SALARY AND LEAVES COMMITTEE 2019-20

APPLICATION FOR SABBATICAL LEAVE

Name of Applicant: Kamran Golestaneh Date: 10/8/2019

Department: Chemistry Division: Natural Sciences

Email: kgolestaneh@mtsac.edu Ext.: 3483 Phone (cell/home): 8183096249

Address: 1640 Ivy Bridge Rd

City: Glendale Zip: 91207

Dates of Adjunct Employment at Mt. SAC: 1994-2000 Accumulated LHE: 30.00

Dates of Full Time Employment at Mt. SAC: 2000-now Dates of last sabbatical: From ____ To ____

Any Previous Sabbatical Leave(s)? ☒No ☐Yes If yes, dates: From ____ To ____

Previous Leave(s) of Absence or breaks in service in the past 10 years?

☐ Yes ☒ No Dates: ____ Paid? ☐ Yes ☐ No

Length of sabbatical leave requested:

10 Month: One semester ☐ Two semesters ☒ **11/12 Month:** Half Year ☐ Full Year ☐

Effective dates for proposed sabbatical leave:

10 Month: Fall (year) 2020 Spring (year) 2021

11/12 Month: Start Date ____ End Date ____

☐ Formal Study ☒ Independent Study ☐ Work Experience

☐ Combination (specify) ____

I plan to use banked leave to supplement my sabbatical leave. ☐ No ☒ Yes*

*(*If yes, you must submit a separate "Use Banked Leave" form to your Division office, be approved by your Dean, and received by Human Resources by the third week of the semester preceding your leave.)*

ATTACHMENTS NEEDED

- ☐ A THREE TO FOUR SENTENCE ABSTRACT OF YOUR PLAN FOR PREPARATION OF THE BOARD OF TRUSTEES AGENDA.
- ☐ A COMPREHENSIVE, WRITTEN STATEMENT OF THE PROPOSED SABBATICAL ACTIVITY(IES) INCLUDING:
  - DESCRIPTION OF THE NATURE OF THE ACTIVITY(IES)
  - TIMELINE OF THE ACTIVITY(IES)
  - PROPOSED RESEARCH DESIGN AND METHOD(S) OF INVESTIGATION, IF APPLICABLE
- ☐ A STATEMENT OF THE ANTICIPATED VALUE AND BENEFIT OF THE PROPOSED SABBATICAL ACTIVITY(IES) TO THE APPLICANT, HIS/HER DEPARTMENT OR SERVICE AREA, AND THE COLLEGE.
- ☐ LETTERS OF RECOMMENDATION (ENCOURAGED).
- ☐ ACADEMIC REFERENCE LIST/ WORKS CITED/SELECTED BIBLIOGRAPHY

Any change or modification of the proposed sabbatical activity(ies) as evaluated and approved by the Salary and Leaves Committee must be submitted (in writing) to the Committee for reconsideration.

Applicant's Signature: [signature] Date: 10/8/2019

MT. SAC
Mt. San Antonio College

SALARY AND LEAVES COMMITTEE 2019-20

Applicant: Kamran Golestaneh

ACKNOWLEDGMENT BY THE DEPARTMENT/DIVISION

- The acknowledgment signatures reflect awareness of the sabbatical plan for the purpose of personnel replacement.
- Department chairs and appropriate administrators are required to submit a statement regarding the value of the sabbatical plan to the College, division/department, and individual, directly to the Office of Instruction.
- Applicants must obtain the signatures of acknowledgment prior to submitting application to the Salary and Leaves committee.

Department Chairperson:

Name: Todd Clements Signature: [signature] Date: 9 Oct 19

☑ I certify that this leave will not be detrimental to the department. (16.K.7)

Division Dean:

Name: Matt Judd Signature: [signature] Date: 28 Oct 19

☑ I certify that this leave will not be detrimental to the department. (16.K.7)

ACKNOWLEDGMENT OF THE APPROPRIATE VICE PRESIDENT (INSTRUCTION OR STUDENT SERVICES)

Signature: ______________________ Date: ______________

Received in Instruction by: ______________________ Date: ______________

SALARY AND LEAVES COMMITTEE 2019-20

Applicant: Kamran Golestaneh

For Salary and Leaves Committee use:

	Date:	By:
Received by Office of Instruction	______	______

Application - Complete/Incomplete? ☐ Complete ☐ Incomplete
(If Incomplete applicant is given 5 working days to resubmit)

Date returned to applicant: ______

Due date for resubmission: ______

Date resubmission received: ______

	Date:	By:
Complete application sent to individual Committee Members for review:	______	______

Reviewed by Committee as a whole:

Action:

☐ Acceptable

☐ Conditionally Acceptable with Additional Information

- Additional information requested. Due back by: ______

☐ Not acceptable – Not recommended to the Board of Trustees

Review of Conditionally Accepted Applications:

☐ Acceptable

☐ Not Acceptable – Not recommended to the Board of Trustees

Recommendation:

☐ Recommended to Board of Trustees
Ranked as # ______ of ______ (# of applications)

Notification:	Date:	By:
☐ Applicant notified of Committee Action	______	______
☐ Applicant notified of Board of Trustees Action	______	______

Signature: ______________________ Date: ______________
Chairperson, Salary and Leaves Committee

Proposal Title: Integration of Student Learning Outcomes, Course Concept Mapping & Transformative Assessments: A Learning Data Analytics Approach Applied to Introductory Chemistry

An Independent Study
Sabbatical Proposal
(2020-21)

By

Prof. Kamran Golestaneh
Chemistry Dept.

Natural Sciences Division
10/8/2019

Project Summary (for Board of Trustees Agenda)

Prof. Kamran Golestaneh's sabbatical proposal involves development of spreadsheet computer applications to integrate student learning outcomes and concept mapping to process student assessment data into a highly informative and individualized "score card" of assessment for his Introductory Chemistry course. The student learning data analytics that will be produced as a result of this independent study is likely to cause student success and effective teaching. Students will know exactly what to focus their learning on and the instructor will know the strength and weaknesses of their students' learning. While this application is specifically developed for Introductory Chemistry (Chem 40), it can be adapted to accommodate any course on campus which deals with specific student learning outcomes (SLOs) and its assessment.

Defining the Problem: How to Improve our Students' Success

Over the years I have had to adjust my teaching style numerous times in order to address a rapidly changing student generation while incorporating the best technology available at the time. While teaching many introductory level chemistry courses throughout my career at the community college level, I have noticed a tremendous growth in technology over the years as well as a changing student body and their approach to learning. In the past, low performing and motivated students would solely rely on my expertise (office hours, etc.) and their textbook to get the help they needed. However, this trend has changed. Students often don't have a physical textbook and rely heavily on on-line learning resources (YouTube videos, etc.) - over the traditional instructor/textbook route. Students study habits are shaped based on economics, convenience and other life commitments such as family through work. Nowadays, smart phones, tablets and portable on-line devices rule our world and are readily available and relatively inexpensive to own. A great majority of all students have access to them. Therefore, students in general have the resources, equipment and the knowledge to use them but my experience shows that access, while important, does not necessarily guarantee or produce the desired learning outcome. There are perhaps close to millions of videos describing Chemistry concepts on sites like YouTube but learning chemistry remains as challenging to decipher as ever.

Over the years, I have observed that a growing number of low performing students face additional challenges as barriers to their learning and academic success. Low performing students often lack prerequisite basic skills (such as math and English), study skills as well as organizational life skills. When students do poorly on their first introductory chemistry exam, the more seriously oriented contenders start looking for a chemistry tutor. They really don't know how to take charge of their learning process. I often get a range of emotional responses; students crying (in my office) to students totally dismissing and indifferent toward failing. All these students are in my class for a reason; they are there to learn chemistry and learning demands highly specific action on both my part and my students'.

The following has been my observation that students fail their learning when they see a low disappointing exam score and don't know what specific actions to take. Assessments are extremely useful to prepare students to learn as well as reflecting what students don't know. An overall assessment score *does little in providing the specific categorical feedback on the topics of coverage that students need in order to take the proper action to succeed at a sustainable level.*

To make matters more complicated a failure in an early exam translated to failure in upcoming exams. When students do not gain a solid understanding of fundamental concepts, they tend to do worse in future exams that rely on the knowledge of these fundamental topics. Low performing students require specific feedback. I strongly believe and have witnessed that when students are provided with a more clearly stated and assessment feedback, they are more likely to succeed. Specific feedback and its clear communication is crucial step in helping students take the specific actions needed to succeed. Therefore, *presenting our students with a failing or poor overall exam score is a recipe for getting poor scores in future exams and ultimately failing the course.*

Another challenging aspect of learning chemistry is its vast scale and the importance of understanding and integrating concepts into a bigger picture. Concept mapping aspect of this proposal is intended to integrate student learning. Chemistry involves study of matter and its atoms and molecules, the tiniest particles of matter. Study of matter at this level demands cultivating a sense of *imagination* in order to visualize and better understand these illusive particles of matter. The new student generation (generation Z) seems to prefer a learning environment that is more dramatic, captivating, engaging, clear, specific and unambiguous. *The new generation of students expect a more explicit context to define what they are learning*. *They do better when we offer them clear and specific learning objectives in a manner that they can see the links and relationships between these learning objectives.* It is not uncommon to observe that low performing students appear careless and indifferent to their academic performance when they don't have the clarity and the bigger picture in their learning. I want to do more in reaching out to low performing students and guide their learning experience in more specific and potentially effective ways.

One of my project goals is to bring clarity and specificity to the topics of importance - as carefully worded student learning outcomes (SLOs). Additionally, I would like to quantify and report on my students' on-going learning progress *not based on an overall assessment grade,* but a score dedicated to gauge their learning in *each topic, stated as a clear learning objective*.

The importance of clear language and communication in our course level learning objectives was communicated to community colleges with the implementation of student learning outcomes (SLOs) within the context of Bloom's Leaning Taxonomy, starting from about 15 years ago (early 2000). However, current SLO assessment reporting requirements are very narrowly defined (1-3 SLO statements), once every 3 years! This infrequent and narrow scope of assessment reporting does not provide any useful and on-going information to a specific course and consequently many instructors perceive its implementation as a useless institutional requirement wasting precious time and resources. Furthermore, in our department, the current practice of gathering overall course-level SLO assessments are non-specific and do not provide specific information for a specific faculty and his/her course.

Based on the availability of assessment analysis technology as of 3-5 years ago, providing a detailed specific assessment feedback was extremely time consuming and an impractical task to consider. Fortunately, new advances in smart devices and their software applications have made this task possible and more practical. Consider the possibility of combining a detailed student response data with the powerful features of a properly designed Excel spreadsheet and the result is highly specific *student learning data analytics*. I will have the necessary tools to gather, analyze, report and track on-going learning progress for each student in my class in the context of clear learning objectives. However, even using the current state of technology, the process outlined requires a high level of computer application development and integration and is currently far from being practical or convenient. For example, the student assessment data, even though readily accessible, requires intensive post-processing of assessment data using Microsoft Excel spreadsheet application. The initial development of processes and mechanisms to achieve the goals set forth in this proposal require careful planning and execution of a series of tasks outlined in this proposal. My Introductory Chemistry course and students who typically take this course, is an ideal course to develop these tools and processes for.

The Need to Develop the Analytics of Student Learning

Learning Chemistry is neither easy nor a natural process for many students. There is often a high barrier to the learning process for many introductory topics. To make learning more challenging for students, *many introductory topics are interrelated and weaknesses in earlier topics translate to poor performance in later topics*. Consequently, learning through integration of knowledge is a challenging task for students. I expect that I will retain more students in the future, and they will do better if I help them integrate their learning using the assessment feedback process that I plan to develop for my Introductory Chemistry course. Furthermore, better performance in this fundamental course will translate to better performance in the next level of courses (General Chemistry I and II). I selected the Introductory Chemistry course, since it is an important entry-level course that feeds many students to our General Chemistry I and II courses. I have been teaching the upper level courses for many years and I frequently encounter students who are not prepared to meet the higher learning demanded in these courses and end up earning low grades or withdraw from the course. Marginally performing students are unprepared and bring many prerequisite deficiencies to higher-level courses such as General Chemistry I and II series.

One important aspect of this project will involve development of course- level learning objectives using a clear and concise language integrated with mapped course objectives that show interrelationship and significance of these learning objectives. Currently, I do present my students with a set of specific and task-oriented learning objectives for each chapter, however, many of my students including low performing students do not refer to them to prepare for upcoming assessments. I feel that many of my current SLO statements are somewhat stand-alone and lack integration and topics mapping. I feel a great necessity to update and modify them in order to better integrate them with my lectures, assigned homework problems and course assessments. During the last two semesters that I taught Introductory Chemistry (Chem 40), I had a higher than usual number of low performing students. I feel that I am dealing with an increasing number of unmotivated, distracted and unprepared students and I believe that these students demand a different level of clarity in my course contents' learning objectives and their assessment of them. Hopefully, I often observe that my low performing and underprepared students show a willingness to try harder which is a positive sign that implementation of this project in my Introductory

Chemistry is expected to be well-received by these students. The products of this proposal are likely to provide effective tools, framework and the mindset to enhance the Introductory Chemistry courses in our department and potentially provide new pathways for faculty who are willing to try these new ideas in their courses. This proposed model of integration of SLOs with learning data analytics is a novel approach which will provide some necessary analytical and computational tools that could potentially benefit faculty and their students across other disciplines.

Promoting a Close Fit Between Teaching and Student Learning Data Analytics

A complex factor in learning chemistry is that concepts interrelate and weaknesses in certain areas tend to impede the mastery of other learning objectives. Currently, I provide a specially formatted sheet where students record their exam feedback of each question they miss. However, I observe that their feedback on their exam is often non-specific and incomplete at best. They tend to miss many categories partly because low performing students *don't know what they don't know*! I frequently observe that underprepared students tend to rely heavily on the instructor to guide them. However, an overall low assessment score equates to a non-specific response on my part; "You pretty much have to study these chapters all over again", which is neither helpful nor specific. Low performing students do need targeted feedback in a manner tied to specific chapter-by-chapter learning objectives. Our course measurable objectives listed in our official Course Outline document in Web CMS are too general and few, while each chapter of the textbook covers far more learning objectives than the entire list published in our Web CMS. Additionally, a detailed, chapter-by-chapter student-level outcomes assessment provides a wealth of information for an instructor to evaluate the effectiveness of his or her teaching strategy. Often, I feel that I have covered certain topics adequately but without access to specific targeted feedback, I can never be sure if my students are understanding these topics. Currently, I assign a set of homework problems to my students after the lecture coverage of sections within each chapter. Low performing students are inattentive to their learning and engage in rote learning while doing these assignments. They tend to model (copy) a process based on worked examples within the textbook and lecture notes and proceed to solve the assigned problems *without* the awareness they need for optimal and analytical learning. A detailed *concept map diagram* and *student learning objectives* (as short action-based statements) will greatly serve to enhance their learning process. I have observed that many low performing students are not able to express what they don't know and that prevents them from a more effective engagement with their professor. They tend to come to exam sessions without being really sure of their skills, hoping for an easy test and a passing grade.

Some of our departmental SLO assessments indicate that the standard deviation for topics scored below a certain passing level is often too large, suggesting a wide gap between how different instructors teach the specifically tested topic. Additionally, certain topics that are at the overall passing level may not be achieving a passing level for certain sections. In this capacity, SLOs fail to provide useful and specific learning outcomes for individual sections and instructors. The success of our program largely depends on how well our instructors (full-time and adjunct) consistently teach a course as well as how well instructors are in tune with the student learning which takes place within their own courses.

There are numerous studies that point to the importance of providing our students with clear, concise and measurable learning objectives and its link to development of an effective assessment. Looking over student responses to my exam questions, I find questions that more than two third of the class miss and I wonder; Was the question fair? Was I clear in instructing my students regarding a specific SLO topic? Were there specific homework assignments that enhanced learning of the topic? A closer examination of our assessments is engaging and improves the course for both students and faculty. In a nutshell, clear communication of learning objectives promotes equity. Students feel more welcome in the course and instead of blaming their lack of performance on the course or its method of delivery, they see a more clear and unobstructed path to their success.

Demonstrating the Power of Learning Data Analytics Through Examples

At the heart of what is proposed here is development and integration of student learning objectives (SLOs) using clear and concise language with student assessment and its clear communication to students using a detailed assessment report card. The detailed assessment data will be integrated with learning outcomes in a format that will provide each student with the specific feedback *they need and should be provided* in order to improve and succeed. In order to make this leap a reality, SLO statements must be defined for each chapter in a clear, specific and attainable manner. SLO statements that are too broad or vague are rather useless for helping students succeed and must be replaced with more specific and action-oriented SLOs based on Bloom's learning taxonomy. For example, "Understanding stoichiometric concepts" is vague and useless statement while replacing the SLO statement with "Performing stoichiometric calculations involving mass-to-mole relationship between reactants and products" is highly useful, informative and students perceive it as an attainable outcome.

Therefore, I will be writing chapter-by-chapter SLOs using an action-oriented, specific and concise language conducive to its integration within the data analytics approach. Furthermore, I will be integrating these statements with a concept map of the topics in a way to show their interconnectedness. The usefulness of these SLO statements also lies in the fact that students pay attention to learning objectives that have a clear connection to what is being assessed. Introductory Chemistry students are assessed three times plus a final exam. Each assessment covers 4 chapters and include questions that are specifically linked to each SLO statement. I will be writing new exam questions and editing pre-existing exam questions for clarity and specificity. My focus will be on the inclusion of multiple-choice questions that will quantify student learning of topics presented as SLOs developed for each topic. Assessment of these SLOs are an important prerequisite to learning higher level and later chapter topics.

Students will miss the knowledge of this important connection, if fundamental topics are either not assessed, weakly assessed or assessed through a bulky or vague question. An important and vital tool is gaining access to my students learning data analytics will involve development of Excel spreadsheets to analyze each student's assessment data in a manner to provide a percentile score for each SLO covered in the exam. My assessments will include two parts composed of a multiple-choice and free-response question/problem sections. Upon completion of each assessment, a personalized score report will be prepared for each student showing performance scores for each learning objective for both exam parts. The spreadsheet designed will have the capability to provide the lumped score for each SLO category. I would like to provide you with an example which shows the proof of concept for this proposal. While work presented here is at its very early developmental stage, it does a fair job demonstrating the proof of concept.

I will highlight potential features of the main product of this study; *Preparation of a transformative assessment and learning data analytics*. The data presented here is based on a pilot study of the first assessment (exam 1) of my Fall 2019 Introductory Chemistry course in which my students were expected to gain mastery over some 30 learning objectives. It should be stated that I created a small list of SLOs to test the data analytics process and the list of learning objectives was not communicated to the students using this current language and style. Upon completion of this independent study I will be developing a considerable number of SLO statements to cover the contents and assess them in each exam. In exam 1, I assessed SLOs in a two-part format; a multiple choice (35 points) and problem solving (20 points) sections. Due to time-consuming nature of preparing such data, I will only concentrate on the multiple-choice section.

Using this 35-question multiple-choice exam, I assessed 23 SLOs, while some questions tested the same objective. Presented here is the detailed "score card report" of assessment data for a hypothetical student "Linda" (Refer to Linda's SLO data analytics column) as well as class performance average and its standard deviation (Std. Dev.) for each SLO. This data is presented in Table 1 (next page). The overall course level statistics for each of the assessed learning objective is included for the course instructor. This data can be used to evaluate the effectiveness of my teaching style for each tested SLO in this assessment cycle. Having access to such specific learning data analytics is prudent to taking the proper action to improve student learning and success.

Upon providing this itemized score card report of learning outcomes to my students, students like Linda will have a much more clear picture of their knowledge level, for each learning objective, in order to make performance improvements in categories at which they score below a certain threshold (ex. 75%). Student Linda has 9 learning outcomes (SLO) categories in which she scored 0-50%. These are all high priority (Level 1) learning outcomes which means poor performance in these categories will also poorly influence how Linda performs in assessing Level 2 and Level 3 SLOs within the assessed topic. Thus, weaknesses and strengths in each student learning objective are clearly communicated to my students. An important aspect of this proposal is linking each assessed SLO to the student performance learning data analytics and its clear and detailed "score card" communication to the students. Linda's score card will only include her SLO data and will not include the Overall statistics shown in Table 1.

Table 1. Sample Student Learning Data Analytics

Exam 1	Assessed 23 Learning Outcomes	Overall	Overall	Individual
Learning Level	Unique (lumped) Learning Outcomes Assessed Set	Class Avg.	Class Std. Dev.	Student "Linda"
1	1. Energy: Identify types	84%	35%	**100%**
1	2. Numbers: Round to Sig Fig	52%	51%	**100%**
2	3. Dim Analysis: Translate, solve	50%	46%	**100%**
1	4. Matter: Classify; pure vs. mixture (impure)	53%	25%	**75%**
1	5. Temperature: Convert	74%	36%	**100%**
1	6. Math operations: Calculator skills (multiply, divide and use of exponent key)	52%	51%	**0%**
1	7. Elements: Recognize symbol	96%	20%	**0%**
2	8. Dim Analysis: Convert between units (1-step)	66%	31%	**50%**
1	9. Numbers: Identify Sig Fig	46%	41%	**50%**
1	10. Numbers: Scientific Exponent	88%	22%	**100%**
1	11. Energy: Calculate; heat formula equation	48%	51%	**100%**
1	12. Matter: Classify; smallest unit of matter	72%	46%	**0%**
1	13. Matter: Classify; compound vs. element	72%	46%	**100%**
1	14. Math operations: Add, Subtract, Sig Fig	28%	46%	**0%**
1	15. Units: Distinguish; metric and English	56%	51%	**100%**
1	16. Energy: Define conservation	56%	51%	**100%**
1	17. Properties of Matter: Distinguish; physical vs. Chemical	32%	48%	**100%**
1	18. Ions: Identify; cation vs. anion	36%	45%	**100%**
1	19. Math operations: Calculator skills (multiply, divide and use exponent key)	44%	51%	**100%**
1	20. Density: Use formula	78%	36%	**100%**
1	21. Electric Charges: Predict properties	72%	46%	**0%**
1	22. Naming: List; Elements vs. symbols	58%	31%	**50%**
1	23. Laws of Chemistry: Identify	52%	51%	**0%**

Another useful feature of having access to a detailed learning data analytics is the data it can provide for improving our courses in specific ways. As the course instructor, I am particularly interested in how well students perform in each learning outcome expressed as an average percentile for each learning objective. Having such data puts me in a unique position to set action levels at 50%, 70% or even 90% depending on the topic's priority level, in order to improve student learning through various interventions using alternative teaching and learning styles.

For example, a targeted course intervention may include one or more of the following actions; Supplement my lecture with a group activity and problem-solving; Create and assign unique and targeted homework problems; Use an alternative method of lecture delivery such as use of videos to show an applied aspect of the concept or perform live chemistry demonstrations. When instructors are provided with detailed assessment data analytics of their assessments, they are better informed and more likely to take the necessary actions. The effectiveness of interventions is supported with use of data. "Does the intervention improve the understanding of my students' learning of a particular SLO in a quantifiable manner?" is a key question.

Furthermore, course improvements are not only tied to a higher average in the performance of students in each category, but they are also reflected in the standard deviation (Std. Dev.) score for each assessed SLO. A notably wide gap in Std. Dev. (higher than say 50%) correlates with the fact there is a wide split in student learning. A high standard deviation value is indicative that are significant groups of students who understand and a significant number of students who do not understand the assessed SLO. The awareness of this learning gap is significant and is missed if one only relies on average performance value for each SLO. For example, an average score of 50% can be obtained by a large number of students performing near 50% or a bimodal distribution in which there is a split in the population and there are significant many who perform well and significant many who perform well below the average.

The current practice of providing an overall assessment score (an overall 66% score for Linda) does not provide the specific feedback that Linda needs to improve in addition to discouraging her, even though she has clearly passed 13 out of 23 of the assessed SLOs at a 100% level!

It is important to realize that overall assessment percentages do not provide useful and targeted data analytics in connection with each learning objective. The development of the products stated in this proposal will provide the kind of assessment data analytics that are highly beneficial and targeted for the success of low performing students. In the absence of such data our low performing students will never know what key objectives to improve upon and instructors will never know the effectiveness of their instructional delivery.

Another useful aspect of having access to detailed learning data analytics is to have quantitative feedback on students' misconceptions of topics covered. Having access to a graphical report of student responses for each multiple-choice question is informative. The following example, provided from a different assessment application, demonstrates the usefulness of such data to improve our assessments or student misconceptions. Furthermore, this data can point to any student misconceptions. If a significant number of students pick a distracting choice, perhaps we should examine the question and the responses more carefully to extract useful information in order to improve the test question and the presented choices or address student misconceptions.

