go along with solutions	7	App
remembering the formulas	4	App
remembering vocab and elements	3	App
remembering the different formulas	4	App
set up equations from lecture	7	App
set up the online software for the class	3	App
set up word problems	6	App
how to determine what a chemical is	3	App
setting up the problems from the information given	3	App
setting up to solve for equations	5	App
studying for the test	4	App
studying for the test	5	App
thinking about the problems critically	4	App
trying to decide which formula you use when	3	App
trying to decide which formula you use when	7	App
using the right units to use the formula	3	App
vocabulary		App
memorizing the names for the prefixes	2	App
density	1	Other
density	5	Other
absorbance	4.5	Other
absorbance	7	Other
absorbance: Beer's Law	2	Other
absorbance: Beer's Law	4	Other
Beer's Law: figuring out the equations on the Beer's law worksheet	7	Other
physical and chemical changes	3	Other
physical and chemical changes	4	Other
physical and chemical changes	7	Other
physical and chemical changes/reactions	5	Other
physical change vs chemical change	2	Other
physical or chemical changes	3	Other
physical vs chemical changes	2	Other
physical vs chemical changes	6	Other
physical vs chemical properties - classification	4	Other
physical vs chemical properties/changes	8	Other

Appendix N: Sample data processing

Semester Survey:

Data collected were tabulated in Excel.
The number of students who selected a particular response was counted.
These data can be found in Appendix I for Clemson and Appendix J for Missouri State University.

Weekly ranking:

A sample student's response is in the table below. Each cell is a new week:

Enthusiam (subject): I would rank it at a 4. Enthusiam (classes): I would rank it at a 3. Hours studied: I spent around 2 hours. Difficult topic: Nothing this week was too difficult but if i had to say something it would be graphing so i would rate it at 2. Easy topic: The easiest topic is measuring by far it is a 2 for sure.
Enthusiam (subject): I would rank it a 3 Enthusiam (classes): I would rank it a 3.5 Hours studied: Around an hour Difficult topic: The most difficult topic would ahve to be dealing with ions. I would rank it as a 5 Easy topic: The easiest topic for me this week is the conversions cause I love math. I would rank it a 1.
Hours studied: I spent about an hour outside of class. Difficult topic: The most difficult part of the week was probably isotopes. I would rate them a 5 Easy topic: The easiest topic was probably calculating density. I would rate it a 2. **Now that you've taken your first test, what was the most difficult topic to study for and which topic do you feel you did the worst on? What was easiest and what do you feel most confident about? Overall i wasnt to hard to study for but i still got stumped up on the isotopes but with all the calculations i was very confident.
Hours studied: I spent about an hour making my flow chart. Difficult topic: Everything this week was pretty simple. I would rank it a 2 Easy topic: Overall, in lab weighing things was really easy and in lecture chapter 6 was alright. I would rate it a 3 With the exam i thought I would have done better and i wish she would go over the answers but she wont.
Enthusiam (subject): I would give it a four. Enthusiam (classes): I would give is a five What topics did you learn this week? How to observe chemical and physical changes. Hours studied: one hour Difficult topic: the most difficult topic would be balancing equations. I would rank it at a 3 Easy topic: The easiest topic would be observing and testing powders in lab. I would rank it a 2
Enthusiam (subject): I would rank it 4 Enthusiam (classes): I would rank it a 6 What topics did you learn this week? Learned about balancing equations and had a midterm in lab Hours studied: about one hour Difficult topic: The most difficult topic is learning the different reactions. I would rank it a 6 What was the easiest topic for you this week? How would you rank its ease? (1-10, 1 being extremely easy and 10 being extremely difficult) The easiest topic was balancing equations. I would rank it a 2
Enthusiam (subject): I would rank it a 3 Enthusiam (classes): I would rank it a 5 What topics did you learn this week? We learned about valence electrons and orbitals Hours studied: Around and hour and a half Difficult topic: Nothing this week was too difficult Easy topic: Drawing out a elements orbitals i would rank it a 3
Enthusiam (subject): I would rank it a 3