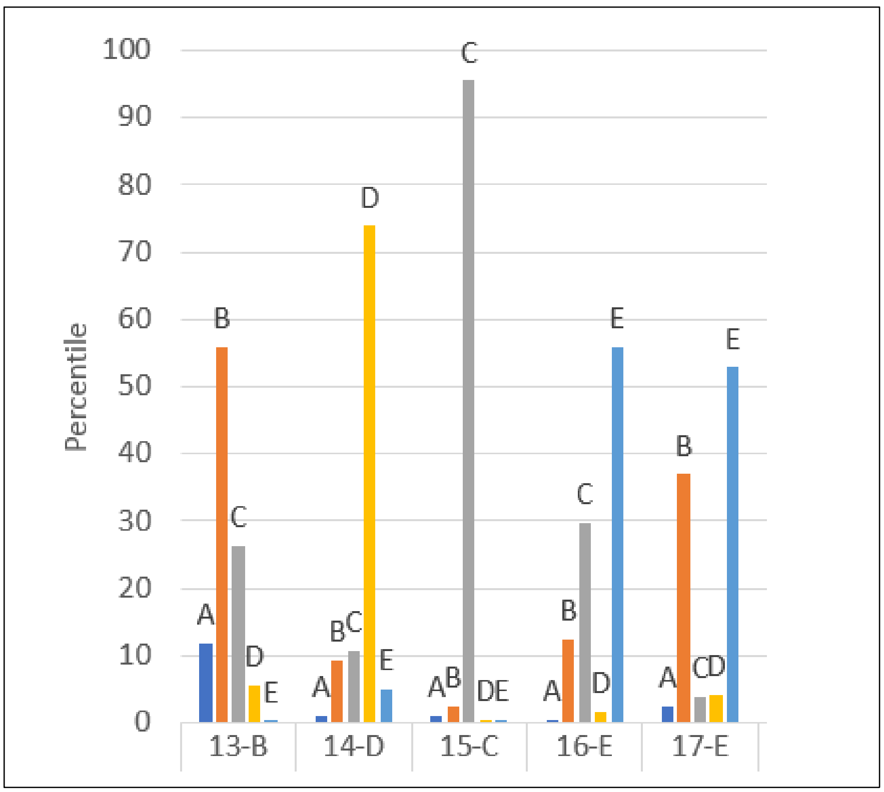

Figure 1. Assessment question data Analytics

For example, let's analyze questions 16 and 17 and the graphical student response data presented in Figure 1. The correct choices are shown next to each question number on the x-axis. The correct response for both questions is choice E. Examining the percentage of students who responded correctly, it is evident that over 25% percent of students chose distractingly wrong choices C (Q16) and B (Q17). Why were significant number of students misled by these choices? Perhaps these questions and/or distractor choices should be edited for clarity or perhaps I should improve on my instructional delivery addressing student misconceptions.

The final component of this proposal involves mapping course topics with chapter-by-chapter SLOs in a way to produce a multi-level level learning matrix showing the interrelationship between these SLOs. Level 1 lists all fundamental SLOs and with the progression to other levels (levels 2 and 3) students can clearly realize how SLOs mastered in previous levels can influence higher level SLOs. This method of categorizing information is highly useful to help students develop a sense of hierarchy among the learned concepts.

The chart presented in the next page (Figure 2) is an example showing a method of concept mapping applied to "Quantitative Problem Solving". This topic is an important skill that is covered in chapters 1-3 of the Introductory Chemistry that is often tested on the first exam. Exam 1 also covers other topics such as matter and energy which were not included in this matrix. We generally cover a number of topics and I will be spending some time to determine the most effective way to map the SLOs for these topics and develop a similar learning matrix for each major topic.

Figure 2. Mapping SLOs in Quantitative Problem Solving Skills

Level 1 (basic skills)	Level 2 (basic problem solving, 1-2 steps)	Level 3 (multi-step problem solving)
Translate and identify conversion factors	Use 1-2 step dim analysis to solve problems	square and cube conversion factors in Dim Analysis
Perform basic math operations (x,/,+,-)	Solve for a variable in an equation	Use multi-step dim analysis to solve problem
Use a calculator correctly	Keep track of sig fig in multi-step calcs	Solve multi-step shape related problems
Simplify units (multiply, divide)	Solve prefix conversion problems	Perform variable analysis in a formula
Memorize SI prefixes	Use proper SI prefix for large and small quantities	
Round any number to given sig fig	Solve percent by mass problems	
Report a math calculation to proper sig fig (multiply, divide)	Solve percent by volume problems	
Report a math calculation to proper sig fig (+,-)	Report a mixed math calculation operation to proper sig fig	
Use the exponent key of your calculator correctly		
Identify Place-values of any digit of a number		
List uncertainty of a number as +/- or range of values		
Identify correct number of sig figs of a measured number		
Recall proper unit abbreviations (for common units)		

<u>The Following actions, products and timelines are suggested:</u>

Note: These actions are listed according to their completion time.

Action 1: Investigate and learn best practices and technology in use as related to student learning outcomes, assessment feedback, concept mapping as well as any teaching strategies to improve student learning. I have targeted two conferences in my field of study and plan to attend one or both. I am planning to attend the BCCE 2020 conference in Oregon State University located in Portland, Oregon. Another key conference in my field is the 2YC3 (Two-Year College Consortium in Chemistry) details of which has not been announced yet.
Note on Product: Attending these conferences in the past has given me an opportunity to create, develop and incorporate active learning components and use of technology in my classrooms in order to promote student learning of basic and challenging concepts. I foresee that attending the above name conferences will benefit this project as well. The program details for these conferences have not been announced yet, so I cannot comment on a selecting a specific talk and its potential contribution to this project.
Timeline : BCCE: July 18-23, 2020, The date of the 2YC3 conference is not announced yet

Action 2: Develop a set of highly specific and action-oriented student learning objectives (SLOs) for each overarching course topic introduced in the Introductory Chemistry course. Currently, the study of fundamentals of Chemistry includes 14 chapters (major topics). These highly specific and action oriented SLOs will be developed in a way to make them suitable for integration and reporting of student learning analytics within the scope of this proposal.
Product 2: There are 14 chapters in the current textbook of Introductory Chemistry (Chem 40). Having 15-20 SLOs per chapter, I will be writing a minimum of 210-280 SLO statements for the Introductory Chemistry (Chem 40) course.
Timeline: **I plan to complete this process by November 2020**

Action 3: Develop a concept map for Introductory Chemistry topics using a 3-level SLO matrix. Chapter SLOs will be prioritized according to 3 levels. Level 1 is the most fundamental level. Level 2 is the intermediate level and an understanding of levels 1 and 2 SLOs supports level 3 SLOs. Development of SLOs at level 3 engages students at a higher critical thinking and analysis. The interrelationship of SLOs between these learning levels provides an integrated approach to learning in which students can identify the significance of any weaknesses in their understanding and realize its impact on other areas. Weaknesses in one level translate to weaknesses in higher levels.

Product 3: I will be developing an SLO concept map for each overarching topic of the introductory chemistry. An example concept mapping matrix for Quantitative Problem Solving Skills, introduced in the Measurements chapter, was provided in the previous section (Figure 2). Since there are 14 chapters in the course, there will be a total of 14, 3-level concept maps that will be developed. Students will be provided with a handout including the mapped SLO concepts prior to starting each chapter. This information will be a useful resource for our large pool of adjunct faculty that commonly teach this course and can serve as a basis for standardizing the instruction levels at which the course is taught by our adjunct faculty.
Timeline: I plan to complete this task by December 2020

Action 4: This action creates the data analytics engine behind my proposal: Design and develop Excel spreadsheets for analyzing the raw assessment data for each student. Spreadsheets will report the student learning data analytics for each assessment. I foresee that fulfillment of this objective and its integration with the other 4 actions stated will be the most time-consuming aspect of this project. Specifically, assessment analytics report will be prepared and configured to communicate the following: o *To the Student:* Student learning data analytics as a “score card report” will be provided to each student. This report will show the score of each SLO based on individual or lumped questions of the multiple choice and written (numerical problem-solving) portion of each assessment. Students will know specifically which SLOs they need to improve upon. o *To the faculty:* Learning data analytics for each SLO averaged for the entire class. This data is presented as % average and the standard deviation of each assessed SLO. o *To the faculty:* A graphical analysis of responses for each question in which the percentage of each answer choice is provided for each question. This information is highly useful to improve the question, choices and/or the instructional delivery of the SLO.
Product 4: I plan to develop one comprehensive Excel spreadsheet for processing the entire course assessment data <u>or</u> 3 individual spreadsheets, one for each midterm assessment. I have not decided on a suitable format yet. The spreadsheet(s) will be created in a flexible manner so that other potentially interested chemistry faculty can map their own student learning objectives with their assessment, in order to obtain detailed student learning data analytics.
Timeline: I plan to complete this task by March 2021

Action 5: In order to test the data analytics process, I will be using my Fall 2019 midterm assessments and create student reports for each midterm exam. These assessments are a combination of multiple choice and written sections.
Product 5: This step will produce the assessment data validity check that is necessary to demonstrate the components of this project. I will be able to use my example to show other faculty how this process works.
Timeline: I plan to complete this task by mid-June 2021

Benefit to the Department and College

Students and Faculty are the direct beneficiary of the products of this independent study. In order to promote student success and retention of fundamental Chemistry concepts, my future Chem 40 courses will include the elements outlined in this proposal in order to gather student success data. The implementation of a detailed learning level assessment will provide valuable information and technical knowledge for the interested faculty within my department (Chemistry) as well as other disciplines across campus in which faculty routinely instruct and assess their students according to a set of student learning objectives. Completion of the Elements of this proposal will provide the basis for other courses in which specific student Learning data analytics will be available to both the student and the instructors in order to make the necessary teaching and learning improvements quantitatively. Additionally, the specificity in the SLO statements and their concept map link will serve both the students and faculty involved in distance learning courses. Students taking a distance learning course are expected to be more successful when they are provided with the highly specific and individualized assessment feedback (and its SLO connection) through the elements of this proposal. When students clearly know what to expect they tend to prepare better and do better.

Currently, implementation of our student Learning outcomes (SLOs) is a state-level requirement that have met with some degree of faculty skepticism since its inception. These requirements are not going away and they have a not served our faculty and students in specific ways due to their grouped, and limited scope. In their current style of implementation (assessed for all sections of the same course), they do not provide the necessary detailed information to instructors or the students. I am not advocating that we should do away with these assessments. In fact, these overall course level assessments should be done to gauge the overall student success for selected SLOs. They can continue to present the department with a snapshot of student learning of specific SLOs. When instructors utilize the kinds of data analytic tools that will be developed in this proposal, they will be far more informed about the effectiveness of their teaching toward student learning in a targeted and specific ways that allows for the necessary interventions. The current model of obtaining SLOs is useful for our program but rather useless when it comes to providing specific instructor/student level feedback. The use of computer-based technology to provide data analytics of student learning has made the breakthroughs described in this proposal possible and can serve other courses in which both faculty and students can benefit from a clear connection between student learning outcomes and their assessment. Faculty can improve upon their instructional delivery and students will have a far more clear understanding of the learning objectives and the necessary areas to improve upon.

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https://learningoutcomesassessment.org/documents/

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October 28, 2019

Dear Sabbatical Committee,

I am writing to offer my support for the sabbatical proposal of Professor Kamran Golestaneh. As the impact of AB 705 and the recent adjusted Math placements have impacted all areas of the sciences, Professor Golestaneh's proposal to assess the efficacy of teaching in Intro Chem Courses, along with assessing the readiness of students and their understanding of key outcomes for introductory courses is coming at a very good time. These are exactly the kinds of questions that need to be asked in many disciplines impacted by our shift in assessments of Math and English.

I believe that his project will also help the Chemistry department better assist and support the adjunct faculty that we have come to rely on. Due to ever expanding enrollments, more and more Chemistry classes are taught by adjuncts, many of whom do not have a lot of teaching experience. Finding ways to better train and support adjuncts is an important way to maintain the consistency and quality of instruction. I am very pleased that Professor Golestaneh's project addresses many of these key needs.

The department can support a faculty member being on sabbatical in terms of class coverage—with adjuncts, and I find considerable merit and possibility for advancing department curriculum and student success within his plan. I give my full support to this proposal.

Sincerely,

Matthew Judd
Dean, Natural Sciences

Integration of Student Learning Outcomes, Course Concept Mapping & Transformative Assessments: A Learning Data Analytics Approach Applied to Introductory Chemistry

An Independent Study
Sabbatical Report
(2020-21)

Prof. Kamran Golestaneh
Chemistry Department
Natural Sciences Division
September 2021

Statement of Purpose

The purpose of this Sabbatical independent study is to develop a spreadsheet-based computer technology application in the form of an Excel spreadsheet. When instructors provide concise, specific and comprehensive chapter-by-chapter learning objectives also known as Student Learning Outcomes (SLOs), or “micro” SLOs. The spreadsheet application tools make the data analysis process convenient and informative for both students and faculty. The data analytics of assessments helps students make the necessary and targeted improvements and helps the faculty to make the necessary and targeted teaching intervention. Specifically, students are able identify and quantify their learning strengths and weaknesses of each assessed micro SLO after an exam, including the final exam. Such SLO data analytics reported for the class extremely valuable to the course instructor right after each major assessment. The comprehensive, specific and timely nature of the SLO data analytics provides the quantitative basis for improvement of teaching and learning. When both faculty and students have access to and utilize such data, teaching and learning becomes more effective. This process can potentially revolutionize and replace the current (and required) practice of dealing with course-level SLOs. The current practice is limited in that it is neither comprehensive in its list of SLO analysis, nor timely in its reporting manner to be of much use to the teaching faculty and their students. Both faculty and students thrive on comprehensive, specific and timely feedback to improve upon their teaching and learning.

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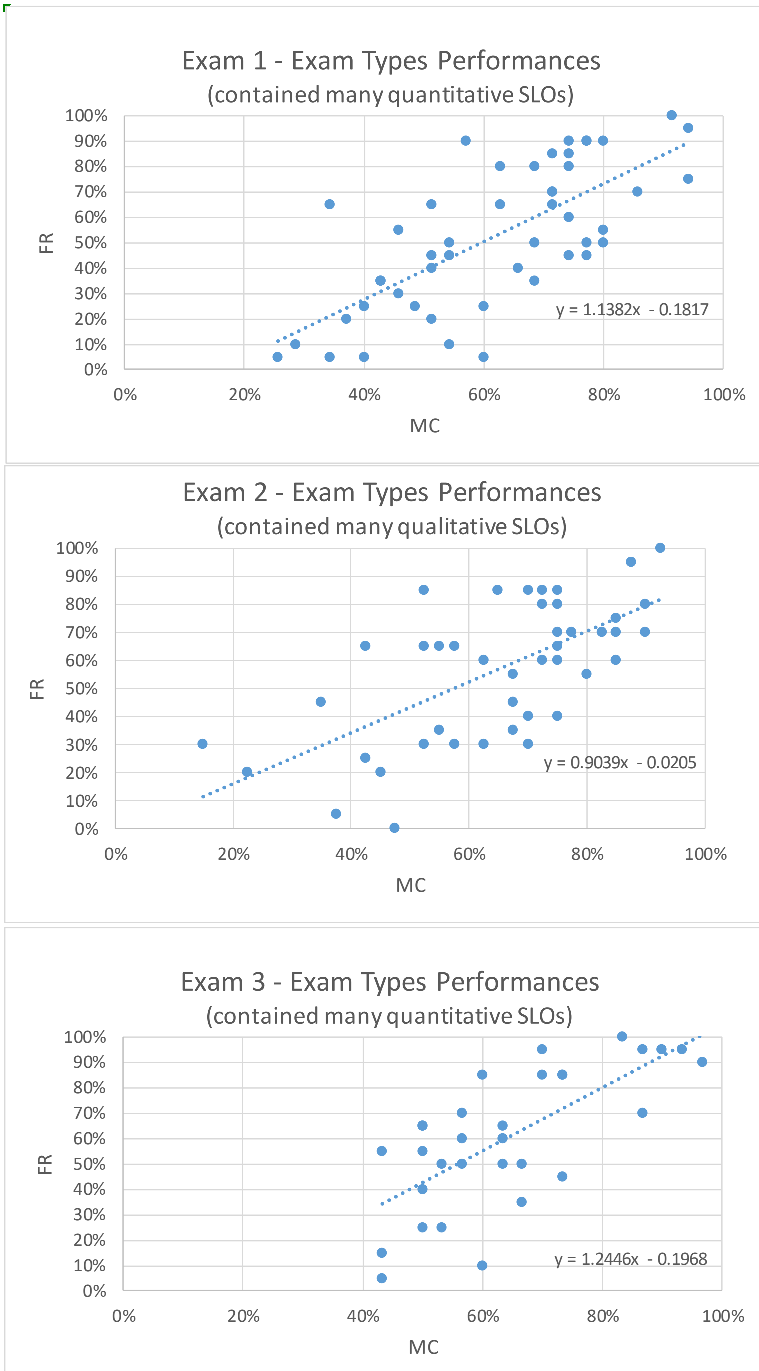
Multiple-choice or Free-response Assessments?

There are clearly advantages and limitations for each assessment type. Free-response exams mimic what students typically do while doing their homework. Exam points can be adjusted depending on a problem's difficulty level, students are not able to "backward solve" or guess at answers as they can more often do with multiple-choice exam problems. Students can potentially earn partial credit. Free-response exams do take much longer to grade, are more suitable for small class sizes and higher-level courses in which problem solving requires a more complex analysis.

On the other hand, multiple-choice exams provide certain advantages. They are quick to grade and serve as accepted as standardized format for potential admission into a number of programs such as medical (MCAT) and law schools (LSAT). It would be advantageous for students to practice with these types of exams that can test both conceptual and problem solving question formats. These tests are often graded in a fast computerized format using a "scantron" machine. While Scantron machines have been the standard method for grading exams, smart phone applications (apps) are quickly replacing these outdated Scantron machines. An app grading analysis of a multiple-choice exam can provide detailed digital raw data of exam results for each student and for each question. This data is invaluable and provided the raw data necessary for this independent study sabbatical project.

I have often provided both exam types for my midterm exams when teaching Introductory Chemistry. While there are always students that do better in one exam type, generally students perform roughly at the same level for both exam types. In order to confirm this point, I analyzed the score correlation between these two exam types in a visual graphical manner for a total of 3 exams administered in my introductory chemistry course (Chem 40) that I taught in Fall 2019. The data plotted as a graph of multiple-choice score (x-axis) versus the Free-response score (y-axis) suggests a roughly linear Excel Trendline with a slope that is close to 1. A slope of "1" means that students scored the same (perfect correlation) on both exam formats. A slope value greater than 1 suggests that students score higher in the multiple-choice format than its free-response counterpart. Interestingly, this is likely to be the case for exams that tend to be more quantitative (calculation-based). However, more exam data and proper statistical analysis of data is necessary to quantify this claim, which is irrelevant to the scope of this project. The data analytics aspects of this independent study will be applied to the SLO analysis of multiple-choice exams.

Figure 1. Exam Type Comparison of Student Performances



FR: Free Response (Written) section score
MC: Multiple-choice section score

In the past after each midterm exam, I allotted class time for my Introductory Chemistry students to go over their graded exam sheets and allowed them time to prepare a question-by-question list of concepts that they missed and give them a few extra credit points for the review process in order to motivate them. Students would complete a 1 page (2-sided) analysis of their exam referred to as the "exam feedback page". One side of the page deals with the multiple-choice exam component questions and the other side deals with the free-response exam component. Often students have a difficult time pin pointing the specific learning objectives (SLOs) that relates to each question. I try to help them during the class review session but many do not ask for help and just state "did not know" on their exam feedback page and turn it in without really knowing which concepts to review and improve upon. An important aspect of this project has to do with helping students pinpoint specific SLOs that they missed and encourage them to review those concepts prior to the next exam.

<u>The Power of Specific, Comprehensive and Timely SLO Data Analytics</u>

A detailed multiple-choice analysis of each exam, when linked with chapter level SLOs is advantageous for the following reasons:

1. Both the grading and the detailed exam analysis data is quick and readily available using a smart phone app.
2. Student learning objectives (SLOs) for each chapter is linked to each exam question helping students know which SLOs are mastered and which SLOs need to be revisited. Each student is provided with their percentile score for <u>each</u> assessed SLO as well as an overall exam score.
3. Fast and convenient spreadsheet (©Microsoft Excel) analysis of each exam question provides invaluable data analytics for both students and faculty.
4. Excel analysis can be used to provide departmental course level feedback for a number of SLOs when administered by course coordinator(s).
5. Lastly and <u>most importantly</u>, the detailed analysis of exam results, when linked to SLOs for each chapter covered in an exam, provides the specific <u>feedback</u> necessary

for both the course instructor and students to improve upon their teaching and learning.

The importance of bullet 5 cannot be overstated and deserves attention. When comprehensive and targeted feedback of each SLO is provided in a timely (exam-by-exam) manner, such feedback is far more valuable and useful than providing an overall exam score, particularly for average and low performing students. Furthermore, such detailed and timely data is far more useful when compared with the required practice of assessing 1-2 SLO statements for the entire course and reporting the results during the following semester! This is the current SLO practice in the Chemistry department. When each course is over, neither the student nor the instructor can benefit from the lumped departmental data, effectively. There are many other issues with the current practice of course-level SLO administration that I have experienced over the years that makes it both inefficient and ineffective.

The implementation of this project produces useful data analytics that support ***student success*** when instructors:

1. Implement this project at the Introductory and basic skills level courses that serve as a prerequisite for higher level courses. For example, Chemistry 40 is the introductory course that is the prerequisite for the General Chemistry I (Chem 50). Also, Chem 50 is the prerequisite course for General Chemistry II (Chem 51).
2. Implement this project for SLO data analytics of the final exam in order to inform students on topics that should be reviewed prior to starting the next level course.
3. Implement this project to design entrance exams for more advanced courses in order to test and report on important and specific skill levels that each student brings to the higher level course. For example, administer a Chem 50 entrance exam based on Chem 40 important SLOs. The entrance exam can be made available to registered students at least 1 week ahead of the course start date in order to help students discover and address their prerequisite deficiencies in each assessed SLO.

Implementation of this project produces useful data analytics that support ***teaching excellence*** when course instructors:

1. Develop a detailed set of specific SLOs for each chapter and share that with their students.
2. Design and use a test bank of multiple-choice questions, where each question is closely aligned with each chapter's micro SLO.
3. Report the percentile score for each tested SLO and have students take further action to review the missed SLOs for a few extra credit points (optionally) and emphasize the importance of not carrying their SLO weakness from one exam to another. Therefore, test questions selected in step 2 should reflect testing student comprehension of the most important SLOs; those that can impact students' learning of future and closely related course topics.
4. Examine each test question and ensure that multiple response choices are stated in such a manner to shed light on student misconceptions and the correct response choice is neither too obvious nor ambiguous.
5. Improve upon their teaching by examining each test question and its class distribution of responses for a common conceptual misconception. For example, if an unexpected wrong choice(s) is selected, further action can be taken to supplement future lecture(s) in order to address student misconception(s).
6. Examine the average percentile score and its % standard deviation (%SD) for each tested SLO and set flag (action) levels. A test performance at or below the flagged level (as well as low %SD) for an important SLO, requires further action on the instructor's part to mitigate the misconception. A higher %SD of a flagged SLO signifies a bimodal distribution in which the class is divided in its ability to get the tested SLO.
7. Study the SLO performance pattern from course to course and optimize the course delivery and content in order to make on going course delivery improvements as necessary.

Part I. Clear and Concise SLOs Stated as a 3-Level Concept Matrix

This sabbatical work advocates for linking 1-3 exam questions to a specific SLO listed for each chapter (major topic). Ideally, one should prepare exams using most important SLOs and have a minimum of 2 questions for each SLO with varying difficulty levels. Exams should be designed in an effort to assess student learning of key concepts. During my sabbatical leave and after developing the data analytics computational component (discussed Part II), I used the Excel application to obtain the data analytics of 4 exams of my Introductory Chemistry (Chem 40) course that I taught in Fall 2019.

Generally, a common student question before any exam is "What should we to focus on to prepare for your exam"? I would typically refer them to their homework problems and direct them to review their lecture notes and examples. While over the years I have prepared a list of learning objectives for each chapter for the courses that I generally teach, I have realized that except for a few high performing students, many of my students never visit these learning objectives. Furthermore, many of my students never see the link between test questions and my learning objectives partly because many "don't know what they don't know"! Perhaps the reason for this total confusion partly has to do with the fact that I have never been able to report students' test performances of each learning objective and perhaps my learning objectives should have been written in a more clear, specific and concise language resembling SLO statements. Consequently, I proposed for this independent study to address these issues.

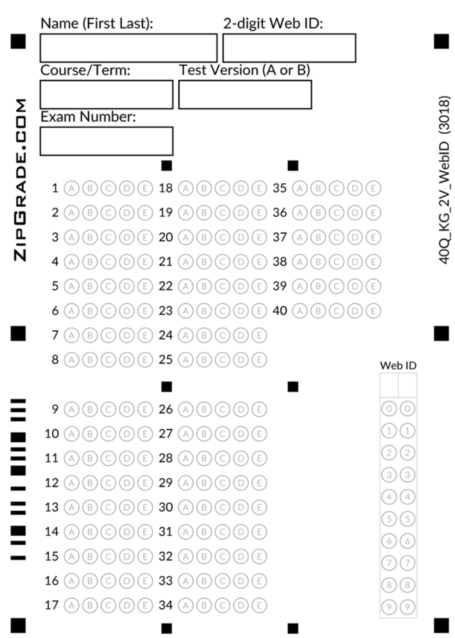
From time to time I have noticed that low performing students tend to repeat their mistakes over and over on each test and feel helpless in *knowing* "what they don't know" in order to make the necessary improvements. I end up curving my exams when my class average falls below a "C-" by offering students a few extra points. However, everyone gets them equally without doing any mitigation work. They just fill out their exam feedback page and turn it in. Completion of this page does not seem to help many of my average and low performing students to pinpoint the missed concepts. Many simply state, "did not know" and never see the link between an exam question and the assessed SLO.

The first important aspect of this project involved revisiting my existing learning objectives and rewriting them into a set of clear and concise SLOs for each chapter organize them in a *3-level concept matrix;* level 1 as the most fundamental (basic skills), level 2 (intermediate) and level 3 stated as an integrated learning level which may include multi-step problem solving or applied analysis. For each course topic (chapter), I added to and edited many of my SLOs in order to fulfil "product 3" stated in my original proposal. Introductory Chemistry now has 209, optimally defined 3-level SLOs over 13 course topics. A topical list of developed SLOs are provided in appendix A as both a 3-level concept matrix (for student use) as well as a sequential list (for instructor use). Every SLO is assigned a global SLO number in order to help instructors assign them to each exam question conveniently (Part II).

Part II. Developing an Excel Exam Data Analytics Spreadsheet

Development of a suitable data analysis Excel-based application rests at the heart of this independent study. What made this step possible was having access to a convenient grading software and a smart phone as a scanner. The grading software application uses a smart phone device for scanning a custom instructor-prepared bubble sheet and it can export the detailed assessment data as a ".csv" (Excel compatible) file. This cost effective phone app is called ZipGrade (registered trademark). A custom bubble sheet was prepared using the online desktop version of the program (www.ZipGrade.com). A sample bubble-sheet is shown in Figure 1. I had been using ZipGrade for 2 years prior to this independent study and was familiar with its features.

Figure 2. 40-question ZipGrade bubble sheet



My students are provided with this bubble sheet. They enter their information on top and bubble their web ID in the space provided. Web ID is a 2 digit random and unique numerical code that I assign to each student so that they can look up their grades online on a private basis. This web ID code also identifies each student record on the exported ZipGrade test file. Students can use pen or pencil (encourage pencil) to bubble their answers and each student's original bubble sheet is digitally recorded on ZipGrade's phone app in order to make it convenient for an instructor to refer to each student's original bubble sheet after the exam, if necessary.

I spent a long time planning, designing and testing an Excel spreadsheet application with many programmed formulas that can convert the raw data into useful data analytics for each exam, and for each student. This spreadsheet is capable of handling a 50-question exam for 32 students, which is more than a single section class size limit. If a double-section class is taught, it is recommended that a different test version of the same exam is prepared and provided to the second half of the class (test version B). A second Excel file can be configured to analyze exam scores of the second student group.

After grading an exam using ZipGrade, an instructor would use the Excel file to enter the SLO of each test question in an Excel sheet named "Exam_SLOs" using the global SLO number shown in the sequential table listing of appendix A. SLOs pop up automatically upon entering their number next to each exam question number. Next, the students' graded ".csv" file (imported from ZipGrade) is copied and pasted into the Excel file's sheet called "Imported_Raw_Data". These steps are outlined in Table 1.

Table 1. Instructor Steps to Generate Exam Data Analytics

Step	Description
1	This spreadsheet can handle 50 exam questions for 32 students for each course section. Enter the global SLO # for each exam question into the "Exam_SLOs" sheet. Change the table heading to proper exam number (Exam 1, etc.). Make sure each student has a unique ID and bubbled in the answer sheet.
2	Scan student bubble sheets using your smart phone and the Zip Grade app.
3	Go to Review Papers (Zip Grade) and select the export icon (top right side) and then select "CSV-Full Data Format" and email the results as a ".CSV" file to yourself.
4	Open your email and download the Excel compatible ".CSV" file using Excel.
5	Select only the data portion (not the heading) and copy the raw data into the "Imported_Raw _Data" sheet. Note: Paste data only (no heading) to the left and top right below the yellow zone. Optionally, enter a numerical "code" for "Quiz Class" column for each student. This code can be a numerical value refering to the course you are teaching.
6	Place the cursor to the availabe row of far left column of "All_Data" sheet and paste the copied data of step 6.
7	Fill in the answer for each test question in the "All_Data" sheet

After completion of the above steps, the spreadsheet processes and reports detailed tabular and graphical SLO data analytics.

Part III. Testing the Excel Application to Prepare a Detailed Analysis of Exam 1

This process was tested on 3 exams and the final exam of my Chem 40. However, the process is discussed in detail for exam 1 while related tables and graphs for other exams are included in the appendixes. Table 1 shows the SLO linked to each test question of exam 1. Retyping of these SLOs is never necessary. Each SLO pops up automatically when its global SLO number is entered in the color-filled column. In this exam, 22 unique SLOs were assessed.

Table 2. SLOs Assessed for Exam 1

Global			Exam 1	
SLO#	Question	Pts	Topic# Title (textbook chapter)	Student Learning Outcome (SLO)
52	1	1	3 Matter & Energy (ch4)	Energy: Define energy and identify types
4	2	1	1 Math & Measurements (ch2)	Sig Fig: Round any number to a given count of sig fig (significant figures)
52	3	1	3 Matter & Energy (ch4)	Energy: Define energy and identify types
1	4	1	1 Math & Measurements (ch2)	Dim Analysis: Translate and identify conversion factors
33	5	1	2 Elements & Compounds (ch3)	Matter: Classify based on visual unifromity (Heterogeneous vs. Homogeneous) & purity
22	6	1	1 Math & Measurements (ch2)	Temperature: Use formula to convert between units
7	7	1	1 Math & Measurements (ch2)	Math: Use your calculator keystrokes correctly including orders of math operations and use of exponent key
34	8	1	2 Elements & Compounds (ch3)	Elements: Recognize symbol of elements (Sy or S) and locate them in the Periodic Table
13	9	1	1 Math & Measurements (ch2)	Solve: using 1-2 step dim analysis to solve problems
4	10	1	1 Math & Measurements (ch2)	Sig Fig: Round any number to a given count of sig fig (significant figures)
8	11	1	1 Math & Measurements (ch2)	Math: Convert a number to scientific exponent
61	12	1	3 Matter & Energy (ch4)	Energy: Solve q=m.c.ΔT equation for an unknown variable
31	13	1	2 Elements & Compounds (ch3)	Matter: Distinguish between an element and a compound
31	14	1	2 Elements & Compounds (ch3)	Matter: Distinguish between an element and a compound
6	15	1	1 Math & Measurements (ch2)	Sig Fig: Report a math calculation to proper sig fig (add, subtract)
13	16	1	1 Math & Measurements (ch2)	Solve: using 1-2 step dim analysis to solve problems
12	17	1	1 Math & Measurements (ch2)	Units: Recall proper unit abbreviations (for common units)
59	18	1	3 Matter & Energy (ch4)	Energy: Describe and identify the law of conservation of energy in a chemical change
22	19	1	1 Math & Measurements (ch2)	Temperature: Use formula to convert between units
8	20	1	1 Math & Measurements (ch2)	Math: Convert a number to scientific exponent
56	21	1	3 Matter & Energy (ch4)	Matter: Distinguish between a physical and chemical change/property
49	22	1	2 Elements & Compounds (ch3)	Bonding: Define an ion, cation and anion versus a neutral atom
28	23	1	1 Math & Measurements (ch2)	Solve: using multi-step dim analysis method
5	24	1	1 Math & Measurements (ch2)	Sig Fig: Report a math calculation to proper sig fig (multiply, divide)
24	25	1	1 Math & Measurements (ch2)	Density: Use formula to calculate a variable
24	26	1	1 Math & Measurements (ch2)	Density: Use formula to calculate a variable
33	27	1	2 Elements & Compounds (ch3)	Matter: Classify based on visual unifromity (Heterogeneous vs. Homogeneous) & purity
33	28	1	2 Elements & Compounds (ch3)	Matter: Classify based on visual unifromity (Heterogeneous vs. Homogeneous) & purity
49	29	1	2 Elements & Compounds (ch3)	Bonding: Define an ion, cation and anion versus a neutral atom
4	30	1	1 Math & Measurements (ch2)	Sig Fig: Round any number to a given count of sig fig (significant figures)
42	31	1	2 Elements & Compounds (ch3)	Bonding: Predict attraction or repulsion between charges
45	32	1	2 Elements & Compounds (ch3)	Elements: Memorize chemical names and symbols of selected elements (handout)
45	33	1	2 Elements & Compounds (ch3)	Elements: Memorize chemical names and symbols of selected elements (handout)
33	34	1	2 Elements & Compounds (ch3)	Matter: Classify based on visual unifromity (Heterogeneous vs. Homogeneous) & purity
55	35	1	3 Matter & Energy (ch4)	Matter: Describe and identify the law of conservation of mass in a chemical change

Next, the raw ZipGrade exam data is copied and pasted into the Excel file's "Imported_Raw_Data" and "All_Data" sheets followed by entering the exam key. A detailed data analytics for Exam 1 is then calculated and reported and shown in a new sheet ("Overall_Lumped") as shown in Table 3. This Excel file has the capability of lumping repeated SLOs into 1 lumped score for each SLO and each student. For example, Table 3 shows that exam 1 had 4 questions that assessed global SLO# 33 (Matter: Classify based on visual uniformity). This SLO reporting page will be communicated to each student. Table 3 shows the page for a student with Web ID 22 (circled). This student obtained a lumped overall average score of 68% in exam 1 as shown. In this student report, each SLO category scored below 70% (a different limit can be set) is automatically flagged by the spreadsheet (highlighted by a color-fill and red font). This flagging method can catch the student's attention to SLO areas that require immediate and targeted improvement.

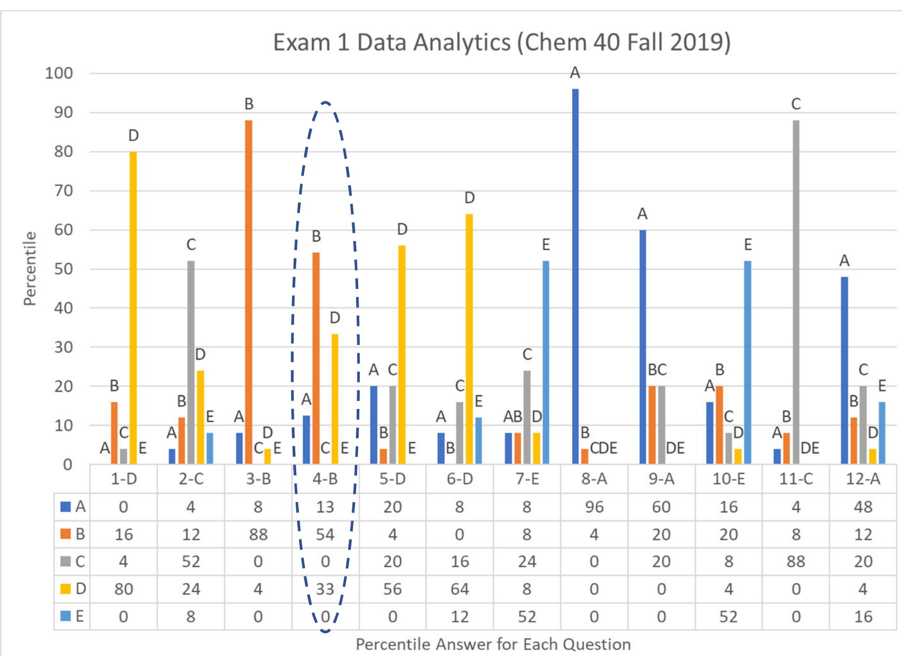
Table 3. Exam 1 Student SLO Data Analytics

	Student Learning Outcomes Exam Data Analytics	Flag SLO at:	70%
Global SLO#	22 Assessed Student Learning Outcomes (Exam 1) Unique (lumped) Set	Max Pts Lumped	22
	Lumped Overall Student Avg --->		68%
52	Energy: Define energy and identify types	2	100%
4	Sig Fig: Round any number to a given count of sig fig (significant figures)	3	67%
1	Dim Analysis: Translate and identify conversion factors	1	100%
33	Matter: Classify based on visual unifromity (Heterogeneous vs. Homogeneous) & purity	4	75%
22	Temperature: Use formula to convert between units	2	100%
7	Math: Use your calculator keystrokes correctly including orders of math	1	0%
34	Elements: Recognize symbol of elements (Sy or S) and locate them in the Periodic Table	1	0%
13	Solve: using 1-2 step dim analysis to solve problems	2	50%
8	Math: Convert a number to scientific exponent	2	100%
61	Energy: Solve q=m.c.ΔT equation for an unknown variable	1	100%
31	Matter: Distinguish between an element and a compound	2	50%
6	Sig Fig: Report a math calculation to proper sig fig (add, subtract)	1	0%
12	Units: Recall proper unit abbreviations (for common units)	1	100%
59	Energy: Describe and identify the law of conservation of energy in a chemical	1	100%
56	Matter: Distinguish between a physical and chemical change/property	1	100%
49	Bonding: Define an ion, cation and anion versus a neutral atom	2	100%
28	Solve: using multi-step dim analysis method	1	100%
5	Sig Fig: Report a math calculation to proper sig fig (multiply, divide)	1	100%
24	Density: Use formula to calculate a variable	2	100%
42	Bonding: Predict attraction or repulsion between charges	1	0%
45	Elements: Memorize chemical names and symbols of selected elements (handout)	2	50%
55	Matter: Describe and identify the law of conservation of mass in a chemical change	1	0%

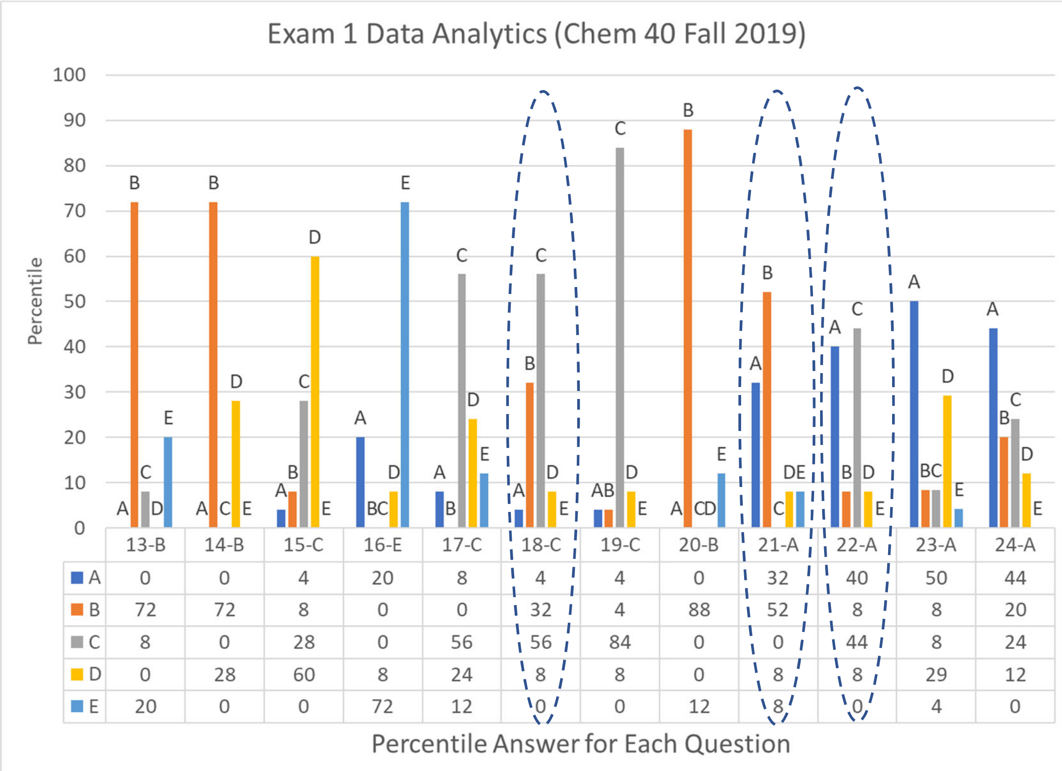
Excel's instructor's view of Table 3 is very similar and shows SLO performances for all students and it also includes two extra columns that show the class average and % standard deviation (%SD) for each assessed SLO. This data is very useful in its capacity to show how well the entire class performed in each tested SLO and the variation in the student responses. SLO concepts connected to test question(s) that result in a low SLO class average, deserve a more in-depth coverage with additionally assigned homework problems. Students should be informed that these SLOs will be retested in the upcoming exam.

Figure 3 shows the data analytics reported for each exam question in a graphical format that deserves instructor's attention. Exam 1 contained 35 questions. Each question is labelled with its correct answer. For example "1-D" label shows the bar graph with the percentile distribution of question 1 for each answer choice with the correct answer being the "D" choice. About 80% of students answered this question correctly and other choices marked are shown are responded below 20% distribution. This was a relatively easy question for the class. It is important to set an action flag level (33% in this case) to examine each question's response distribution in more depth, if flagged. Flagged questions are marked using a dashed oval. These questions deserve a more in-depth analysis.

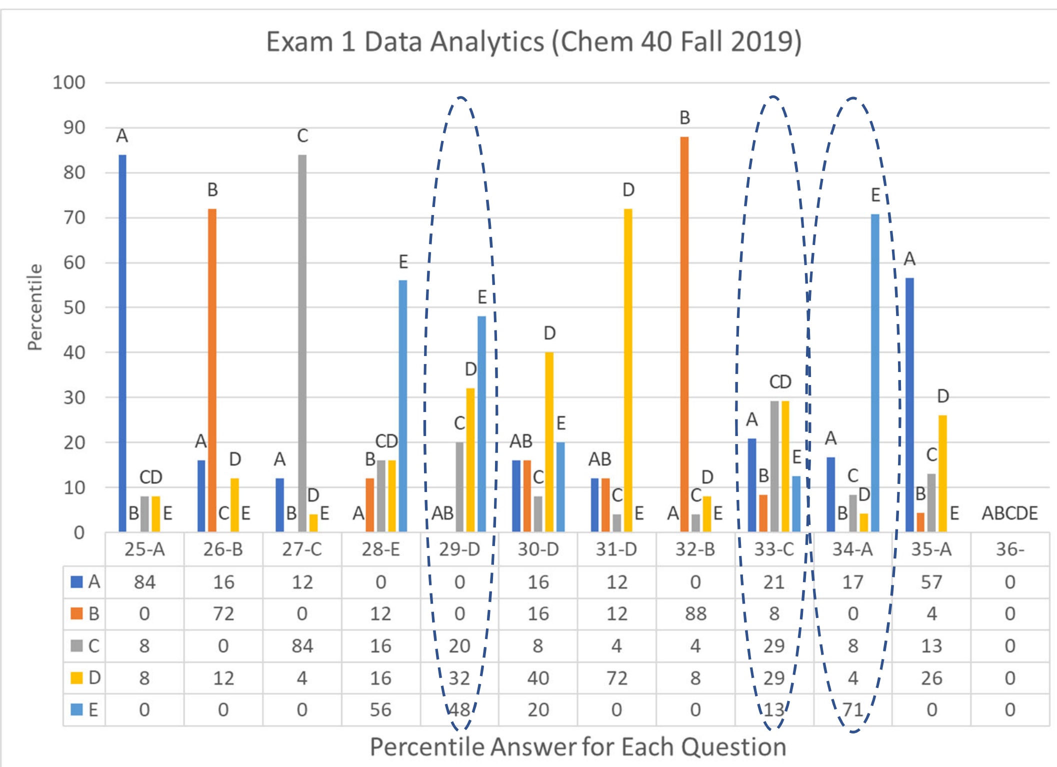
Figure 3. Exam 1 Data Analytics for Questions 1-35 (3 graphs as shown)



	1-D	2-C	3-B	4-B	5-D	6-D	7-E	8-A	9-A	10-E	11-C	12-A
A	0	4	8	13	20	8	8	96	60	16	4	48
B	16	12	88	54	4	0	8	4	20	20	8	12
C	4	52	0	0	20	16	24	0	20	8	88	20
D	80	24	4	33	56	64	8	0	0	4	0	4
E	0	8	0	0	0	12	52	0	0	52	0	16



	13-B	14-B	15-C	16-E	17-C	18-C	19-C	20-B	21-A	22-A	23-A	24-A
A	0	0	4	20	8	4	4	0	32	40	50	44
B	72	72	8	0	0	32	4	88	52	8	8	20
C	8	0	28	0	56	56	84	0	0	44	8	24
D	0	28	60	8	24	8	8	0	8	8	29	12
E	20	0	0	72	12	0	0	12	8	0	4	0



	25-A	26-B	27-C	28-E	29-D	30-D	31-D	32-B	33-C	34-A	35-A	36-
A	84	16	12	0	0	16	12	0	21	17	57	0
B	0	72	0	12	0	16	12	88	8	0	4	0
C	8	0	84	16	20	8	4	4	29	8	13	0
D	8	12	4	16	32	40	72	8	29	4	26	0
E	0	0	0	56	48	20	0	0	13	71	0	0

The answer choice distribution bar graphs for these marked questions can show anomalies in student responses at a glance. Note that a majority of students answered questions 21, 22 and 29 and 34 incorrectly! This deserves our immediate attention referring back to the test contents. After examining question 21, I noticed that one of the answer choices included a process that students were not familiar with and I remember my lecture notes (and the textbook coverage) did not do a thorough job explaining the process. Additionally, there were no homework problems emphasizing the importance of this SLO. Students need the homework exposure to practice with each SLO.

Questions 22 and 29 had to do with an important terminology that students should have reviewed. I am not sure why many missed them and frankly do not recall the details since it has been more than year since I taught the course. Question 34 was a complex question dealing with mixtures and I know I did not spend enough time covering this topic and there were no homework problems reinforcing this SLO.

I plan to set a flag level of 33% (⅓) as an action level. For example, if at least ⅓ of my students answer a question incorrectly, I will go over the concept and assign additional homework problems to mitigate the misconception. Questions 4 and 18's response distribution fall into that category. For question 18's SLO (related to the law of conservation of energy), I noticed that this question addressed energy terminology that I did not explain thoroughly to my students and there were no homework problems reinforcing the topic. Question 4's SLO (Translate and identify conversion factors) is a very important key concept that about 46% of students missed. A significant number of students (33%) answered choice "D" and I know (now!) exactly how they arrived at the wrong answer! They did not solve their dimensional analysis problem for time, therefore the correct answer is the inverse of their answer! The Excel spreadsheet shows that for this SLO (Global SLO # 1), the class average is only 52% with a standard deviation of 51% suggesting that the class is divided in their ability to master this SLO. This SLO falls clearly at a flagged action level and requires intervention to help students master this micro SLO.

In addition, there were many equally wrong choices for question 33's SLO (memorize names and symbols of elements). I think many students needed more time to memorize names and symbols of long list of elements in the Periodic Table. Analysis of exam 1 SLOs reveals invaluable information about students' understanding of these targeted and specific SLOs.

Table 3 lists the average (and %SD) of performance of my students in exam 1. I set an action level of 70% for these SLOs. Having had access to this data analytics, I would have chosen a teaching strategy to help my students master these important basic skills concepts and perhaps even retest these SLOs in the next exam. SLOs with low response levels are automatically highlighted in Table 4 in a colored-fill and a red font to draw attention to these low-performing micro SLOs.

Table 4. Exam 1 Class Average for Each Assessed SLO

	Student Learning Outcomes Exam Data Analytics	Flag SLO at:	70%	
Global SLO#	**22 Assessed Student Learning Outcomes (Exam 1) Unique (lumped) Set**	**Max Pts Lumped**	**Student Web ID---> Class Avg**	**Std Dev**
	Lumped Overall Student Avg --->			
52	Energy: Define energy and identify types	2	84%	35%
4	Sig Fig: Round any number to a given count of sig fig (significant figures)	3	**48%**	37%
1	Dim Analysis: Translate and identify conversion factors	1	**52%**	51%
33	Matter: Classify based on visual unifromity (Heterogeneous vs. Homogeneous) & purity	4	**53%**	25%
22	Temperature: Use formula to convert between units	2	74%	36%
7	Math: Use your calculator keystrokes correctly including orders of math	1	**52%**	51%
34	Elements: Recognize symbol of elements (Sy or S) and locate them in the Periodic Table	1	96%	20%
13	Solve: using 1-2 step dim analysis to solve problems	2	**66%**	31%
8	Math: Convert a number to scientific exponent	2	88%	22%
61	Energy: Solve q=m.c.ΔT equation for an unknown variable	1	**48%**	51%
31	Matter: Distinguish between an element and a compound	2	72%	33%
6	Sig Fig: Report a math calculation to proper sig fig (add, subtract)	1	**28%**	46%
12	Units: Recall proper unit abbreviations (for common units)	1	**56%**	51%
59	Energy: Describe and identify the law of conservation of energy in a chemical	1	**56%**	51%
56	Matter: Distinguish between a physical and chemical change/property	1	**32%**	48%
49	Bonding: Define an ion, cation and anion versus a neutral atom	2	**36%**	45%
28	Solve: using multi-step dim analysis method	1	**48%**	51%
5	Sig Fig: Report a math calculation to proper sig fig (multiply, divide)	1	**44%**	51%
24	Density: Use formula to calculate a variable	2	78%	36%
42	Bonding: Predict attraction or repulsion between charges	1	72%	46%
45	Elements: Memorize chemical names and symbols of selected elements (handout)	2	**58%**	31%
55	Matter: Describe and identify the law of conservation of mass in a chemical change	1	**52%**	51%

Detailed List of Activities and Timeline (based on proposed actions listed on Page 16)

The following activities was performed according to the proposed timeline, in order to design and test the components of this independent study project. The actual completion date for each proposed action is included. Please note that each numerical bullet correlates with each action that I proposed in my original proposal (Refer to page 16).