Enthusiam (classes): I would rank it a 5 What topics did you learn this week? We learned about the different laws and how to solve problems with them. Hours studied: About an hour Difficult topic: The most difficult part would be deciding the right formula to use. Rank it a 3 Easy topic: The easiest topic would be solving the equation and all that once i had the formula. Rank it a 2
Enthusiam (subject): A 4 Enthusiam (classes): A 6 What topics did you learn this week? We finished learning about dipole-dipole and polar and nonpolar and then we had our exam. Hours studied: About 3 hours Difficult topic: I had difficult with polar and nonpolar. Ranked a 4 Easy topic: The easiest topic was probably in using the laws to solve problems. Ranked a 2
Enthusiam (subject): A 4 Enthusiam (classes): A 6 What topics did you learn this week? We learned about ions and conductivity. Hours studied: Around one hour Difficult topic: Everything this week was really easy for me. I would rank it a 2 Easy topic: Deterimining if a solution was a base or an acid. I would rank it a 2
Enthusiam (subject): A 4 Enthusiam (classes): A 5 What topics did you learn this week? We learned about concentration and new laws. Hours studied: Around 1.5 Difficult topic: I am having a really hard time wiht find the molarity. I would rank it a 5 Easy topic: The easiest topic for me would have to be using the formulas to solve problems. I would rank it a 2

From these data, the difficult topics and their ranking were placed into a new table (as seen in Appendix M). The topics that were the same or extremely similar were coded according to the thirty-four topics of the end of semester ranking question, and then each topic was averaged for calculations.

For this student, the topics that were evaluated were:
Graphing – 2
Ions – 5
Isotopes – 5
Balancing equations – 3
Different reactions – 6
Deciding the right formula to use – 3
Polar and nonpolar – 4
Molarity – 5

These numbers were averaged with other students' responses for the values considered.

End of semester ranking:

Students were given a list of thirty-four topics. They were asked to give values for each topic. A sample student rank would be:

A Scientific notation, significant digits, dimensional analysis, and graph reading
1
B Error analysis
2
C Electron configurations and orbitals
2
D Property trends (electron configuration, ionization energy, electron affinity, atomic size, ionic size, reactivity)
3
E Alpha, beta and gamma radiation
7- We really didn't not go over the much in the lecture, but I think if we had elaborated on it a little more it wouldn't be to bad.
F Half-lives
G Types of bonding (ionic and covalent)
6- This is something that I have always struggled on. I honestly just need to memorize what is what.
H Lewis dot structures
1
I Oxidation numbers
J Names and formulas for ionic and covalent compounds
2
K Intermolecular forces
L Bonding characteristics of carbon
M Structural formulas and names of simple hydrocarbons
N Organic chemistry/compounds
O Balancing equations (simple synthesis, decomposition, single replacement, double replacement and combustion)
1
P Predicting products of acid-base reactions
7- This is something that we are going over in class right now, so I am still figuring it all out.
Q Endothermic and exothermic reactions
2
R The concept of moles
1
S Percent yield, mass of excess and limiting reagent
1
T Oxidation and reduction processes
7- I was not in lecture the day that we went over this topic due to illness, so it is something that I would like to have explained to me.

U Electrochemistry
V Chemical equilibrium and Le Chatelier's principle
W Behaviors of gas and gas laws (relationship of pressure, volume or temperature)
2
X Heating and cooling curves
2
Y Saturated solutions, solubility and precipitates
2
Z Colligative properties of solutions (freezing point depression and boiling point elevation)
2
AA Concentration of solutions in terms of molarity and percent weight/mass
2
BB Properties of salts, acids and bases
6- Again, this has to do with acids and bases, so it is something that I still need to look over until I have got it.
CC Strong and weak acids and bases and their properties
5- I understand the pH scale, so this will just take some practice to understand
DD pH and pOH
4
EE Titrations
3
FF Solubility curves
2
GG Separating mixtures (distillation, crystallization filtration, paper chromatography, and centrifuge)
HH Solubility rules
2

These numbers were tabulated and averaged with other responses for each topic. This average was used for evaluation.