1. The post-OVID19 world coincided with implementation of the first component of my proposal (Action 1). All in-person chemistry professional seminar and conferences that were scheduled for Summer of 2020 including BCCE (Biennial Conference on Chemical Education, planned for July 18-23 2020 were canceled due to Covid-19 pandemic. Therefore, I had to wait and attend offered conferences in the coming months. 2YC3 (Two-Year College Chemistry Conference) is a professional chemistry education organization) that offered several webinars. I attended the following webinar presentations over Zoom; "Fostering Student Learning in the Online Environment: Moving Beyond the Typical Lecture Video" on *October 30 2020*, "What's Working and What Isn't?" on *November 10 2020*, "Chemistry Education Today for our 2050 World" on *November 13 2020* and "Hibernating Bears, Migrating Salmon, Seaweed Eating Sheep, and Food Fraud: A Different Approach to Teaching General and Organic Chemistry" on *January 29 2021*. While informative in some aspects of teaching and learning, neither of these webinars addressed student learning outcomes, concept mapping and analysis of assessments which were topics related to this independent study. I moved to work on Action 2.
2. Starting on *August 24 2020*, and for a period of nearly 3 months, I examined a number of introductory Chemistry textbooks, including the textbook that we currently use, and worked on developing a comprehensive list of SLOs for each chapter of Chem 40 keeping in mind that many of these students would move on to take the follow up course, General Chemistry I. After examining the chapter layout of these textbooks and their relationship to General Chemistry I, I divided the Introductory Chemistry coverage into 13 major topics over a number of chapters. I tried to shift my focus on topics rather than textbook chapters because textbooks change but these important course topics do not. For the first 2 major

topics I started each SLO statement with an overarching and highly general topic (such as "Math" or "Temperature") followed by an SLO statement that starts with an action verb such as "Identify" or "Determine", in order to first draw the student attention to the topic itself. Based on my teaching experience, students who take this course for the first time generally benefit by identifying the overarching concept. However, I did not find it necessary to continue this practice (starting with an overarching description) for the SLO topics of future chapters because by ten students become more familiar with the overarching topic. For example, there are 31 SLOs for the "Math and Measurements" (topic 1) covered in chapter 2. This tedious task resulted in developing a comprehensive list of 209 concise and specific SLOs for the course, organized and presented over 13 major topics. Developing a learning data analytics required that I assign a numerical value to each SLO (Global SLO#). This task was finally completed on *November 15 2020*.

3. Next, I needed to organize the SLOs developed for each chapter into a 3-level concept matrix to address proposed Action 3. This task was necessary to help students distinguish between learning the fundamentals (Level 1) and higher learning levels (Level 2 and Level 3). Problems with fundamental SLOs shown in Level 1 *will* result in learning difficulties for other levels, if not mastered. Refer to Appendix A for a topical list of these 3-level concept maps. This task was completed on *December 25, 2020*.

4. I started working on Action 4 of my project starting at the beginning of Spring 2021 on *February 22, 2021*. My first activity involved working with Zip Grader (a multiple-response scanning and grading app). Zip grader is capable of exporting a raw data of student assessment. I examined this raw data with the purpose of finding numerical spreadsheet methods to extract and process the raw data into useful data analytics. This process proved to be tedious and required many trial and error attempts. Finally, I managed to extract the key assessment data by designing a number of Excel commands into useful computational functions. A key design aspect was to include a special "counter" numerical method to extract the proper assessment data. Finally, it turned out that the most flexible method was to design 1 general Excel spreadsheet that can be used for any exam with some

alterations. I incorporated all Chem 40 SLOs in this excel spreadsheet in a manner that SLOs are specified by selecting their global SLO designator number (SLO#). I had originally set a completion task of March 2021 but this computational process took a bit longer than expected and I completed the task on *April 15 2021*. It was now time to address the last proposed action by creating student assessment data analytics for the Introductory Chemistry course (Chem 40) that I taught in Fall 2019.

5. Action 5 required that I use the created spreadsheet and generate the exam-by-exam data analytics. I used the 4 exam files from Fall 2019 and generated comprehensive graphs and tables and analyzed the results as outlined in detail in Part III of the report body. I discovered some calculation and design issues with my Excel spreadsheet and altered some formulas to produce the correct data. This validity check was a critical step to test the ultimate product of this independent study (product 5) using real student assessment data. This task was completed on *May 30, 2021* after which, I organized all data in order to prepare this report. I completed my sabbatical report on *June 15, 2021.*

Conclusion

This independent study sabbatical produced amazing results that I am very excited to try in my future courses. While the next Introductory Chemistry is the ideal course to implement this project, I will be able to use the data analytics aspects of this project for other courses that I typically teach, as well. The products developed as a result of this independent study has the potential to serve other Mt SAC faculty in order to help them use computer technology to align their "micro" chapter-by-chapter SLOs with the data analytics of their assessment and optimal student reporting. Upon communicating these SLOs with our students, students are well informed of their strengths and weaknesses, in a timely manner, to help them increase their performance level. After each exam, the newly developed Excel spreadsheet product can significantly help the interested faculty to communicate the detailed data analytics of their students' midterm assessments in a way never imagined before. Students will know their specific weaknesses specific to each SLO (within a major topic) and the course instructor will know class weaknesses and strengths and will be in an ideal position to mitigate student misconceptions. Implementation of this project within courses that have clearly defined SLOs will benefit both faculty and students and promote excellence in teaching and learning.

When students are clear about their learning strengths and weaknesses and follow a clearly defined process to address them, they tend to succeed.

When instructors are better aware of their students' learning misconceptions, they tend to make the necessary adjustments to improve their course content and delivery.

This is a self-fulfilling and rewarding teaching and learning process very closely aligned with why I chose this profession.

Appendix A

Topical and Sequential list of developed SLOs for Chem 40

Global	Total Number of 3-Level Course SLOs:	209				
SLO #	Topic #	Topic# Title (chapter)	No.	Level	Specific Student Learning Outcome (SLO)	Exam No.
1	1	1 Math & Measurements (ch2)	1	1	Dim Analysis: Translate and identify conversion factors	1
2	1	1 Math & Measurements (ch2)	2	1	Dim Analysis: Recognize units of measure (and unit abbreviations) for mass, volume, length, time, temperature	1
3	1	1 Math & Measurements (ch2)	3	1	Dim Analysis: Convert from one SI prefix to another	1
4	1	1 Math & Measurements (ch2)	4	1	Sig Fig: Round any number to a given count of sig fig (significant figures)	1
5	1	1 Math & Measurements (ch2)	5	1	Sig Fig: Report a math calculation to proper sig fig (multiply, divide)	1
6	1	1 Math & Measurements (ch2)	6	1	Sig Fig: Report a math calculation to proper sig fig (add, subtract)	1
7	1	1 Math & Measurements (ch2)	7	1	Math: Use your calculator keystrokes correctly including orders of math operations and use of exponent key	1
8	1	1 Math & Measurements (ch2)	8	1	Math: Convert a number to scientific exponent	1
9	1	1 Math & Measurements (ch2)	9	1	Math: Identify Place-values of any digit in a number	1
10	1	1 Math & Measurements (ch2)	10	1	Sig Figs: List uncertainty of a number as +/- or range of values	1
11	1	1 Math & Measurements (ch2)	11	1	Sig Figs: Identify correct number of sig figs of a measured number	1
12	1	1 Math & Measurements (ch2)	12	1	Units: Recall proper unit abbreviations (for common units)	1
13	1	1 Math & Measurements (ch2)	13	1	Solve: using 1-2 step dim analysis to solve problems	1
14	1	1 Math & Measurements (ch2)	14	2	Math: Solve for a variable in an equation	1
15	1	1 Math & Measurements (ch2)	15	2	Sig Fig: Keep track of sig fig in multi-step calcs	1
16	1	1 Math & Measurements (ch2)	16	2	Solve: prefix conversion problems	1
17	1	1 Math & Measurements (ch2)	17	2	Math: Use proper SI prefix for large and small quantities	1
18	1	1 Math & Measurements (ch2)	18	2	Solve: percent by mass problems	1
19	1	1 Math & Measurements (ch2)	19	2	Solve: percent by volume problems	1
20	1	1 Math & Measurements (ch2)	20	2	Sig Fig: Report a mixed math calculation operation to proper sig fig	1
21	1	1 Math & Measurements (ch2)	21	2	Temperature: Define meaning	1
22	1	1 Math & Measurements (ch2)	23	2	Temperature: Use formula to convert between units	1
23	1	1 Math & Measurements (ch2)	24	2	Mass: Distinguish between mass and weight, operation of a scale and the unit used to measure it.	1
24	1	1 Math & Measurements (ch2)	25	3	Density: Use formula to calculate a variable	1
25	1	1 Math & Measurements (ch2)	26	3	Density: Determine relationship to temperature	1
26	1	1 Math & Measurements (ch2)	27	3	Density: Predict sink or float behavior	1
27	1	1 Math & Measurements (ch2)	28	3	Solve: square and cube conversion factors in dim analysis	1
28	1	1 Math & Measurements (ch2)	29	3	Solve: using multi-step dim analysis method	1
29	1	1 Math & Measurements (ch2)	30	3	Solve: using multi-step shape related problems	1
30	1	1 Math & Measurements (ch2)	31	3	Math: Perform variable analysis using formula	1
31	2	2 Elements & Compounds (ch3)	1	1	Matter: Distinguish between an element and a compound	1
32	2	2 Elements & Compounds (ch3)	2	1	Matter: Define matter	1
33	2	2 Elements & Compounds (ch3)	3	1	Matter: Classify based on visual unifromity (Heterogeneous vs. Homogeneous) & purity	1
34	2	2 Elements & Compounds (ch3)	4	1	Elements: Recognize symbol of elements (Sy or S) and locate them in the Periodic Table	1
35	2	2 Elements & Compounds (ch3)	5	1	Elements: Name important element groups (1A-8A)	1
36	2	2 Elements & Compounds (ch3)	6	1	Elements: Locate metals, metalloids, non-metals	1
37	2	2 Elements & Compounds (ch3)	7	1	Elements: List metallic versus non-metalic elemental properties	1
38	2	2 Elements & Compounds (ch3)	8	1	Elements: List metallic versus non-metalic elemental properties	1
39	2	2 Elements & Compounds (ch3)	9	1	Elements: Distinguish between groups and periods	1
40	2	2 Elements & Compounds (ch3)	10	1	Elements: Define an atom as building spherical particales of matter	1
41	2	2 Elements & Compounds (ch3)	11	1	Bonding: Recognize 3 types of bonding based on atomic level drawing of a compound	1
42	2	2 Elements & Compounds (ch3)	12	1	Bonding: Predict attraction or repulsion between charges	1
43	2	2 Elements & Compounds (ch3)	13	1	Bonding: Distinguish between covalent and ionic bonding based on elements involved	1
44	2	2 Elements & Compounds (ch3)	14	2	Matter: Distinguish between states of matter (g,l,s) diagrams and list each state's properties	1
45	2	2 Elements & Compounds (ch3)	15	2	Elements: Memorize chemical names and symbols of selected elements (handout)	1
46	2	2 Elements & Compounds (ch3)	16	2	Chemical Formula: Recognize a formula and what it represents (diagram ionic vs. covalent matter)	1
47	2	2 Elements & Compounds (ch3)	17	2	Chemical Formula: List differences between molecular and ionic units (fomula units)	1
48	2	2 Elements & Compounds (ch3)	18	2	Chemical Formula: Count total atoms in a given number of molecular units	1
49	2	2 Elements & Compounds (ch3)	19	2	Bonding: Define an ion, cation and anion versus a neutral atom	1
50	2	2 Elements & Compounds (ch3)	20	3	Solve: percent (mass) composition of elements in a formula based on listed "amu" for each element	1
51	2	2 Elements & Compounds (ch3)	21	3	Bonding: Draw layout of ions of a simple ionic compound	1
52	3	3 Matter & Energy (ch4)	1	1	Energy: Define energy and identify types	1
53	3	3 Matter & Energy (ch4)	2	1	Energy: Express the sign of heat energy as loss (-) or gain (+)	1
54	3	3 Matter & Energy (ch4)	3	1	Energy: List units of energy and convert between them	1
55	3	3 Matter & Energy (ch4)	4	1	Matter: Describe and identify the law of conservation of mass in a chemical change	1
56	3	3 Matter & Energy (ch4)	5	1	Matter: Distinguish between a physical and chemical change/property	1
57	3	3 Matter & Energy (ch4)	6	1	Matter: Identify the products and reactants in a chemical change as shown with compound/element formulas in a chemical reaction or chemical equation	1
58	3	3 Matter & Energy (ch4)	7	2	Energy: Define specific heat of a substance	1

Global SLO #	Topic #	Topic# Title (chapter)	No.	Level	Specific Student Learning Outcome (SLO)	Exam No.
	Total Number of 3-Level Course SLOs:	209				
59	3	3 Matter & Energy (ch4)	8	2	Energy: Describe and identify the law of conservation of energy in a chemical change	1
60	3	3 Matter & Energy (ch4)	9	2	Energy: Recall that bonded atoms have a lower potential bond energy than isolated atoms due to forces of attraction.	1
61	3	3 Matter & Energy (ch4)	10	2	Energy: Solve q=m.c.ΔT equation for an unknown variable	1
62	3	3 Matter & Energy (ch4)	11	3	Energy: Identify exothermic and edothermic processes	1
63	3	3 Matter & Energy (ch4)	13	3	Energy: Solve problems for an unknown variable when there is an exchange of heat between 2 substances	1
64	4	4 Atomic Theroy (ch5)	1	1	List the generalizations involved in Dalton's atomic theory including law of definite proportion or constant composition.	2
65	4	4 Atomic Theroy (ch5)	2	1	Provide the group number/names for important groups of the Periodic Table (PT) – Alkali metals, etc.). These are "A" group elements only.	2
66	4	4 Atomic Theroy (ch5)	3	1	Recall the 2n2 rule in calculating total number of electrons that can fit in a principal energy level	2
67	4	4 Atomic Theroy (ch5)	4	1	Recall three fundamental atomic particles and compare their relative masses and their charge unit (+1,-1,0).	2
68	4	4 Atomic Theroy (ch5)	5	1	Define an isotope and relate its properties to its nuclear symbol	2
69	4	4 Atomic Theroy (ch5)	6	2	Calculate mass of an atom given its proton, electron and neutron count and mass of each atomic particle	2
70	4	4 Atomic Theroy (ch5)	7	2	Recall the details and importance of Rutherford's gold foil experiment in elucidating the structure of the atom	2
71	4	4 Atomic Theroy (ch5)	8	2	Solve: Perform average atomic mass calculations (recall formula) to determine average masses shown on the PT (given each isotope mass and its % abundance)	2
72	4	4 Atomic Theroy (ch5)	9	3	Calculate volume of an atom given its diameter or radius and express using an appropriate metric prefix	2
73	5	5 Nomenclature (ch6)	1	1	Memorize the formulas of diatomic an multiatomic elements, H2,N2,O2,X2,P4,S8	2
74	5	5 Nomenclature (ch6)	2	1	Recall names of important element groups (alkali metals, alkaline earth metals, halogens, noble gases) and recognize metals, nonmetals and semimetals (metalloids)	2
75	5	5 Nomenclature (ch6)	3	1	Review general bonding trend for metals and nonmetals based on their affinity toward electron(s) and determine the type of bond that is likely to take place between elements, if any.	2
76	5	5 Nomenclature (ch6)	4	1	Determine cation and anion charge of an element upon gaining or losing electrons	2
77	5	5 Nomenclature (ch6)	5	1	Define an ionic bond based on its stable energy compared to ions separated from one another	2
78	5	5 Nomenclature (ch6)	6	1	Draw a simple structure of alternating cations and anions for an ionic compound	2
79	5	5 Nomenclature (ch6)	7	1	Name simple binary ionic compounds given a formula or vice versa and apply Roman numerals to denote the state of charge of transition metals	2
80	5	5 Nomenclature (ch6)	8	2	Identify ions given a formula. Write ions inside a bracket howing their charge	2
81	5	5 Nomenclature (ch6)	9	2	Recall the ion charge of representative groups (A groups) based on the location of the elements	2
82	5	5 Nomenclature (ch6)	10	2	Memorize a list of polyatomic ions and their corresponding acid names and formulas	2
83	5	5 Nomenclature (ch6)	11	2	Name a polyatomic ionic compound given its formula and vice versa and recognize correct formulas.	2
84	5	5 Nomenclature (ch6)	12	2	Name simple binary covalent (molecular) compounds	2
85	5	5 Nomenclature (ch6)	13	3	Name binary acids for if the compound is dissolved in water ("aq" state)	2
86	5	5 Nomenclature (ch6)	14	3	Name acids based on polyatomic ions	2
87	6 M	6 Modern Atom (ch10)	1	1	Define light and recall the sequence of waves in the electromagnetic spectrum	2
88	6 M	6 Modern Atom (ch10)	2	1	Define wave properties (wavelength, frequency, energy) and predict the proportionality between these quantities.	2
89	6 M	6 Modern Atom (ch10)	3	1	Distinguish between continuous and line spectrum.	2
90	6 M	6 Modern Atom (ch10)	4	1	Recall and draw the wave shapes of 1s and 2p energy levels.	2
91	6 M	6 Modern Atom (ch10)	5	1	Recall basic features of a standing wave (ex. energized guitar string)	2
92	6 M	6 Modern Atom (ch10)	6	1	Recall general shapes of 1s, 2s and 2p (Px,py,pz) orbitals	2
93	6 M	6 Modern Atom (ch10)	7	1	Recall total number of orbitals as well as max number of electrons) in each sublevel: s,p,d,f	2
94	6 M	6 Modern Atom (ch10)	8	1	Recall the chromium and copper group exception when writing electron configuration	2
95	6 M	6 Modern Atom (ch10)	9	1	Recall the order in energy of sublevels (s,p,d,f) within a principal energy level	2
96	6 M	6 Modern Atom (ch10)	10	1	Relate to the electron's excitation and relaxation processes upon absorbing and releasing energy equivalent to the difference between atomic energy levels	2
97	6 M	6 Modern Atom (ch10)	11	1	Relate to the quantum view that electron(s) occupy a volume outside the nucleous standing waves of certain shape and energy	2
98	6 M	6 Modern Atom (ch10)	12	1	Use a Periodic Table to write the electron configuration of an element	2
99	6 M	6 Modern Atom (ch10)	13	1	Write the ground state electron configuration for each element using a periodic table only	2
100	6 M	6 Modern Atom (ch10)	14	2	Connect line spectrum to the atomic processes involving energy and elecrons	2
101	6 M	6 Modern Atom (ch10)	15	2	Identify core vs. valence electron configuration of an element	2
102	6 M	6 Modern Atom (ch10)	16	2	Recall the filling order of electrons as well as the spin direction in a given sublevel.	2

Global SLO #	Total Number of 3-Level Course SLOs: 209					
	Topic #	Topic# Title (chapter)	No.	Level	Specific Student Learning Outcome (SLO)	Exam No.
103	6 M	6 Modern Atom (ch10)	17	3	Idenify an atom given a feature of its electron configuration. For example, nitrogen is the atom with a half-filed 2p orbital. Also, be able to provide list of atoms that share the same group electron configuation	2
104	7	7 Chemical Bonding (ch11)	1	1	Determine the nuclear charge "felt" by the valence electron of atoms going across a period of PT	2
105	7	7 Chemical Bonding (ch11)	2	1	Determine the nuclear charge "felt" by the valence electron of atoms going down a group	2
106	7	7 Chemical Bonding (ch11)	3	1	Relate the attraction for valence electrons to the electronegativity scale assigned to an element	2
107	7	7 Chemical Bonding (ch11)	4	1	Recall atomic size trend going across a period and down a group	2
108	7	7 Chemical Bonding (ch11)	5	1	Define ionization energy and relate to its relationship to atomic size	2
109	7	7 Chemical Bonding (ch11)	6	1	Place valence electrons on an element called Lewis dot symbol	2
110	7	7 Chemical Bonding (ch11)	7	1	Show the Lewis dot structure of a cation or anion and the specific noble gas that they resemble	2
111	7	7 Chemical Bonding (ch11)	8	1	Distinguish lone pairs and shared (bonded) pairs of electrons in a Lewis structure of a molecule	2
112	7	7 Chemical Bonding (ch11)	9	1	Pick the best atom to be the central atom while doing Lewis structure of simple molecules	2
113	7	7 Chemical Bonding (ch11)	10	2	Draw Lewis structrure for a simple neutral molecule or a polyatomic ion given its formula	2
114	7	7 Chemical Bonding (ch11)	11	2	Recall the 3 EG structures based on the number of electron groups and memorize the angles between the electron groups	2
115	7	7 Chemical Bonding (ch11)	12	2	Determine the electron group (EG) geometry classification based on VSEPR principle	2
116	7	7 Chemical Bonding (ch11)	13	2	Draw the 3-D Lewis structure based on EG classification and determine bond angles	2
117	7	7 Chemical Bonding (ch11)	14	2	Determine the molecular shape (MS) or molecular geometry classification	2
118	7	7 Chemical Bonding (ch11)	15	3	Determine bond polarity based on electronegativity trend. Place dipole symbol on a bond	2
119	7	7 Chemical Bonding (ch11)	16	3	Determine the molecular polarity based on summing charge points (report polar or non-polar)	2
120	8	8 Formula Calculations (ch7)	1	1	Calculate molar mass given a formula	3
121	8	8 Formula Calculations (ch7)	2	1	Perform mass-mole formula claculations	3
122	8	8 Formula Calculations (ch7)	3	1	Perform mole-count formula calculations	3
123	8	8 Formula Calculations (ch7)	4	1	Calculate percent composition (by mass) of elements, given a formula	3
124	8	8 Formula Calculations (ch7)	5	1	Calculate percent composition (by mass) of elements, given elemetal masses	3
125	8	8 Formula Calculations (ch7)	6	2	Perform multistep cacluations involving mass-mole-count	3
126	8	8 Formula Calculations (ch7)	7	2	Distinguish between molecular and empirical formulas	3
127	8	8 Formula Calculations (ch7)	8	2	Determine empirical formula given percent composition or mass of elements	3
128	8	8 Formula Calculations (ch7)	9	2	Determine molecular formula given empirical formula and molar mass	3
129	8	8 Formula Calculations (ch7)	10	3	Determine molecular formula, given percent composition (or mass) data as well as molar mass	3
130	8	8 Formula Calculations (ch7)	11	3	Perform mole-mass-count claculations on a formula component (element, simple ion, polyatomic ion)	3
131	8	8 Formula Calculations (ch7)	12	3	Calculate percent composition of a polyatomic ion(s) given a formula	3
132	9	9 Chemical Reactions (ch8)	1	1	Balance a chemical reaction (using lowest whole number coefficients) which transforms it into a chemical equation	3
133	9	9 Chemical Reactions (ch8)	2	1	Identify the 5 reaction types	3
134	9	9 Chemical Reactions (ch8)	3	1	Predict elemental products of a decomposition reaction	3
135	9	9 Chemical Reactions (ch8)	4	1	Predict ionic product of a synthesis (combination) reaction	3
136	9	9 Chemical Reactions (ch8)	5	1	Predict products of a combustion reaction	3
137	9	9 Chemical Reactions (ch8)	6	1	Predict products of a double replacement reaction and write the total and net ionic equation	3
138	9	9 Chemical Reactions (ch8)	7	1	Predict products of a single replacement reaction (Inculding reactions of metals with water and halogen SR reactions) and write the total and net ionic equations	3
139	9	9 Chemical Reactions (ch8)	8	1	Recall abbreviations of 4 states of matter (g,l,s,aq)	3
140	9	9 Chemical Reactions (ch8)	9	1	Recall evidence of a chemical reaction (color, gas, solid, liquid, change of temperature)	3
141	9	9 Chemical Reactions (ch8)	10	1	Recall formulas and states of diatomic and multiatomic elements as well as ionic compounds	3
142	9	9 Chemical Reactions (ch8)	11	1	Translate a reaction given in words and nomenclature into a reaction symbol involving formulas	3
143	9	9 Chemical Reactions (ch8)	12	1	Use the activity series of metals table to predict if a single replacement reaction takes place	3
144	9	9 Chemical Reactions (ch8)	13	2	Classify a reaction based on energy into endothermic and exothermic reaction	3
145	9	9 Chemical Reactions (ch8)	14	2	Identify the reaction energy diagram for an enothermic vs. exothermic reaction	3
146	9	9 Chemical Reactions (ch8)	15	2	Memorize solubility rules of common ionic compounds in water	3
147	9	9 Chemical Reactions (ch8)	16	2	Place the quantity of energy (kJ) on the correct side of a reaction given a reaction description	3

Global SLO #	Topic #	Topic# Title (chapter)	No.	Level	Specific Student Learning Outcome (SLO)	Exam No.
		Total Number of 3-Level Course SLOs: 209				
148	9	9 Chemical Reactions (ch8)	17	2	Relate the energy classification to the overall potential energy stored in the reactant and product bonds	3
149	9	9 Chemical Reactions (ch8)	18	2	Show a diagram showing polar interactions between a cation and water	3
150	9	9 Chemical Reactions (ch8)	19	2	Show the chemical equation process for a soluble compound dissolving in water (solubility reaction)	3
151	9	9 Chemical Reactions (ch8)	20	3	Predict products of reactions involving mixture of ions	3
152	9	9 Chemical Reactions (ch8)	21	3	Show a diagram showing polar interactions between an anion and water	3
153	10	10 Stoichiometry (ch9)	1	1	Relate to coefficients of a chemical equation as mole or count of element or compound involved	3
154	10	10 Stoichiometry (ch9)	2	1	Perform mole-to-mole stoichiometry	3
155	10	10 Stoichiometry (ch9)	3	1	Perform mole-to-mass stoichiometry	3
156	10	10 Stoichiometry (ch9)	4	1	Perform mass-to-mass stoichiometry	3
157	10	10 Stoichiometry (ch9)	5	2	Calculate product quantity using excess/limiting stoichiometry	3
158	10	10 Stoichiometry (ch9)	6	2	Calculate reactant quantity using excess/limiting stoichiometry	3
159	10	10 Stoichiometry (ch9)	7	2	Calculate percent yield of a product given actual yield and reactant quantity	3
160	10	10 Stoichiometry (ch9)	8	3	Calculate excess quantity of reactant left over	3
161	11	11 Gases (ch12)	1	1	List common physical properties of gases	3
162	11	11 Gases (ch12)	2	1	List important gas variables (V,T,P,n) and their units of measure.	3
163	11	11 Gases (ch12)	3	1	Define pressure as force exerted per unit area and convert from one pressure unit to another. Memorize 760 (exact) torr = 1 atm	3
164	11	11 Gases (ch12)	4	1	State the cause of atmospheric pressure and its variation with altitude	3
165	11	11 Gases (ch12)	5	1	Describe how atmospheric pressure is measured and the equipment (barometer) used to measure it	3
166	11	11 Gases (ch12)	6	1	Use the master equation: P.V/(n.T)=R to describe the interdependency of gas variables to solve for an unknown variable (Ideal Gas law)	3
167	11	11 Gases (ch12)	7	1	Use the general combined gas law equation: P1.V1/(n1.T1)=P2.T2/(n2.T2) to solve for an unknown variable and determine variable proportionality as stated in various gas laws.	3
168	11	11 Gases (ch12)	8	2	Describe Boyle's law as proportionality, equation as well as its graphical relationship	3
169	11	11 Gases (ch12)	9	2	Describe Charles' law as proportionality, equation as well as its graphical relationship	3
170	11	11 Gases (ch12)	10	2	Describe Avogadro's law as proportionality as well as combining gas volumes in a chemical equation	3
171	11	11 Gases (ch12)	11	2	Define the state of STP, memorize the molar volume of any gas at STP (22.41 L/mol) and use as a conversion factor.	3
172	11	11 Gases (ch12)	12	2	Describe the principle assumptions of the Kinetic Molecular Theory of gases	3
173	11	11 Gases (ch12)	13	2	Describe Dalton's law of partial pressures and solve for an unknown gas pressure	3
174	11	11 Gases (ch12)	14	3	Solve gas problems involving collecting a gas over water (application of Dalton's law)	3
175	11	11 Gases (ch12)	15	3	Solve multi-step gas stoichiometry problems when a gas is collected over water.	3
176	11	11 Gases (ch12)	16	3	Solve gas stoichiometry problems involving STP	3
177	11	11 Gases (ch12)	17	3	Solve multi-step gas stoichiometry problems using the ideal gas law equation.	3
178	12	12 Solutions (ch14)	1	1	Define saturated, unsaturated, concentrated and dilute terms	Final
179	12	12 Solutions (ch14)	2	1	Define the terms solution, solvent and solute	Final
180	12	12 Solutions (ch14)	3	1	Describe the process of water dissolving an ionic solid (Key terms: polarity interactions and hydration process).	Final
181	12	12 Solutions (ch14)	4	1	Draw a simple diagram for hydration of ions involving water and ions showing charges	Final
182	12	12 Solutions (ch14)	5	1	Express a concentration to molality unit	Final
183	12	12 Solutions (ch14)	6	1	Recall concentration definitions and their formulas; percent by mass (m/m), percent by volume (v/v) and molarity	Final
184	12	12 Solutions (ch14)	7	1	Recall examples of gas, liquid and solid solutions	Final
185	12	12 Solutions (ch14)	8	1	Use metric prefixes to express small solute mass (g) or molarity concentration (ex. mM, nM, etc.)	Final
186	12	12 Solutions (ch14)	9	2	Define the dilution process and solve dilution problems using the C1.V1 = C2.V2 equation	Final
187	12	12 Solutions (ch14)	10	2	Given molarity and volume of a solution, find mole or mass of molecular or ionic solutes	Final
188	12	12 Solutions (ch14)	11	2	Recall solution properties that change with concentration (freezing and boiling) and apply the equation : $\Delta T = K . m$	Final
189	12	12 Solutions (ch14)	12	2	Work with a solubility graph of ionic compounds in water to determine the state of a solution (saturated or unstaturated) upon addition of a solute to a a given mass of water and determine mass of solute that precipitates when a solution is cooled.	Final
190	12	12 Solutions (ch14)	13	2	Write a balanced "solubility reaction" for a soluble ionic substance that dissolves in water. Relate to this process as salt ionization or salt dissociation in water.	Final
191	12	12 Solutions (ch14)	14	3	Define parts per million (ppm) and parts per billion (ppb) concentration units and use them to express very small ion or compound concentrations in water (assume a density of 1.00 g/mL)	Final
192	12	12 Solutions (ch14)	15	3	Given molarity of an ionic compound in water, find molarity of each ion	Final
193	12	12 Solutions (ch14)	16	3	Perform stoichiometric calculations using molarity solution concentration	Final

Global	Total Number of 3-Level Course SLOs:	209				
SLO #	Topic #	Topic# Title (chapter)	No.	Level	Specific Student Learning Outcome (SLO)	Exam No.
194	13	13 Acids & Bases (ch15)	1	1	Define acids and bases based on Arrhenius and Bronsted-Lowry definitions	Final
195	13	13 Acids & Bases (ch15)	2	1	Write ionization reaction of any weak or strong acid in water.	Final
196	13	13 Acids & Bases (ch15)	3	1	Differentiate between a complete reaction using a single forward arrow “” or an incomplete (equilibrium) reaction using a double arrow “D”.	Final
197	13	13 Acids & Bases (ch15)	4	1	Memorize the 6 strong acids. These acids all form into strong electrolytes and dissociate or ionize in water completely. Show any weak acid’s equilibrium reaction in water. These dissociate partially in water and form into weak electrolytes.	Final
198	13	13 Acids & Bases (ch15)	5	1	Recall acid nomenclature.	Final
199	13	13 Acids & Bases (ch15)	6	1	Identify the conjugate acid-base pairs and predict products of acid-base reactions in water and	Final
200	13	13 Acids & Bases (ch15)	7	1	Write the the auto ionization of water reaction where water acts as both an acid and base.	Final
201	13	13 Acids & Bases (ch15)	8	1	Memorize the equilibrium expression of water and the value, Kw=1.0x10-14 and its significance	Final
202	13	13 Acids & Bases (ch15)	9	2	Given hydronium or hydroxide concentrations (as M, pH, or pOH), calculate the other concentration (as M, pH or pOH) and classify solution as acidic, basic or neutral.	Final
203	13	13 Acids & Bases (ch15)	10	2	Memorize pH and pOH formulas, equilibrium expression of water as well as pH + pOH = 14.00	Final
204	13	13 Acids & Bases (ch15)	11	2	Note: Use your calculator’s log and antilog feature and solve equations “c” and “d” for either variable.	Final
205	13	13 Acids & Bases (ch15)	12	2	Recall the neutral state of a solution where pH=7.00 and pOH=7.00 and relate these to hydronium and hydroxide molarity concentrations.	Final
206	13	13 Acids & Bases (ch15)	13	3	Solve stoichiometry problems involving two solutions which containg dissolved reactants. Calculate mass of product formed	Final
207	13	13 Acids & Bases (ch15)	14	3	Solve titration stoichiometry problems	Final
208	13	13 Acids & Bases (ch15)	15	3	Calculate volume or molarity of one reactant given volume and molarity of another reactant	Final
209	13	13 Acids & Bases (ch15)	16	3	Calculate pH of a strong acid or strong base compound in water given its quanity and solution volume	Final

1 Math & Measurements (ch2)

Total Topic SLOs = 31

13 SLOs	11 SLOs	7 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
Dim Analysis: Translate and identify conversion factors	Math: Solve for a variable in an equation	Density: Determine relationship to temperature
Dim Analysis: Recognize units of measure (and unit abbreviations) for mass, volume, length, time, temperature	Sig Fig: Keep track of sig fig in multi-step calcs	Density: Predict sink or float behavior
Dim Analysis: Convert from one SI prefix to another	Solve: prefix conversion problems	Solve: square and cube conversion factors in dim analysis
Sig Fig: Round any number to a given count of sig fig (significant figures)	Math: Use proper SI prefix for large and small quantities	Solve: using multi-step dim analysis method
Sig Fig: Report a math calculation to proper sig fig (multiply, divide)	Solve: percent by mass problems	Solve: using multi-step shape related problems
Sig Fig: Report a math calculation to proper sig fig (add, subtract)	Solve: percent by volume problems	Math: Perform variable analysis using formula
Math: Use your calculator keystrokes correctly including orders of math operations and use of exponent key	Sig Fig: Report a mixed math calculation operation to proper sig fig	Math: Analyze the relationship between a proportionality and an equation
Math: Convert a number to scientific exponent	Temperature: Define meaning	
Math: Identify Place-values of any digit in a number	Temperature: Use formula to convert between units	
Sig Figs: List uncertainty of a number as +/- or range of values	Mass: Distinguish between mass and weight, operation of a scale and the unit used to measure it.	
Sig Figs: Identify correct number of sig figs of a measured number	Density: Use formula to calculate a variable	
Units: Recall proper unit abbreviations (for common units)		
Solve: using 1-2 step dim analysis to solve problems		

2 Elements & Compounds (ch3)

Total Topic SLOs = 21

13 SLOs	6 SLOs	2 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
Matter: Distinguish between an element and a compound	Matter: Distinguish between states of matter (g,l,s) diagrams and list each state's properties	Solve: percent (mass) composition of elements in a formula based on listed "amu" for each element
Matter: Define matter	Elements: Memorize chemical names and symbols of selected elements (handout)	Bonding: Draw layout of ions of a simple ionic compound
Matter: Classify based on visual unifromity (Heterogeneous vs. Homogeneous) & purity	Chemical Formula: Recognize a formula and what it represents (diagram ionic vs. covalent matter)	
Elements: Recognize symbol of elements (Sy or S) and locate them in the Periodic Table	Chemical Formula: List differences between molecular and ionic units (fomula units)	
Elements: Name important element groups (1A-8A)	Chemical Formula: Count total atoms in a given number of molecular units	
Elements: Locate metals, metalloids, non-metals	Bonding: Define an ion, cation and anion versus a neutral atom	
Elements: List metallic versus non-metalic elemental properties		
Elements: List metallic versus non-metalic elemental properties		
Elements: Distinguish between groups and periods		
Elements: Define an atom as building spherical particales of matter		
Bonding: Recognize 3 types of bonding based on atomic level drawing of a compound		
Bonding: Predict attraction or repulsion between charges		
Bonding: Distinguish between covalent and ionic bonding based on elements involved		

3 Matter & Energy (ch4)

Total Topic SLOs = 12

6 SLOs	4 SLOs	2 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
Energy: Define energy and identify types	Energy: Define specific heat of a substance	Energy: Identify exothermic and edothermic processes
Energy: Express the sign of heat energy as loss (-) or gain (+)	Energy: Describe and identify the law of conservation of energy in a chemical change	Energy: Solve problems for an unknown variable when there is an exchange of heat between 2 substances
Energy: List units of energy and convert between them	Energy: Recall that bonded atoms have a lower potential bond energy than isolated atoms due to forces of attraction.	
Matter: Describe and identify the law of conservation of mass in a chemical change	Energy: Solve $q=m.c.\Delta T$ equation for an unknown variable	
Matter: Distinguish between a physical and chemical change/property		
Matter: Identify the products and reactants in a chemical change as shown with compound/element formulas in a		

4 Atomic Theroy (ch5)

Total Topic SLOs = 9

5 SLOs	3 SLOs	1 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
List the generalizations involved in Dalton's atomic theory including law of definite proportion or constant composition.	Calculate mass of an atom given its proton, electron and neutron count and mass of each atomic particle	Calculate volume of an atom given its diameter or radius and express using an appropriate metric prefix
Provide the group number/names for important groups of the Periodic Table (PT) – Alkali metals, etc.). These are "A" group elements only.	Recall the details and importance of Rutherford's gold foil experiment in elucidating the structure of the atom	
Recall the $2n^2$ rule in calculating total number of electrons that can fit in a principal energy level	Solve: Perform average atomic mass calculations (recall formula) to determine average masses shown on the PT (given	
Recall three fundamental atomic particles and compare their relative masses and their charge unit (+1,-1,0).		
Define an isotope and relate its properties to its nuclear symbol		

5 Nomenclature (ch6)

Total Topic SLOs = 14

7 SLOs	5 SLOs	2 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
Memorize the formulas of diatomic an multiatomic elements, H_2,N_2,O_2,X_2,P_4,S_8	Identify ions given a formula. Write ions inside a bracket howing their charge	Name binary acids for if the compound is dissolved in water ("aq" state)
Recall names of important element groups (alkali metals, alkaline earth metals, halogens, noble	Recall the ion charge of representative groups (A groups) based on the location of the elements	Name acids based on polyatomic ions
Review general bonding trend for metals and nonmetals based on their affinity toward electron(s) and determine the type of bond that is likely to take place between elements, if any.	Memorize a list of polyatomic ions and their corresponding acid names and formulas	
Determine cation and anion charge of an element upon gaining or losing electrons	Name a polyatomic ionic compound given its formula and vice versa and recognize correct formulas.	
Define an ionic bond based on its stable energy compared to ions separated from one another	Name simple binary covalent (molecular) compounds	
Draw a simple structure of alternating cations and anions for an ionic compound		
Name simple binary ionic compounds given a formula or vice versa and apply Roman numerals to denote the state of charge of transition metals		

6 Modern Atom (ch10)

Total Topic SLOs = 17

13 SLOs	3 SLOs	1 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
Define light and recall the sequence of waves in the electromagnetic spectrum	Connect line spectrum to the atomic processes involving energy and elecrons	Idenify an atom given a feature of its electron configuration. For example, nitrogen is the atom with a half-filed 2p orbital. Also, be able to provide list of atoms that share the same group electron configuation
Define wave properties (wavelength, frequency, energy) and predict the proportionality between these quantities.	Identify core vs. valence electron configuration of an element	
Distinguish between continuous and line spectrum.	Recall the filling order of electrons as well as the spin direction in a given sublevel.	
Recall and draw the wave shapes of 1s and 2p energy levels.		
Recall basic features of a standing wave (ex. energized guitar string)		
Recall general shapes of 1s, 2s and 2p (Px,py,pz) orbitals		
Recall total number of orbitals as well as max number of electrons) in each sublevel: s,p,d,f		
Recall the chromium and copper group exception when writing electron configuration		
Recall the order in energy of sublevels (s,p,d,f) within a principal energy level		
Relate to the electron's excitation and relaxation processes upon absorbing and releasing energy equivalent to the difference between atomic energy levels		
Relate to the quantum view that electron(s) occupy a volume outside the nucleous standing waves of certain shape and energy		
Use a Periodic Table to write the electron configuration of an element		
Write the ground state electron configuration for each element using a periodic table only		

7 Chemical Bonding (ch11)

Total Topic SLOs = 16

9 SLOs	5 SLOs	2 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
Determine the nuclear charge "felt" by the valence electron of atoms going across a period of PT	Draw Lewis structrure for a simple neutral molecule or a polyatomic ion given its formula	Determine bond polarity based on electronegativity trend. Place dipole symbol on a bond
Determine the nuclear charge "felt" by the valence electron of atoms going down a group	Recall the 3 EG structures based on the number of electron groups and memorize the angles between the electron groups	Determine the molecular polarity based on summing charge points (report polar or non-polar)
Relate the attraction for valence electrons to the electronegativity scale assigned to an element	Determine the electron group (EG) geometry classification based on VSEPR principle	
Recall atomic size trend going across a period and down a group	Draw the 3-D Lewis structure based on EG classification and determine bond angles	
Define ionization energy and relate to its relationship to atomic size	Determine the molecular shape (MS) or molecular geometry classification	
Place valence electrons on an element called Lewis dot symbol		
Show the Lewis dot structure of a cation or anion and the specific noble gas that they resemble		
Distinguish lone pairs and shared (bonded) pairs of electrons in a Lewis structure of a molecule		
Pick the best atom to be the central atom while doing Lewis structure of simple molecules		

8 Formula Calculations (ch7)

Total Topic SLOs = 12

5 SLOs	4 SLOs	3 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
Calculate molar mass given a formula	Perform multistep cacluations involving mass-mole-count	Determine molecular formula, given percent composition (or mass) data as well as molar mass
Perform mass-mole formula claculations	Distinguish between molecular and empirical formulas	Perform mole-mass-count claculations on a formula component (element, simple ion, polyatomic ion)
Perform mole-count formula calculations	Determine empirical formula given percent composition or mass of elements	Calculate percent composition of a polyatomic ion(s) given a formula
Calculate percent composition (by mass) of elements, given a formula	Determine molecular formula given empirical formula and molar mass	
Calculate percent composition (by mass) of elements, given elemetal masses		

9 Chemical Reactions (ch8)

Total Topic SLOs = 21

12 SLOs	7 SLOs	2 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
Balance a chemical reaction (using lowest whole number coefficients) which transforms it into a chemical equation	Classify a reaction based on energy into endothermic and exothermic reaction	Predict products of reactions involving mixture of ions
Identify the 5 reaction types	Identify the reaction energy diagram for an enothermic vs. exothermic reaction	Show a diagram showing polar interactions between an anion and water
Predict elemental products of a decomposition reaction	Memorize solubility rules of common ionic compounds in water	
Predict ionic product of a synthesis (combination) reaction	Place the quantity of energy (kJ) on the correct side of a reaction given a reaction description	
Predict products of a combustion reaction	Relate the energy classification to the overall potential energy stored in the reactant and product bonds	
Predict products of a double replacement reaction and write the total and net ionic equation	Show a diagram showing polar interactions between a cation and water	
Predict products of a single replacement reaction (Inculding reactions of metals with water and halogen SR reactions) and write the total and net ionic equations	Show the chemical equation process for a soluble compound dissolving in water (solubility reaction)	
Recall abbreviations of 4 states of matter (g,l,s,aq)		
Recall evidence of a chemical reaction (color, gas, solid, liquid, change of temperature)		
Recall formulas and states of diatomic and multiatomic elements as well as ionic compounds		
Translate a reaction given in words and nomenclature into a reaction symbol involving formulas		
Use the activity series of metals table to predict if a single replacement reaction takes place		

10 Stoichiometry (ch9)

Total Topic SLOs = 12

4 SLOs	3 SLOs	5 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
Relate to coefficients of a chemical equation as mole or count of element or compound involved	Calculate product quantity using excess/limiting stoichiometry	Calculate excess quantity of reactant left over
Perform mole-to-mole stoichiometry	Calculate reactant quantity using excess/limiting stoichiometry	
Perform mole-to-mass stoichiometry	Calculate percent yield of a product given actual yield and reactant quantity	
Perform mass-to-mass stoichiometry		

11 Gases (ch12)

Total Topic SLOs = 17

7 SLOs	6 SLOs	4 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
List common physical properties of gases	Describe Boyle's law as proportionality, equation as well as its graphical relationship	Solve gas problems involving collecting a gas over water (application of Dalton's law)
List important gas variables (V,T,P,n) and their units of measure.	Describe Charles' law as proportionality, equation as well as its graphical relationship	Solve multi-step gas stoichiometry problems when a gas is collected over water.
Define pressure as force exerted per unit area and convert from one pressure unit to another. Memorize 760 (exact) torr = 1 atm	Describe Avogadro's law as proportionality as well as combining gas volumes in a chemical equation	Solve gas stoichiometry problems involving STP
State the cause of atmospheric pressure and its variation with altitude	Define the state of STP, memorize the molar volume of any gas at STP (22.41 L/mol) and use as a conversion factor.	Solve multi-step gas stoichiometry problems using the ideal gas law equation.
Describe how atmospheric pressure is measured and the equipment (barometer) used to measure it	Describe the principle assumptions of the Kinetic Molecular Theory of gases	
Use the master equation: $P.V/(n.T)=R$ to describe the interdependency of gas variables to solve for an unknown variable (Ideal Gas law)	Describe Dalton's law of partial pressures and solve for an unknown gas pressure	
Use the general combined gas law equation: $P1.V1/(n1.T1)=P2.T2/(n2.T2)$ to solve for an unknown variable and determine variable proportionality as stated in various gas laws.		

12 Solutions (ch14)

Total Topic SLOs = 16

8 SLOs	5 SLOs	3 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
Define saturated, unsaturated, concentrated and dilute terms	Define the dilution process and solve dilution problems using the C1.V1 = C2.V2 equation	Define parts per million (ppm) and parts per billion (ppb) concentration units and use them to express very small ion or compound concentrations in water (assume a density of 1.00 g/mL)
Define the terms solution, solvent and solute	Given molarity and volume of a solution, find mole or mass of molecular or ionic solutes	Given molarity of an ionic compound in water, find molarity of each ion
Describe the process of water dissolving an ionic solid (Key terms: polarity interactions and hydration process).	Recall solution properties that change with concentration (freezing and boiling) and apply the equation : $\Delta T = K \cdot m$	Perform stoichiometric calculations using molarity solution concentration
Draw a simple diagram for hydration of ions involving water and ions showing charges	Work with a solubility graph of ionic compounds in water to determine the state of a solution (saturated or unstaturated) upon addition of a solute to a a given mass of water and determine mass of solute that precipitates when a solution is cooled.	
Express a concentration to molality unit	Write a balanced “solubility reaction” for a soluble ionic substance that dissolves in water. Relate to this process as salt ionization or salt dissociation in water.	
Recall concentration definitions and their formulas; percent by mass (m/m), percent by volume (v/v) and molarity		
Recall examples of gas, liquid and solid solutions		

13 Acids & Bases (ch15)

Total Topic SLOs = 16

8 SLOs	4 SLOs	4 SLOs
Level 1 - basic skills	**Level 2 - intermediate**	**Level 3 - concept integration**
Define acids and bases based on Arrhenius and Bronsted-Lowry definitions	Given hydronium or hydroxide concentrations (as M, pH, or pOH), calculate the other concentration (as M, pH or pOH) and classify solution as acidic, basic or neutral.	Solve titration stoichiometry problems
Write ionization reaction of any weak or strong acid in water.	Memorize pH and pOH formulas, equilibrium expression of water as well as pH + pOH = 14.00	Calculate volume or molarity of one reactant given volume and molarity of another reactant
Differentiate between a complete reaction using a single forward arrow "→" or an incomplete (equilibrium) reaction using a double arrow "⇆".	Note: Use your calculator's log and antilog feature and solve equations "c" and "d" for either variable.	Calculate pH of a strong acid or strong base compound in water given its quanity and solution volume
Memorize the 6 strong acids. These acids all form into strong electrolytes and dissociate or ionize in water completely. Show any weak acid's equilibrium reaction in water. These dissociate partially in water and form into weak electrolytes.	Recall the neutral state of a solution where pH=7.00 and pOH=7.00 and relate these to hydronium and hydroxide molarity concentrations.	
Recall acid nomenclature.		
Identify the conjugate acid-base pairs and predict products of acid-base reactions in water and		
Write the the auto ionization of water reaction where water acts as both an acid and base.		
Memorize the equilibrium expression of water and the value, K_w=1.0x10-14 and its significance		

Appendix B

SLO Exam Data Analytics of 4 Exams

Included in the following pages are the SLO data analytics of 4 exams (3 midterm exams and a final exam) of Fall 2019 Chem 40 and for graded groups of students. These printouts are hard to read due to the large selected print area but show the overall results for each graded group of students. Any SLO at a percentile value equal or below 70% is highlighted in a colored fill with red fonts.

Student Learning Outcomes Exam Data Analytics

Flag SLO at: 70%

Global SLO#	22 Assessed Student Learning Outcomes (Exam 1) Unique (lumped) Set	Max Pts Lumped	Student Web ID---> Class Avg	Std Dev	22	19	51	33	32	58	3	48	30	71	11	50	16	67	73	7	63	34	45	29	74	31	21	62	56
	Lumped Overall Student Avg --->				68%	48%	25%	58%	72%	65%	47%	78%	69%	73%	63%	44%	42%	64%	36%	72%	78%	77%	50%	39%	38%	93%	78%	42%	50%
52	Energy: Define energy and identify types	2	84%	35%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	50%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%	50%	0%
4	Sig Fig: Round any number to a given count of sig fig (significant figures	3	48%	37%	67%	33%	0%	0%	67%	100%	67%	100%	33%	100%	100%	0%	33%	67%	0%	67%	33%	67%	67%	0%	0%	100%	67%	0%	33%
1	Dim Analysis: Translate and identify conversion factors	1	52%	51%	100%	0%	0%	100%	100%	0%	0%	100%	100%	100%	100%	0%	0%	100%	100%	100%	100%	0%	0%	0%	0%	100%	0%	0%	100%
33	Matter: Classify based on visual unifromity (Heterogeneous vs. Homogeneous) & purity	4	53%	25%	75%	25%	50%	25%	75%	75%	25%	75%	25%	100%	25%	25%	50%	50%	50%	75%	25%	75%	75%	50%	25%	100%	50%	25%	75%
22	Temperature: Use formula to convert between units	2	74%	36%	100%	100%	50%	0%	100%	100%	50%	100%	50%	100%	100%	50%	50%	100%	50%	100%	100%	100%	100%	50%	0%	100%	100%	0%	100%
7	Math: Use your calculator keystrokes correctly including orders of math operations	1	52%	51%	0%	0%	0%	100%	100%	0%	0%	100%	0%	100%	0%	100%	0%	0%	0%	100%	100%	100%	0%	100%	0%	100%	100%	100%	100%
34	Elements: Recognize symbol of elements (Sy or S) and locate them in the Periodic Table	1	96%	20%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
13	Solve: using 1-2 step dim analysis to solve problems	2	66%	31%	50%	50%	0%	50%	100%	50%	50%	100%	100%	100%	100%	100%	50%	50%	0%	50%	50%	100%	50%	50%	50%	100%	100%	100%	50%
8	Math: Convert a number to scientific exponent	2	88%	22%	100%	100%	50%	100%	100%	100%	100%	100%	100%	100%	50%	50%	100%	100%	50%	100%	100%	100%	100%	50%	50%	100%	100%	100%	100%
61	Energy: Solve q=m.c.ΔT equation for an unknown variable	1	48%	51%	100%	100%	0%	0%	100%	100%	0%	100%	0%	100%	100%	0%	0%	0%	0%	0%	100%	100%	100%	0%	0%	100%	100%	0%	0%
31	Matter: Distinguish between an element and a compound	2	72%	33%	50%	100%	50%	100%	100%	100%	100%	100%	100%	50%	0%	100%	0%	50%	50%	100%	100%	50%	100%	50%	50%	100%	50%	50%	100%
6	Sig Fig: Report a math calculation to proper sig fig (add, subtract)	1	28%	46%	0%	0%	0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	100%	0%	100%	0%	100%	0%	0%	0%	100%	100%	0%	0%	0%
12	Units: Recall proper unit abbreviations (for common units)	1	56%	51%	100%	100%	0%	100%	0%	100%	100%	100%	100%	100%	0%	100%	0%	100%	0%	0%	0%	100%	0%	0%	100%	100%	100%	0%	0%
59	Energy: Describe and identify the law of conservation of energy in a chemical chang	1	56%	51%	100%	0%	0%	0%	100%	100%	0%	100%	0%	0%	100%	0%	0%	100%	0%	100%	100%	100%	0%	0%	100%	100%	100%	100%	100%
56	Matter: Distinguish between a physical and chemical change/property	1	32%	48%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	100%	0%	0%	100%	100%	100%	0%	0%	100%	100%	0%	0%
49	Bonding: Define an ion, cation and anion versus a neutral atom	2	36%	45%	100%	0%	0%	0%	0%	50%	0%	0%	100%	100%	0%	50%	50%	0%	100%	0%	100%	0%	100%	0%	0%	0%	100%	50%	0%
28	Solve: using multi-step dim analysis method	1	48%	51%	100%	0%	0%	100%	100%	0%	0%	0%	100%	100%	100%	0%	0%	100%	0%	100%	0%	100%	0%	0%	0%	100%	100%	0%	100%
5	Sig Fig: Report a math calculation to proper sig fig (multiply, divide)	1	44%	51%	100%	100%	0%	100%	0%	0%	0%	100%	0%	0%	100%	0%	100%	0%	0%	100%	100%	0%	0%	100%	0%	100%	100%	0%	0%
24	Density: Use formula to calculate a variable	2	78%	36%	100%	100%	100%	50%	50%	100%	100%	100%	100%	100%	100%	50%	100%	0%	50%	100%	100%	100%	0%	100%	50%	100%	100%	0%	100%
42	Bonding: Predict attraction or repulsion between charges	1	72%	46%	0%	0%	100%	100%	100%	100%	0%	100%	100%	0%	100%	100%	0%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%
45	Elements: Memorize chemical names and symbols of selected elements (handout)	2	58%	31%	50%	50%	50%	50%	100%	50%	50%	50%	100%	50%	50%	50%	100%	100%	50%	100%	100%	100%	0%	0%	0%	50%	50%	50%	50%
55	Matter: Describe and identify the law of conservation of mass in a chemical change	1	52%	51%	0%	0%	0%	100%	100%	100%	100%	100%	100%	0%	100%	0%	0%	100%	100%	100%	0%	100%	0%	0%	0%	100%	0%	100%	0%

Student Learning Outcomes Exam Data Analytics

Flag SLO at: 70%

Global SLO#	18 Assessed Student Learning Outcomes (Exam 2) Unique (lumped) Set	Max Pts Lumped	Class Avg	Std Dev	31	63	40	67	71	45	3	30	48	58	56	33	6	34	27	69	62	7	73	29	68
	Lumped Overall Student Avg --->				90%	91%	56%	88%	73%	91%	91%	80%	77%	56%	40%	44%	94%	70%	46%	71%	31%	67%	53%	44%	65%
84	Name simple binary covalent (molecular) compounds	2	69%	33%	100%	100%	0%	100%	100%	50%	100%	100%	50%	50%	50%	100%	100%	100%	50%	50%	0%	100%	50%	50%	50%
111	Distinguish lone pairs and shared (bonded) pairs of electrons in a Lewis structure of a	1	86%	36%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%	0%	100%	100%	100%	100%	100%	0%
114	Recall the 3 EG structures based on the number of electron groups and memorize the	1	67%	48%	100%	100%	100%	0%	100%	100%	100%	100%	100%	0%	0%	0%	100%	0%	0%	100%	0%	100%	100%	100%	100%
108	Define ionization energy and relate to its relationship to atomic size	1	67%	48%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	0%	0%	100%	0%	0%	100%	0%	100%	100%	0%	100%
93	Recall max number of electrons that fill each s,p,d,f sublevel)	2	74%	34%	100%	50%	100%	100%	100%	100%	100%	50%	50%	100%	0%	0%	100%	100%	50%	100%	50%	50%	50%	100%	100%
116	Draw the 3-D Lewis structure based on EG classification and determine bond angles	2	62%	27%	100%	100%	50%	50%	50%	100%	100%	100%	50%	50%	50%	50%	100%	50%	50%	50%	50%	50%	50%	0%	50%
83	Name a polyatomic ionic compound given its formula and vice versa and recognize correct formulas.	2	55%	31%	100%	50%	50%	100%	50%	100%	100%	100%	50%	50%	50%	0%	50%	50%	50%	50%	50%	50%	50%	0%	0%
75	Review general bonding rend for metals and nonmetals based on attitude toward	3	67%	38%	100%	100%	100%	100%	67%	100%	100%	0%	100%	33%	33%	0%	100%	100%	33%	67%	67%	100%	0%	33%	67%
117	Determine the molecular shape (MS) or molecular geometry classification	1	76%	44%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	0%	0%	100%	0%	100%
118	Determine bond polarity based on electronegativity trend. Place dipole symbol on a bond	2	64%	36%	50%	100%	100%	100%	50%	50%	0%	50%	50%	50%	0%	100%	100%	100%	100%	0%	50%	50%	50%	100%	100%
74	Recall names of important element groups (alkali metals, alkaline earth metals, halogens, noble gases)	1	71%	46%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	0%	100%	100%	100%	100%	0%	100%	0%	0%	100%
99	Write the ground state electron configuration for each element using a periodic table only	1	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
88	Define wave properties (wavelength, frequency, energy) and predict the proportionality between these quantities.	1	62%	50%	100%	100%	0%	100%	100%	100%	100%	100%	0%	100%	100%	0%	100%	100%	0%	100%	0%	0%	0%	0%	100%
112	Pick the best atom to be the central atom while doing Lewis structure of simple	1	67%	48%	100%	100%	0%	100%	100%	100%	100%	100%	100%	0%	100%	0%	100%	0%	0%	100%	0%	100%	100%	0%	100%
68	Relate the nuclear symbol (given symbol and mass number) to the number of each atomic particle	3	27%	25%	67%	33%	0%	33%	0%	33%	33%	33%	33%	67%	33%	33%	33%	67%	0%	67%	0%	0%	0%	0%	0%
107	Recall atomic size trend going across a period and down a group	1	76%	44%	0%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	0%	100%	100%	100%	0%	100%	100%	100%	100%	0%
86	Name acids based on polyatomic ions	1	43%	51%	100%	100%	0%	100%	0%	100%	100%	0%	100%	0%	0%	100%	100%	0%	0%	100%	0%	0%	0%	0%	0%
81	Recall the ion charge of representative groups (A groups) based on the location of the elements	1	81%	40%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%	100%	0%	100%	100%

Student Learning Outcomes Exam Data Analytics

Flag SLO at: 70%

Global SLO#	20 Assessed Student Learning Outcomes (Exam 3) Unique (lumped) Set	Max Pts Lumped	Class Avg	Std Dev
	Lumped Overall Student Avg --->			
122	Perform mole-count formula calculations	3	83%	22%
130	Perform mole-mass-count claculations on a formula component (element, simple	3	66%	29%
132	Balance a chemical reaction (using lowest whole number coefficients) which	1	91%	30%
126	Distinguish between molecular and empirical formulas	2	55%	32%
146	Memorize solubility rules of common ionic compounds in water	1	78%	42%
121	Perform mass-mole formula claculations	1	100%	0%
144	Classify a reaction based on energy into endothermic and exothermic reaction	1	66%	48%
153	Relate to coefficients of a chemical equation as mole or count of element or	2	58%	29%
170	Describe Avogadro's law as proportionality as well as combining gas volumes in a chemical equation	1	47%	51%
128	Determine molecular formula given empirical formula and molar mass	2	58%	40%
137	Predict products of a double replacement reaction and write the total and net ionic equation	2	39%	30%
154	Perform mole-to-mole stoichiometry	1	84%	37%
171	Define the state of STP and memorize the molar volume of any gas at STP (22.41 L/mol)	2	50%	36%
176	Solve gas stoichiometry problems involving STP	1	44%	50%
135	Predict ionic product of a synthesis (combination) reaction	1	31%	47%
136	Predict products of a combustion reaction	2	61%	28%
163	Define pressure as force exerted per unit area	1	59%	50%
167	Use the general combined gas law equation: P1.V1/(n1.T1)=P2.T2/(n2.T2) to solve for an unknown variable and determine variable proportionality as stated in various	1	72%	46%
120	Calculate molar mass given a formula	1	97%	18%
127	Determine empirical formula given percent composition or mass of elements	1	50%	51%

Student Web ID--->	31	7	60	70	23	26	38	71	57	58	69	6	24	14	49	63
Lumped Overall Student Avg	93%	77%	88%	51%	53%	73%	47%	64%	63%	63%	45%	88%	72%	85%	53%	88%
122	100%	100%	100%	67%	67%	100%	100%	100%	67%	100%	67%	100%	100%	100%	33%	100%
130	100%	33%	100%	100%	33%	67%	33%	33%	100%	67%	33%	67%	33%	100%	33%	100%
132	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%
126	100%	50%	100%	50%	50%	100%	50%	50%	0%	100%	50%	50%	100%	100%	50%	50%
146	100%	100%	100%	100%	100%	0%	0%	0%	100%	100%	100%	100%	0%	100%	100%	100%
121	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
144	100%	100%	100%	100%	100%	100%	0%	0%	0%	100%	100%	100%	100%	100%	0%	0%
153	50%	50%	50%	50%	50%	100%	0%	50%	100%	50%	50%	50%	100%	100%	50%	100%
170	0%	0%	100%	0%	0%	100%	100%	100%	0%	100%	0%	100%	100%	0%	0%	100%
128	100%	100%	50%	0%	100%	100%	100%	0%	50%	50%	50%	100%	100%	100%	100%	100%
137	100%	50%	100%	0%	50%	50%	0%	50%	50%	0%	0%	50%	50%	50%	0%	100%
154	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%
171	100%	100%	50%	50%	50%	0%	100%	50%	0%	0%	0%	50%	100%	50%	50%	100%
176	100%	100%	100%	0%	0%	100%	0%	100%	0%	0%	0%	100%	100%	100%	0%	100%
135	100%	100%	100%	0%	0%	0%	100%	100%	0%	0%	0%	100%	0%	0%	0%	100%
136	100%	50%	100%	0%	50%	50%	50%	50%	100%	100%	50%	100%	50%	100%	50%	100%
163	100%	100%	100%	0%	0%	0%	0%	100%	100%	0%	0%	100%	0%	100%	100%	100%
167	100%	100%	100%	100%	0%	100%	0%	100%	100%	100%	100%	100%	0%	100%	100%	100%
120	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%
127	100%	0%	0%	0%	100%	100%	0%	0%	100%	0%	0%	100%	100%	100%	0%	100%

Student Web ID--->	21	50	2	3	67	34	13	21	23	19	40	48	30	28	65	16	45
Lumped Overall Student Avg	73%	41%	48%	67%	62%	58%	42%	73%	53%	68%	68%	49%	63%	69%	70%	58%	95%
122	100%	67%	67%	100%	67%	33%	67%	100%	67%	100%	100%	100%	33%	67%	100%	100%	100%
130	100%	100%	33%	33%	67%	67%	67%	100%	33%	100%	67%	33%	33%	67%	100%	67%	100%
132	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%
126	50%	0%	100%	50%	50%	0%	50%	50%	50%	50%	0%	50%	50%	0%	100%	50%	100%
146	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	0%	0%	100%	100%	100%	100%	100%
121	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
144	100%	0%	0%	0%	100%	100%	0%	100%	100%	0%	100%	100%	100%	100%	100%	0%	100%
153	50%	50%	50%	50%	50%	100%	50%	50%	50%	50%	0%	100%	50%	50%	100%	0%	100%
170	0%	0%	0%	100%	100%	0%	100%	0%	0%	0%	100%	100%	0%	100%	0%	100%	100%
128	0%	50%	100%	100%	50%	50%	0%	0%	100%	0%	50%	50%	50%	0%	50%	0%	100%
137	50%	0%	0%	50%	50%	50%	50%	50%	50%	0%	50%	0%	50%	50%	0%	50%	100%
154	100%	0%	0%	100%	100%	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
171	50%	0%	50%	100%	0%	100%	0%	50%	50%	50%	50%	0%	50%	100%	50%	50%	100%
176	100%	0%	0%	0%	0%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	100%	100%
135	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	100%	0%	0%	100%	100%
136	50%	50%	50%	50%	100%	50%	50%	50%	50%	100%	50%	50%	50%	50%	0%	50%	100%
163	100%	0%	100%	100%	0%	100%	0%	100%	0%	100%	100%	0%	100%	100%	100%	0%	100%
167	100%	100%	100%	0%	0%	100%	0%	100%	0%	100%	100%	0%	100%	100%	100%	0%	100%
120	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
127	100%	0%	0%	100%	100%	0%	0%	100%	100%	100%	100%	0%	0%	0%	100%	0%	0%

Student Learning Outcomes Exam Data Analytics

Flag SLO at: 70%

Global SLO#	34 Assessed Student Learning Outcomes (Final Exam) Unique (lumped) Set	Max Pts Lumped	Student Web ID---> Class Avg	Std Dev	7	60	31	65	49	21	30	50	24	48	14	57	23	6	2	26
	Lumped Overall Student Avg --->				59%	72%	85%	70%	63%	50%	39%	33%	60%	43%	73%	49%	52%	73%	31%	55%
156	Perform mass-to-mass stoichiometry	1	67%	48%	0%	100%	100%	100%	100%	100%	0%	0%	100%	0%	100%	100%	100%	100%	0%	0%
62	Energy: Identify exothermic and edothermic processes	1	77%	43%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%
117	Determine the molecular shape (MS) or molecular geometry classification	2	38%	31%	0%	50%	50%	50%	50%	0%	0%	50%	0%	50%	50%	0%	50%	50%	50%	50%
97	Relate to the quantum view that electron(s) occupy a volume outside the nucleous standing waves of certain shape and energy	1	83%	38%	100%	100%	0%	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%
123	Calculate percent composition (by mass) of elements, given a formula	1	87%	35%	100%	100%	100%	100%	100%	0%	100%	0%	100%	100%	100%	100%	0%	100%	100%	100%
61	Energy: Solve q=m.c.ΔT equation for an unknown variable	1	53%	51%	100%	100%	100%	100%	100%	0%	0%	0%	100%	0%	100%	0%	100%	100%	0%	0%
173	Describe Dalton's law of partial pressures and solve for an unknown gas pressure	1	67%	48%	100%	100%	100%	100%	100%	100%	0%	0%	100%	0%	100%	0%	0%	100%	0%	100%
195	Write ionization reaction of any weak or strong acid in water.	1	30%	47%	0%	0%	0%	0%	100%	0%	0%	100%	100%	0%	0%	100%	0%	0%	0%	0%
83	Name a polyatomic ionic compound given its formula and vice versa and recognize correct formulas.	2	70%	36%	100%	50%	100%	100%	0%	50%	50%	100%	50%	100%	100%	100%	50%	100%	50%	100%
167	Use the general combined gas law equation: P1.V1/(n1.T1)=P2.T2/(n2.T2) to solve for an unknown variable and determine variable proportionality as stated in various gas laws.	2	58%	32%	50%	50%	100%	50%	100%	100%	50%	50%	0%	50%	100%	50%	50%	100%	50%	100%
199	Identify the conjugate acid-base pairs and predict products of acid-base reactions in water and	5	59%	25%	80%	80%	80%	80%	60%	80%	20%	60%	40%	80%	80%	60%	40%	80%	0%	60%
114	Recall the 3 EG structures based on the number of electron groups and memorize the angles between the electron groups	1	80%	41%	100%	0%	100%	100%	100%	0%	0%	100%	100%	0%	100%	100%	100%	100%	100%	100%
186	Define the dilution process and solve dilution problems using the C1.V1 = C2.V2 equation	3	50%	31%	67%	67%	100%	33%	33%	0%	67%	33%	67%	33%	33%	67%	100%	33%	0%	0%
194	Define acids and bases based on Arrhenius and Bronsted-Lowry definitions	1	30%	47%	0%	100%	100%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
170	Describe Avogadro's law as proportionality as well as combining gas volumes in a chemical equation	2	20%	28%	100%	50%	50%	50%	50%	0%	0%	0%	0%	0%	50%	0%	0%	0%	50%	50%
137	Predict products of a double replacement reaction and write the total and net ionic equation	2	62%	36%	50%	50%	100%	50%	50%	50%	100%	0%	100%	50%	100%	50%	100%	100%	50%	50%
201	Memorize the equilibrium expression of water and the value, Kw=1.0x10-14 and its significance	1	43%	50%	100%	0%	0%	100%	100%	0%	0%	0%	100%	0%	100%	0%	0%	100%	100%	100%
119	Determine the molecular polarity based on summing charge points (report polar or non-polar)	2	32%	40%	100%	100%	100%	50%	50%	0%	0%	50%	0%	0%	100%	0%	0%	50%	0%	0%
200	Write the the auto ionization of water reaction where water acts as both an acid and base.	1	87%	35%	100%	100%	100%	100%	100%	100%	100%	0%	0%	100%	100%	100%	100%	100%	0%	100%
202	Given hydronium or hydroxide concentrations (as M, pH, or pOH), calculate the other concentration (as M, pH or pOH) and classify solution as acidic, basic or neutral.	3	34%	28%	0%	67%	100%	67%	0%	67%	33%	33%	0%	0%	33%	33%	33%	67%	67%	67%
187	Given molarity and volume of a solution, find mole or mass of molecular or ionic solutes	1	77%	43%	100%	100%	100%	100%	100%	0%	100%	0%	100%	100%	100%	100%	100%	0%	0%	0%
209	Calculate pH of a strong acid or strong base compound in water given its quanity and solution volume	2	23%	31%	0%	0%	100%	0%	50%	50%	0%	50%	0%	0%	50%	0%	0%	100%	50%	0%
1	Dim Analysis: Translate and identify conversion factors	1	83%	38%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%
18	Solve: percent by mass problems	1	70%	47%	100%	100%	100%	100%	100%	100%	0%	0%	100%	100%	100%	0%	0%	100%	0%	100%
76	Determine cation and anion charge of an element upon gaining or losing electrons	1	50%	51%	0%	100%	0%	100%	100%	100%	0%	0%	100%	0%	100%	0%	100%	100%	0%	0%
132	Balance a chemical reaction (using lowest whole number coefficients) which transforms it into a chemical equation	2	75%	34%	50%	100%	100%	50%	100%	100%	100%	0%	100%	0%	100%	100%	50%	100%	0%	100%
113	Draw Lewis structrure for a simple neutral molecule or a polyatomic ion given its formula	1	13%	35%	0%	100%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
82	Memorize a list of polyatomic ions and their corresponding acid names and formulas	1	73%	45%	0%	100%	100%	100%	100%	100%	100%	0%	0%	0%	0%	0%	100%	100%	100%	100%
95	Recall the order in energy of sublevels (s,p,d,f) within a principal energy level	1	97%	18%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
79	Name simple binary ionic compounds given a formula or vice versa and apply Roman numerals to denote the state of charge of transition metals	1	37%	49%	0%	100%	100%	0%	0%	0%	0%	0%	100%	100%	100%	100%	0%	100%	0%	0%
179	Define the terms solution, solvent and solute	1	63%	49%	100%	100%	100%	100%	0%	0%	0%	100%	100%	100%	100%	0%	100%	100%	0%	100%
183	Recall concentration definitions and their formulas; percent by mass (m/m), percent by volume (v/v) and molarity	1	33%	48%	0%	0%	100%	100%	0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%
192	Given molarity of an ionic compound in water, find molarity of each ion	1	40%	50%	100%	0%	100%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%	100%	0%
146	Memorize solubility rules of common ionic compounds in water	1	53%	51%	0%	100%	100%	0%	100%	0%	100%	0%	100%	100%	0%	100%	100%	0%	0%	0%

Global SLO#	45	13	71	34	58	38	67	3	70	19	63	16	28	69
Lumped Overall Student Avg --->	71%	46%	59%	55%	72%	61%	52%	40%	61%	47%	63%	37%	57%	60%
156	100%	100%	0%	100%	100%	100%	0%	0%	100%	100%	100%	0%	100%	100%
62	100%	0%	0%	100%	100%	0%	0%	100%	100%	100%	0%	100%	100%	100%
117	100%	50%	50%	0%	0%	50%	100%	0%	0%	100%	50%	0%	50%	50%
97	100%	0%	100%	100%	100%	100%	100%	0%	100%	0%	100%	100%	100%	100%
123	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
61	0%	100%	0%	0%	0%	100%	0%	0%	0%	100%	100%	100%	100%	100%
173	100%	0%	100%	100%	100%	0%	100%	0%	100%	100%	100%	100%	100%	0%
195	100%	100%	0%	0%	100%	0%	0%	0%	100%	0%	100%	0%	0%	0%
83	100%	100%	50%	100%	0%	100%	50%	100%	50%	50%	100%	0%	100%	0%
167	50%	0%	50%	100%	50%	50%	0%	50%	100%	50%	50%	0%	100%	50%
199	20%	80%	80%	20%	80%	20%	60%	80%	80%	40%	80%	40%	60%	40%
114	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%	0%	100%	100%
186	100%	33%	67%	33%	67%	100%	33%	33%	67%	100%	67%	0%	33%	33%
194	0%	100%	0%	0%	100%	100%	0%	0%	100%	0%	100%	0%	0%	100%
170	0%	50%	0%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	50%
137	50%	0%	50%	100%	100%	0%	100%	50%	100%	0%	100%	50%	0%	100%
201	100%	100%	0%	0%	100%	0%	100%	100%	0%	0%	0%	0%	0%	0%
119	100%	0%	0%	0%	0%	50%	50%	0%	0%	0%	100%	50%	0%	0%
200	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%
202	0%	0%	67%	67%	0%	0%	33%	33%	33%	0%	33%	33%	33%	33%
187	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	0%	100%	100%
209	0%	50%	0%	0%	0%	0%	50%	50%	0%	0%	50%	50%	0%	0%
1	100%	0%	100%	100%	100%	100%	100%	0%	100%	0%	0%	100%	100%	100%
18	100%	0%	100%	100%	100%	100%	100%	0%	0%	100%	100%	100%	0%	100%
76	100%	0%	100%	100%	100%	0%	0%	0%	0%	0%	100%	100%	100%	0%
132	100%	100%	100%	50%	100%	100%	100%	50%	50%	50%	100%	50%	50%	100%
113	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
82	100%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
95	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%	100%
79	0%	0%	100%	0%	100%	0%	0%	0%	100%	0%	100%	0%	0%	0%
179	100%	0%	100%	0%	100%	100%	100%	0%	0%	100%	0%	0%	100%	100%
183	0%	0%	100%	0%	100%	100%	100%	0%	0%	100%	0%	0%	100%	0%
192	100%	0%	0%	100%	0%	100%	0%	100%	100%	0%	0%	0%	0%	100%
146	0%	100%	100%	0%	100%	100%	0%	100%	100%	0%	0%	100%	0%	100%

Appendix C

Assessed SLOs for Exams 2, 3 and Final

Included here are the assessed SLOs of exams 2 and 3 and final exam. Each SLO is automatically selected by entering its global SLO# in the far left column.

Global SLO#	Question	Pts	Exam 2 Topic# Title (textbook chapter)	Student Learning Outcome (SLO)
84	1	1	5 Nomenclature (ch6)	Name simple binary covalent (molecular) compounds
111	2	1	7 Chemical Bonding (ch11)	Distinguish lone pairs and shared (bonded) pairs of electrons in a Lewis
114	3	1	7 Chemical Bonding (ch11)	Recall the 3 EG structures based on the number of electron groups and
108	4	1	7 Chemical Bonding (ch11)	Define ionization energy and relate to its relationship to atomic size
93	5	1	6 Modern Atom (ch10)	Recall max number of electrons that fill each s,p,d,f sublevel)
116	6	1	7 Chemical Bonding (ch11)	Draw the 3-D Lewis structure based on EG classification and determine bond
83	7	1	5 Nomenclature (ch6)	Name a polyatomic ionic compound given its formula and vice versa and recognize correct formulas.
84	8	1	5 Nomenclature (ch6)	Name simple binary covalent (molecular) compounds
83	9	1	5 Nomenclature (ch6)	Name a polyatomic ionic compound given its formula and vice versa and
75	10	1	5 Nomenclature (ch6)	Review general bonding rend for metals and nonmetals based on attitude
117	11	1	7 Chemical Bonding (ch11)	Determine the molecular shape (MS) or molecular geometry classification
118	12	1	7 Chemical Bonding (ch11)	Determine bond polarity based on electronegativity trend. Place dipole
74	13	1	5 Nomenclature (ch6)	Recall names of important element groups (alkali metals, alkaline earth
93	14	1	6 Modern Atom (ch10)	Recall max number of electrons that fill each s,p,d,f sublevel)
75	15	1	5 Nomenclature (ch6)	Review general bonding rend for metals and nonmetals based on attitude
99	16	1	6 Modern Atom (ch10)	Write the ground state electron configuration for each element using a
118	17	1	7 Chemical Bonding (ch11)	Determine bond polarity based on electronegativity trend. Place dipole
88	18	1	6 Modern Atom (ch10)	Define wave properties (wavelength, frequency, energy) and predict the proportionality between these quantities.
112	19	1	7 Chemical Bonding (ch11)	Pick the best atom to be the central atom while doing Lewis structure of
68	20	1	4 Atomic Theroy (ch5)	Relate the nuclear symbol (given symbol and mass number) to the number of
68	21	1	4 Atomic Theroy (ch5)	Relate the nuclear symbol (given symbol and mass number) to the number of
116	22	1	7 Chemical Bonding (ch11)	Draw the 3-D Lewis structure based on EG classification and determine bond
68	23	1	4 Atomic Theroy (ch5)	Relate the nuclear symbol (given symbol and mass number) to the number of
107	24	1	7 Chemical Bonding (ch11)	Recall atomic size trend going across a period and down a group
86	25	1	5 Nomenclature (ch6)	Name acids based on polyatomic ions
75	26	1	5 Nomenclature (ch6)	Review general bonding rend for metals and nonmetals based on attitude toward electrons
81	27	1	5 Nomenclature (ch6)	Recall the ion charge of representative groups (A groups) based on the location of the elements

Global SLO#	Question	Pts	Exam 3 Topic# Title (textbook chapter)	Student Learning Outcome (SLO)
122	1	1	8 Formula Calculations (ch7)	Perform mole-count formula calculations
122	2	1	8 Formula Calculations (ch7)	Perform mole-count formula calculations
130	3	1	8 Formula Calculations (ch7)	Perform mole-mass-count claculations on a formula component (element, simple ion, polyatomic ion)
132	4	1	9 Chemical Reactions (ch8)	Balance a chemical reaction (using lowest whole number coefficients) which transforms it into a chemical equation
126	5	1	8 Formula Calculations (ch7)	Distinguish between molecular and empirical formulas
146	6	1	9 Chemical Reactions (ch8)	Memorize solubility rules of common ionic compounds in water
121	7	1	8 Formula Calculations (ch7)	Perform mass-mole formula claculations
144	8	1	9 Chemical Reactions (ch8)	Classify a reaction based on energy into endothermic and exothermic reaction
130	9	1	8 Formula Calculations (ch7)	Perform mole-mass-count claculations on a formula component (element, simple ion, polyatomic ion)
126	10	1	8 Formula Calculations (ch7)	Distinguish between molecular and empirical formulas
153	11	1	10 Stoichiometry (ch9)	Relate to coefficients of a chemical equation as mole or count of element or compound involved
170	12	1	11 Gases (ch12)	Describe Avogadro's law as proportionality as well as combining gas volumes in a chemical equation
130	13	1	8 Formula Calculations (ch7)	Perform mole-mass-count claculations on a formula component (element, simple ion, polyatomic ion)
128	14	1	8 Formula Calculations (ch7)	Determine molecular formula given empirical formula and molar mass
137	15	1	9 Chemical Reactions (ch8)	Predict products of a double replacement reaction and write the total and net ionic equation
137	16	1	9 Chemical Reactions (ch8)	Predict products of a double replacement reaction and write the total and net ionic equation
154	17	1	10 Stoichiometry (ch9)	Perform mole-to-mole stoichiometry
171	18	1	11 Gases (ch12)	Define the state of STP and memorize the molar volume of any gas at STP (22.41 L/mol)
171	19	1	11 Gases (ch12)	Define the state of STP and memorize the molar volume of any gas at STP (22.41 L/mol)
176	20	1	11 Gases (ch12)	Solve gas stoichiometry problems involving STP
135	21	1	9 Chemical Reactions (ch8)	Predict ionic product of a synthesis (combination) reaction
136	22	1	9 Chemical Reactions (ch8)	Predict products of a combustion reaction
163	23	1	11 Gases (ch12)	Define pressure as force exerted per unit area
167	24	1	11 Gases (ch12)	Use the general combined gas law equation: P1.V1/(n1.T1)=P2.T2/(n2.T2) to solve for an unknown variable and determine variable proportionality as stated in various gas laws.
153	25	1	10 Stoichiometry (ch9)	Relate to coefficients of a chemical equation as mole or count of element or compound involved
136	26	1	9 Chemical Reactions (ch8)	Predict products of a combustion reaction
120	27	1	8 Formula Calculations (ch7)	Calculate molar mass given a formula
122	28	1	8 Formula Calculations (ch7)	Perform mole-count formula calculations
127	29	1	8 Formula Calculations (ch7)	Determine empirical formula given percent composition or mass of elements
128	30	1	8 Formula Calculations (ch7)	Determine molecular formula given empirical formula and molar mass

Global SLO#	Question	Pts	Final Exam Topic# Title (textbook chapter)	Student Learning Outcome (SLO)
156	1	1	10 Stoichiometry (ch9)	Perform mass-to-mass stoichiometry
62	2	1	3 Matter & Energy (ch4)	Energy: Identify exothermic and edothermic processes
117	3	1	7 Chemical Bonding (ch11)	Determine the molecular shape (MS) or molecular geometry classification
97	4	1	6 Modern Atom (ch10)	Relate to the quantum view that electron(s) occupy a volume outside the nucleous standing waves of certain shape and energy
123	5	1	8 Formula Calculations (ch7)	Calculate percent composition (by mass) of elements, given a formula
61	6	1	3 Matter & Energy (ch4)	Energy: Solve q=m.c.ΔT equation for an unknown variable
173	7	1	11 Gases (ch12)	Describe Dalton's law of partial pressures and solve for an unknown gas pressure
195	8	1	13 Acids & Bases (ch15)	Write ionization reaction of any weak or strong acid in water.
83	9	1	5 Nomenclature (ch6)	Name a polyatomic ionic compound given its formula and vice versa and recognize correct formulas.
167	10	1	11 Gases (ch12)	Use the general combined gas law equation: P1.V1/(n1.T1)=P2.T2/(n2.T2) to solve for an unknown variable and determine variable proportionality as stated in various gas laws.
199	11	1	13 Acids & Bases (ch15)	Identify the conjugate acid-base pairs and predict products of acid-base reactions in water and
114	12	1	7 Chemical Bonding (ch11)	Recall the 3 EG structures based on the number of electron groups and memorize the angles between the electron groups
186	13	1	12 Solutions (ch14)	Define the dilution process and solve dilution problems using the C1.V1 = C2.V2 equation
83	14	1	5 Nomenclature (ch6)	Name a polyatomic ionic compound given its formula and vice versa and recognize correct formulas.
194	15	1	13 Acids & Bases (ch15)	Define acids and bases based on Arrhenius and Bronsted-Lowry definitions
170	16	1	11 Gases (ch12)	Describe Avogadro's law as proportionality as well as combining gas volumes in a chemical equation
137	17	1	9 Chemical Reactions (ch8)	Predict products of a double replacement reaction and write the total and net ionic equation
201	18	1	13 Acids & Bases (ch15)	Memorize the equilibrium expression of water and the value, Kw=1.0x10-14 and its significance
119	19	1	7 Chemical Bonding (ch11)	Determine the molecular polarity based on summing charge points (report polar or non-polar)
200	20	1	13 Acids & Bases (ch15)	Write the the auto ionization of water reaction where water acts as both an acid and base.
202	21	1	13 Acids & Bases (ch15)	Given hydronium or hydroxide concentrations (as M, pH, or pOH), calculate the other concentration (as M, pH or pOH) and classify solution as acidic, basic or neutral.
187	22	1	12 Solutions (ch14)	Given molarity and volume of a solution, find mole or mass of molecular or ionic solutes
117	23	1	7 Chemical Bonding (ch11)	Determine the molecular shape (MS) or molecular geometry classification
209	24	1	13 Acids & Bases (ch15)	Calculate pH of a strong acid or strong base compound in water given its quanity and solution volume
1	25	1	1 Math & Measurements (ch2)	Dim Analysis: Translate and identify conversion factors
186	26	1	12 Solutions (ch14)	Define the dilution process and solve dilution problems using the C1.V1 = C2.V2 equation
18	27	1	1 Math & Measurements (ch2)	Solve: percent by mass problems
167	28	1	11 Gases (ch12)	Use the general combined gas law equation: P1.V1/(n1.T1)=P2.T2/(n2.T2) to solve for an unknown variable and determine variable proportionality as stated in various gas laws.
76	29	1	5 Nomenclature (ch6)	Determine cation and anion charge of an element upon gaining or losing electrons
132	30	1	9 Chemical Reactions (ch8)	Balance a chemical reaction (using lowest whole number coefficients) which transforms it into a chemical equation

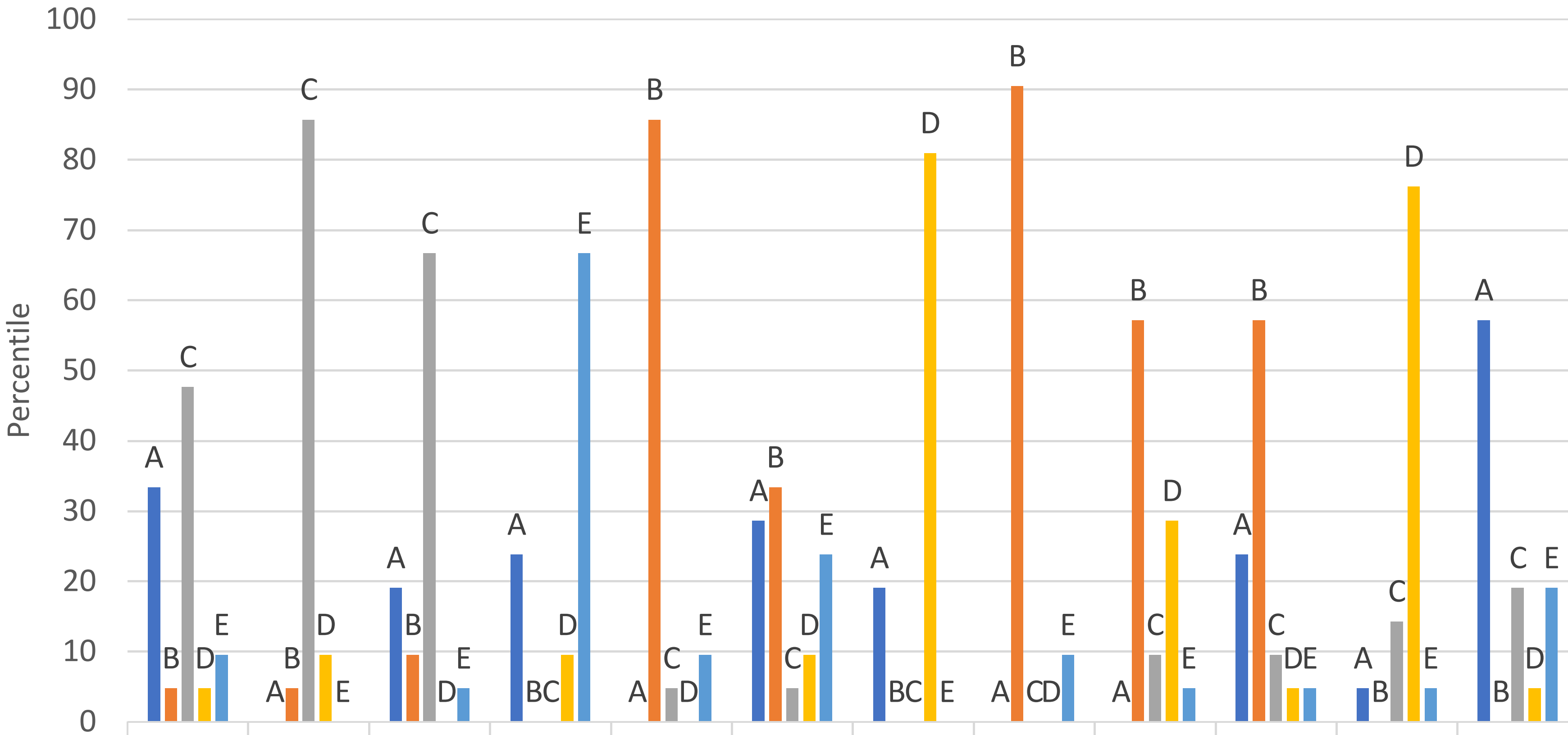
Global SLO#	Question	Pts	Final Exam Topic# Title (textbook chapter)	Student Learning Outcome (SLO)
113	31	1	7 Chemical Bonding (ch11)	Draw Lewis structrure for a simple neutral molecule or a polyatomic ion given its formula
82	32	1	5 Nomenclature (ch6)	Memorize a list of polyatomic ions and their corresponding acid names and formulas
199	33	1	13 Acids & Bases (ch15)	Identify the conjugate acid-base pairs and predict products of acid-base reactions in water and
202	34	1	13 Acids & Bases (ch15)	Given hydronium or hydroxide concentrations (as M, pH, or pOH), calculate the other concentration (as M, pH or pOH) and classify solution as acidic, basic or neutral.
199	35	1	13 Acids & Bases (ch15)	Identify the conjugate acid-base pairs and predict products of acid-base reactions in water and
209	36		13 Acids & Bases (ch15)	Calculate pH of a strong acid or strong base compound in water given its quanity and solution volume
95	37		6 Modern Atom (ch10)	Recall the order in energy of sublevels (s,p,d,f) within a principal energy level
132	38		9 Chemical Reactions (ch8)	Balance a chemical reaction (using lowest whole number coefficients) which transforms it into a chemical equation
137	39		9 Chemical Reactions (ch8)	Predict products of a double replacement reaction and write the total and net ionic equation
119	40		7 Chemical Bonding (ch11)	Determine the molecular polarity based on summing charge points (report polar or non-polar)
79	41		5 Nomenclature (ch6)	Name simple binary ionic compounds given a formula or vice versa and apply Roman numerals to denote the state of charge of transition metals
202	42		13 Acids & Bases (ch15)	Given hydronium or hydroxide concentrations (as M, pH, or pOH), calculate the other concentration (as M, pH or pOH) and classify solution as acidic, basic or neutral.
199	43		13 Acids & Bases (ch15)	Identify the conjugate acid-base pairs and predict products of acid-base reactions in water and
170	44		11 Gases (ch12)	Describe Avogadro's law as proportionality as well as combining gas volumes in a chemical equation
199	45		13 Acids & Bases (ch15)	Identify the conjugate acid-base pairs and predict products of acid-base reactions in water and
179	46		12 Solutions (ch14)	Define the terms solution, solvent and solute
183	47		12 Solutions (ch14)	Recall concentration definitions and their formulas; percent by mass (m/m), percent by volume (v/v) and molarity
186	48		12 Solutions (ch14)	Define the dilution process and solve dilution problems using the C1.V1 = C2.V2 equation
192	49		12 Solutions (ch14)	Given molarity of an ionic compound in water, find molarity of each ion
146	50		9 Chemical Reactions (ch8)	Memorize solubility rules of common ionic compounds in water

Appendix D

Question-by-Question Data Analytics of Exams 2,3 and the Final Exam

Included in this section is the graphical representation of student response distribution for exams 2, 3 and the final exam. As detailed in the body of the report for exam 1, instructors can examine each question's percentile distribution for each choice and extract useful information.

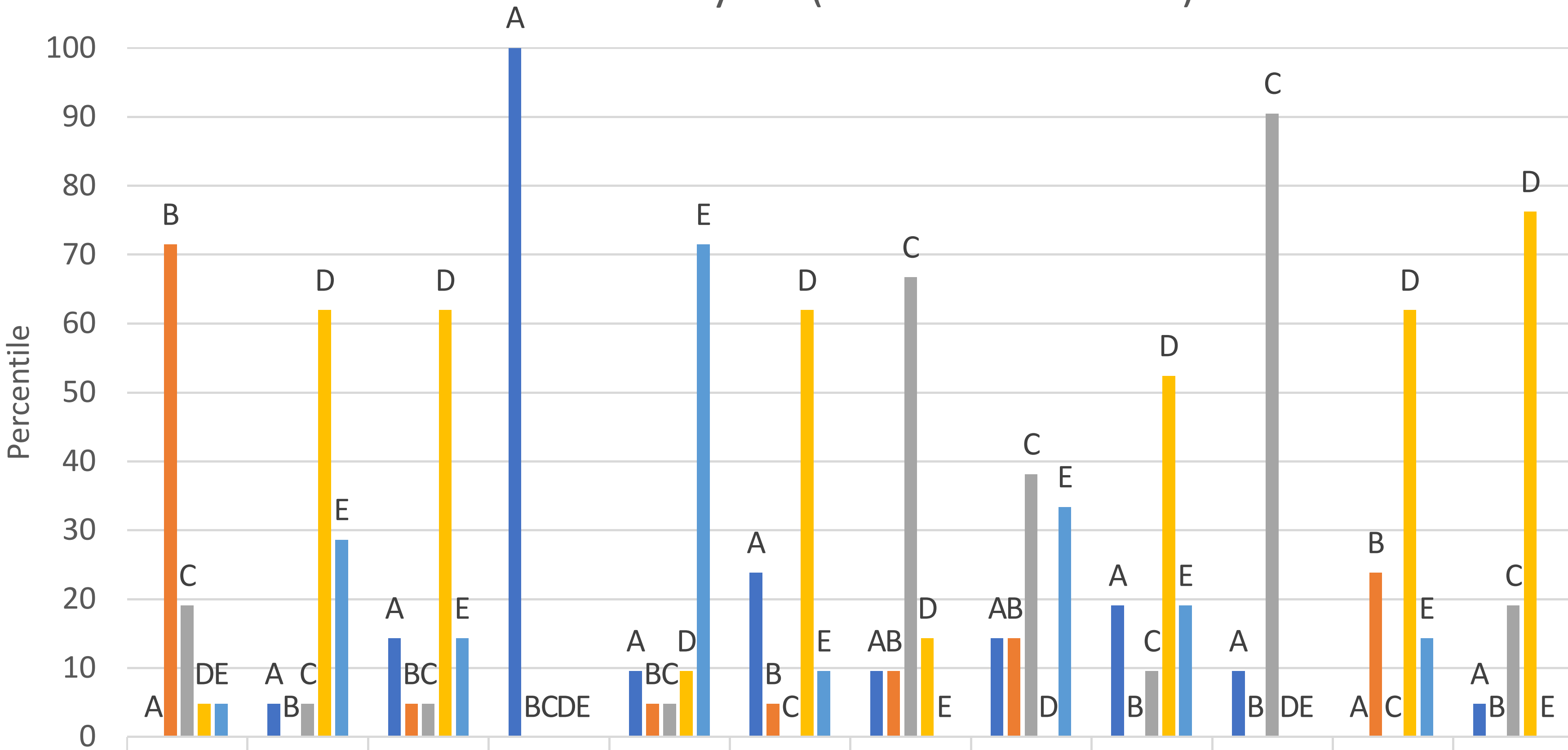
Exam 2 Data Analytics (Chem 40 Fall 2019)



	1-C	2-C	3-C	4-E	5-B	6-B	7-D	8-B	9-D	10-B	11-D	12-A
A	33	0	19	24	0	29	19	0	0	24	5	57
B	5	5	10	0	86	33	0	90	57	57	0	0
C	48	86	67	0	5	5	0	0	10	10	14	19
D	5	10	0	10	0	10	81	0	29	5	76	5
E	10	0	5	67	10	24	0	10	5	5	5	19

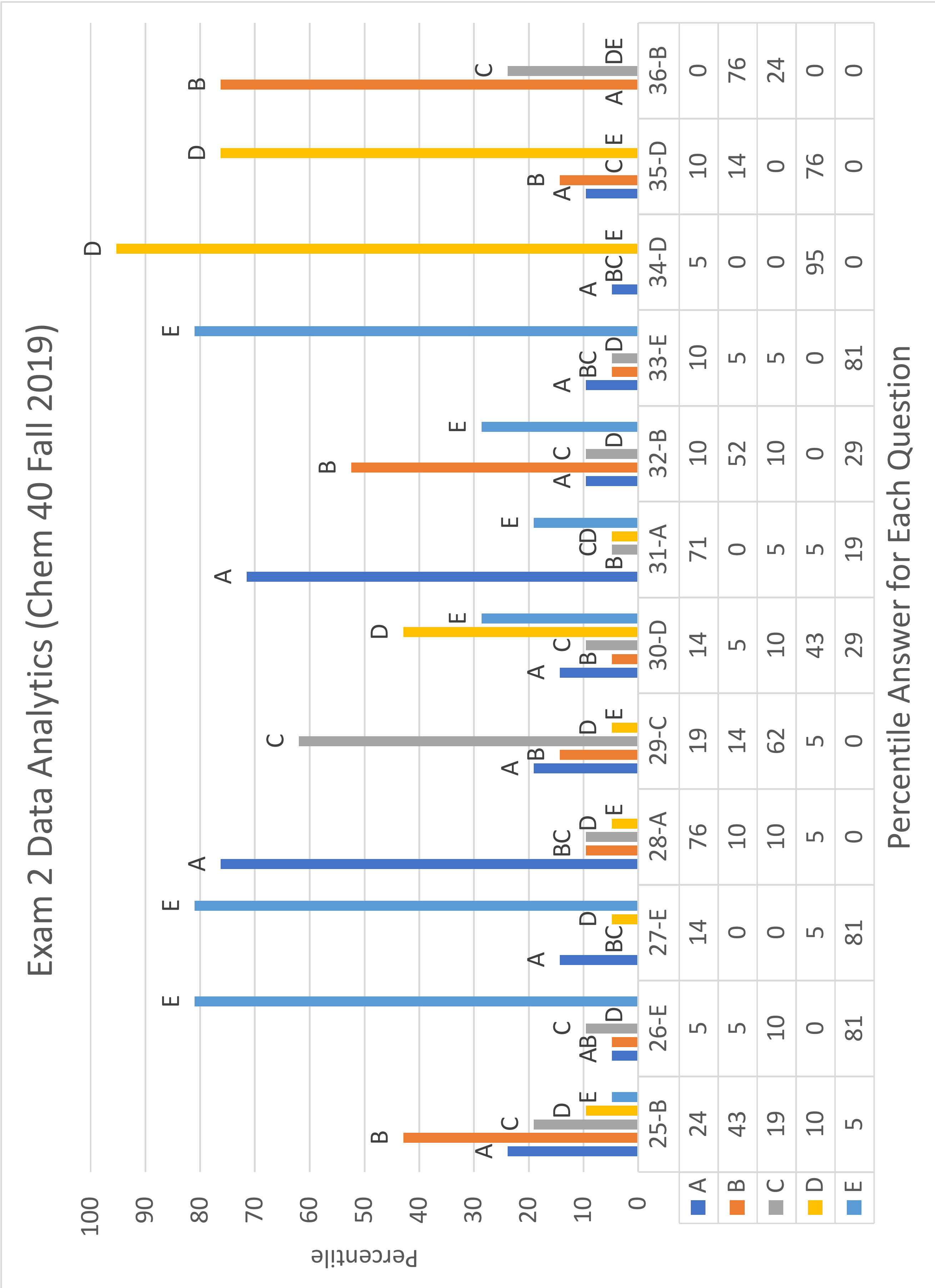
Percentile Answer for Each Question

Exam 2 Data Analytics (Chem 40 Fall 2019)



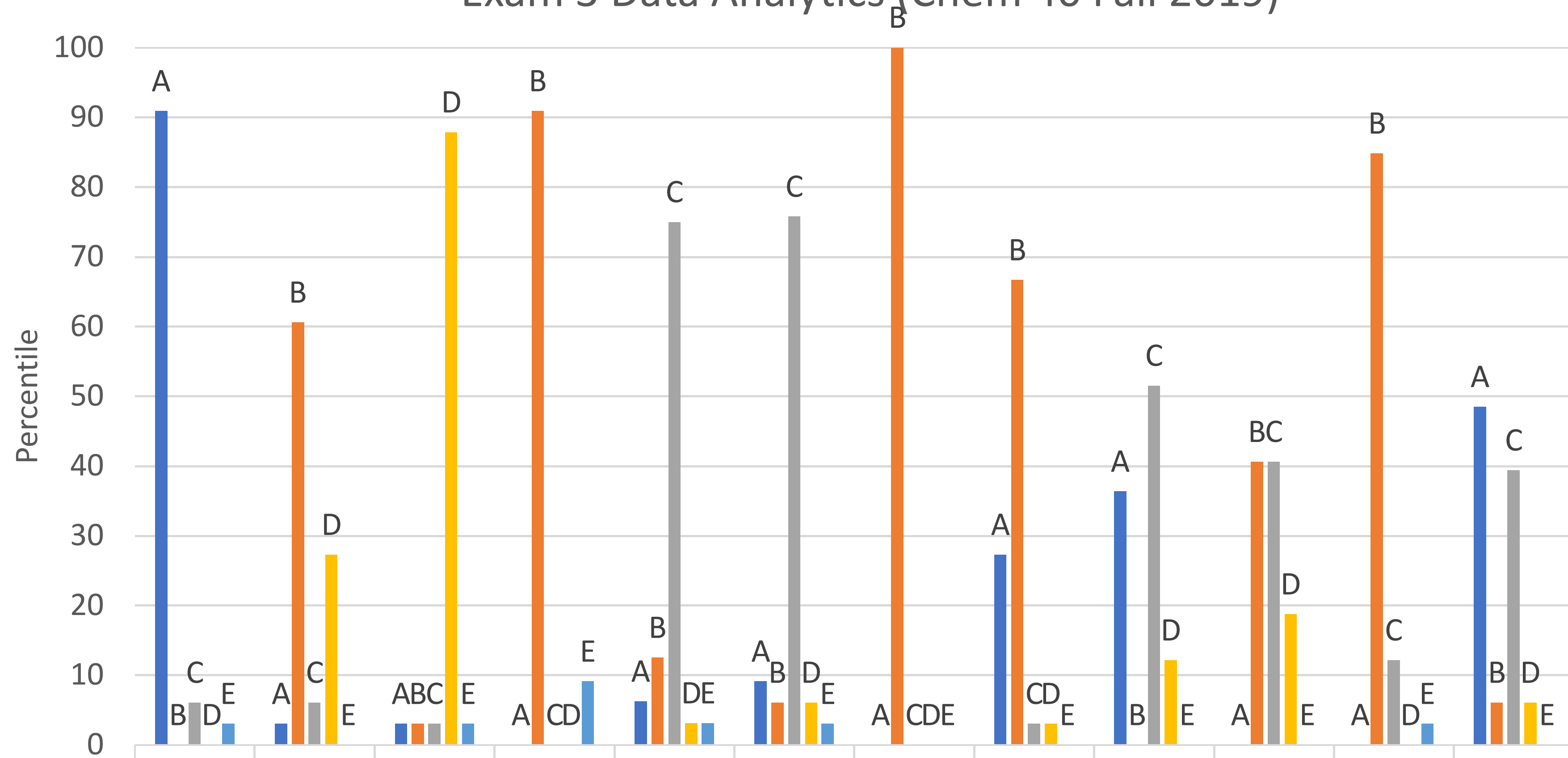
	13-B	14-D	15-D	16-A	17-E	18-D	19-C	20-B	21-D	22-C	23-E	24-D
A	0	5	14	100	10	24	10	14	19	10	0	5
B	71	0	5	0	5	5	10	14	0	0	24	0
C	19	5	5	0	5	0	67	38	10	90	0	19
D	5	62	62	0	10	62	14	0	52	0	62	76
E	5	29	14	0	71	10	0	33	19	0	14	0

Percentile Answer for Each Question



	25-B	26-E	27-E	28-A	29-C	30-D	31-A	32-B	33-E	34-D	35-D	36-B
A	24	5	14	76	19	14	71	10	10	5	10	0
B	43	5	0	10	14	5	0	52	5	0	14	76
C	19	10	0	10	62	10	5	10	5	0	0	24
D	10	0	5	5	5	43	5	0	0	95	76	0
E	5	81	81	0	0	29	19	29	81	0	0	0

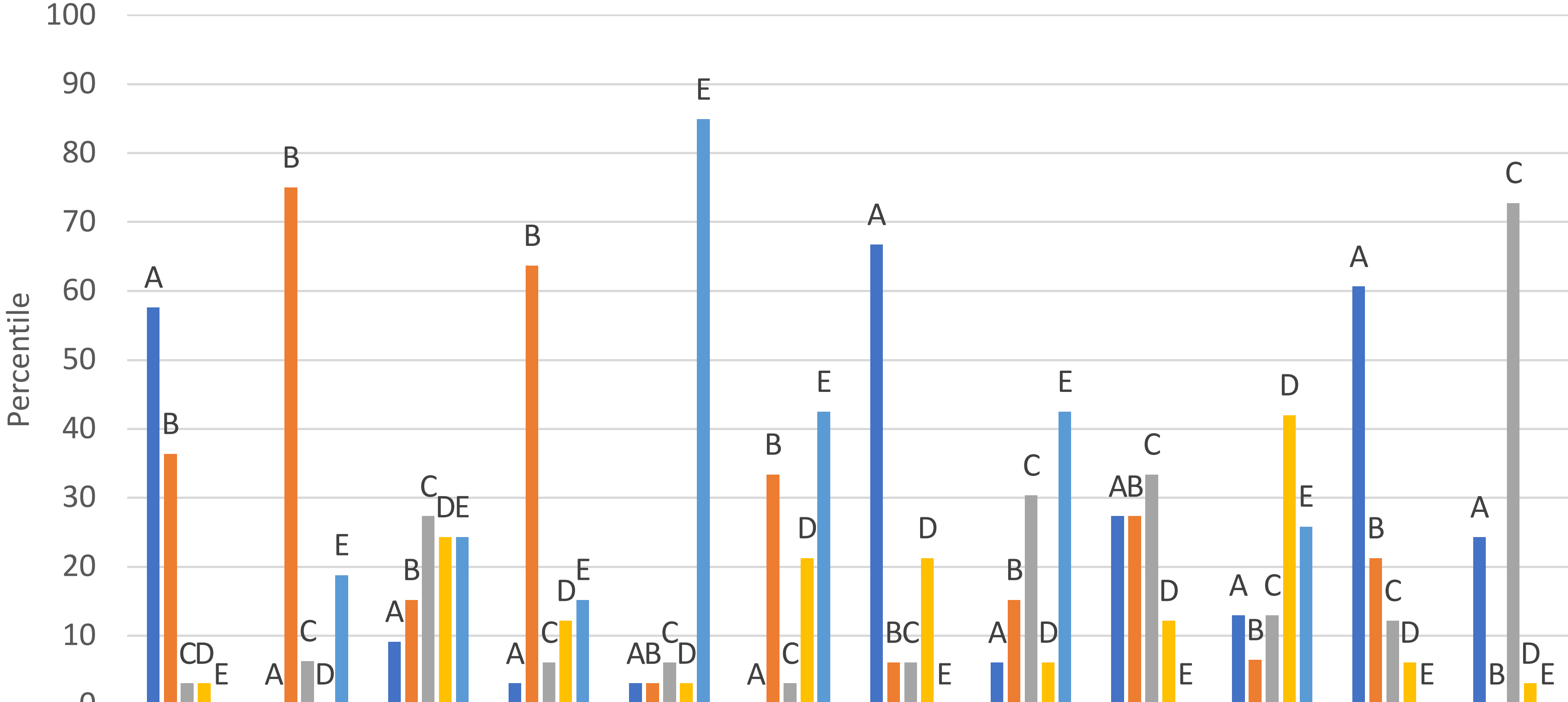
Exam 3 Data Analytics (Chem 40 Fall 2019)



	1-A	2-B	3-D	4-B	5-C	6-C	7-B	8-B	9-C	10-B	11-B	12-A
A	91	3	3	0	6	9	0	27	36	0	0	48
B	0	61	3	91	13	6	100	67	0	41	85	6
C	6	6	3	0	75	76	0	3	52	41	12	39
D	0	27	88	0	3	6	0	3	12	19	0	6
E	3	0	3	9	3	3	0	0	0	0	3	0

Percentile Answer for Each Question

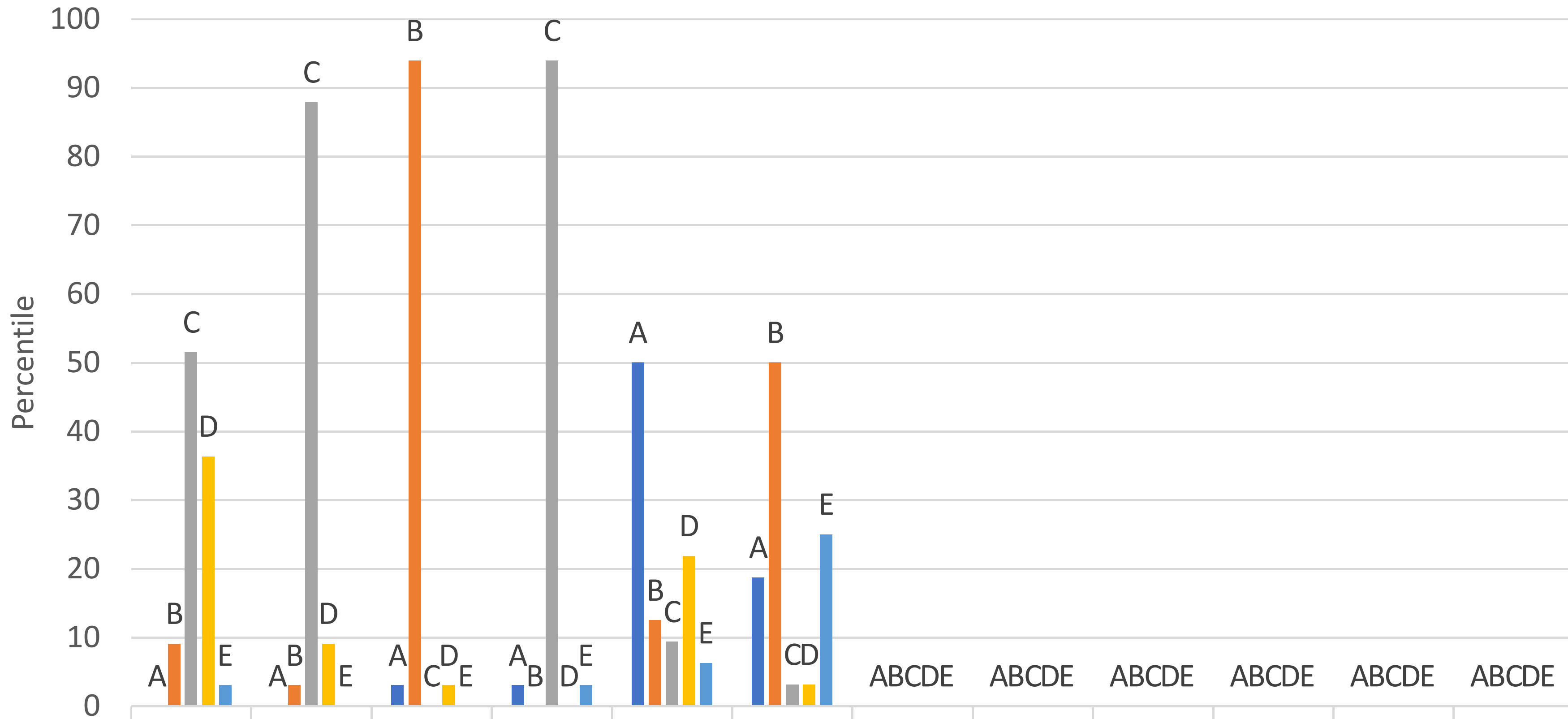
Exam 3 Data Analytics (Chem 40 Fall 2019)



	13-A	14-B	15-B	16-B	17-E	18-B	19-A	20-E	21-C	22-D	23-A	24-C
A	58	0	9	3	3	0	67	6	27	13	61	24
B	36	75	15	64	3	33	6	15	27	6	21	0
C	3	6	27	6	6	3	6	30	33	13	12	73
D	3	0	24	12	3	21	21	6	12	42	6	3
E	0	19	24	15	85	42	0	42	0	26	0	0

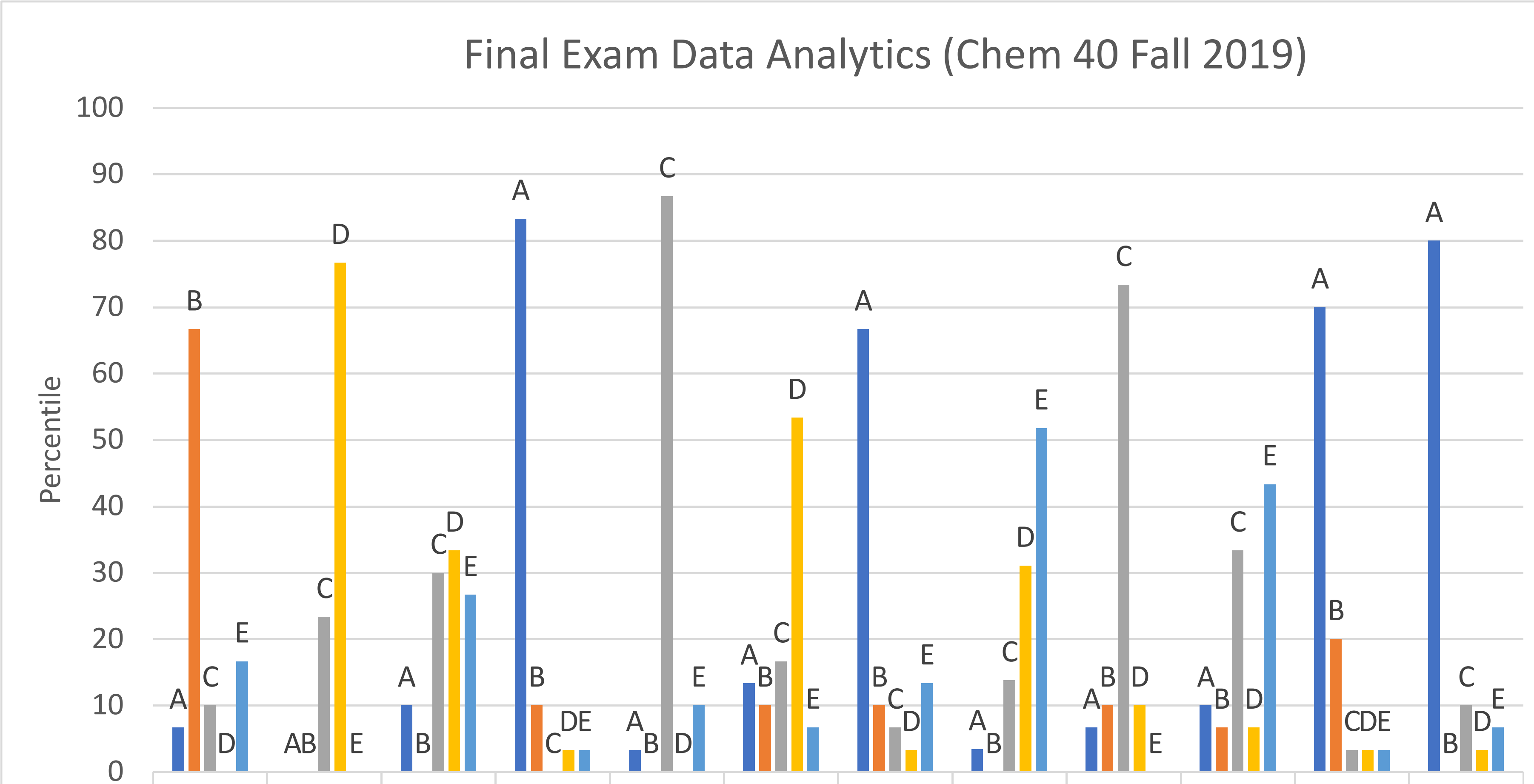
Percentile Answer for Each Question

Exam 3 Data Analytics (Chem 40 Fall 2019)



	25-D	26-C	27-B	28-C	29-A	30-B	31-	32-	33-	34-	35-	36-
A	0	0	3	3	50	19	0	0	0	0	0	0
B	9	3	94	0	13	50	0	0	0	0	0	0
C	52	88	0	94	9	3	0	0	0	0	0	0
D	36	9	3	0	22	3	0	0	0	0	0	0
E	3	0	0	3	6	25	0	0	0	0	0	0

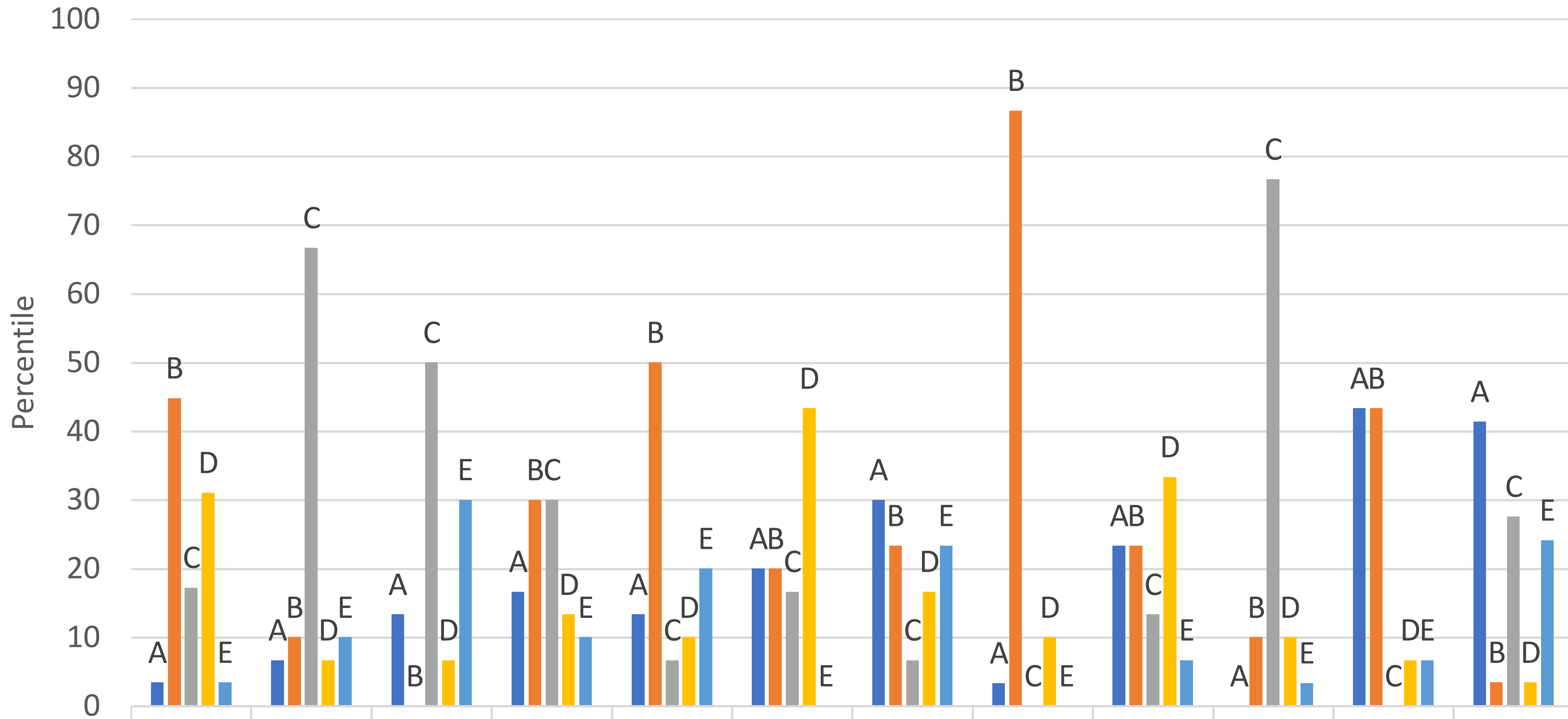
Percentile Answer for Each Question



	1-B	2-D	3-D	4-A	5-C	6-D	7-A	8-D	9-C	10-E	11-A	12-A
A	7	0	10	83	3	13	67	3	7	10	70	80
B	67	0	0	10	0	10	10	0	10	7	20	0
C	10	23	30	0	87	17	7	14	73	33	3	10
D	0	77	33	3	0	53	3	31	10	7	3	3
E	17	0	27	3	10	7	13	52	0	43	3	7

Percentile Answer for Each Question

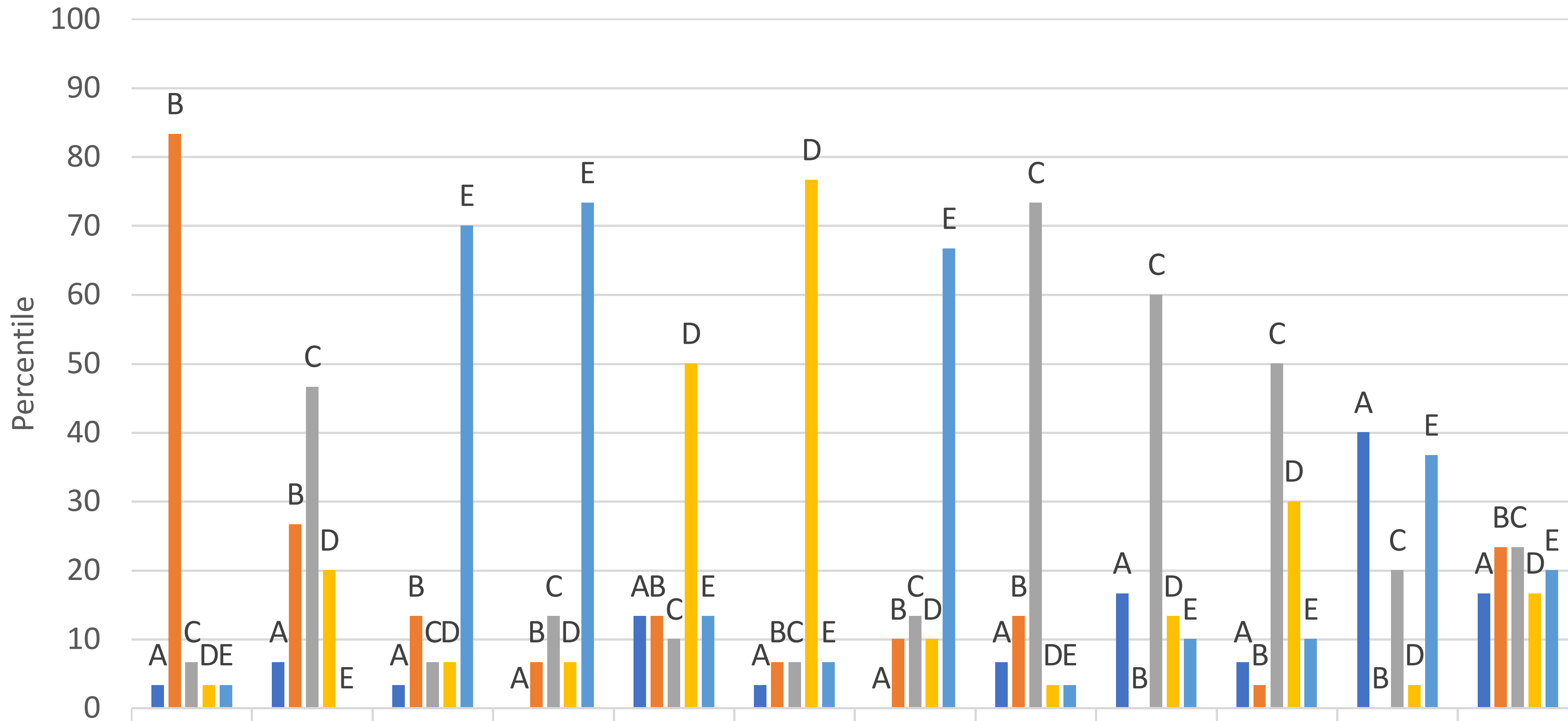
Final Exam Data Analytics (Chem 40 Fall 2019)



	13-B	14-C	15-E	16-A	17-B	18-D	19-A	20-B	21-A	22-C	23-B	24-C
A	3	7	13	17	13	20	30	3	23	0	43	41
B	45	10	0	30	50	20	23	87	23	10	43	3
C	17	67	50	30	7	17	7	0	13	77	0	28
D	31	7	7	13	10	43	17	10	33	10	7	3
E	3	10	30	10	20	0	23	0	7	3	7	24

Percentile Answer for Each Question

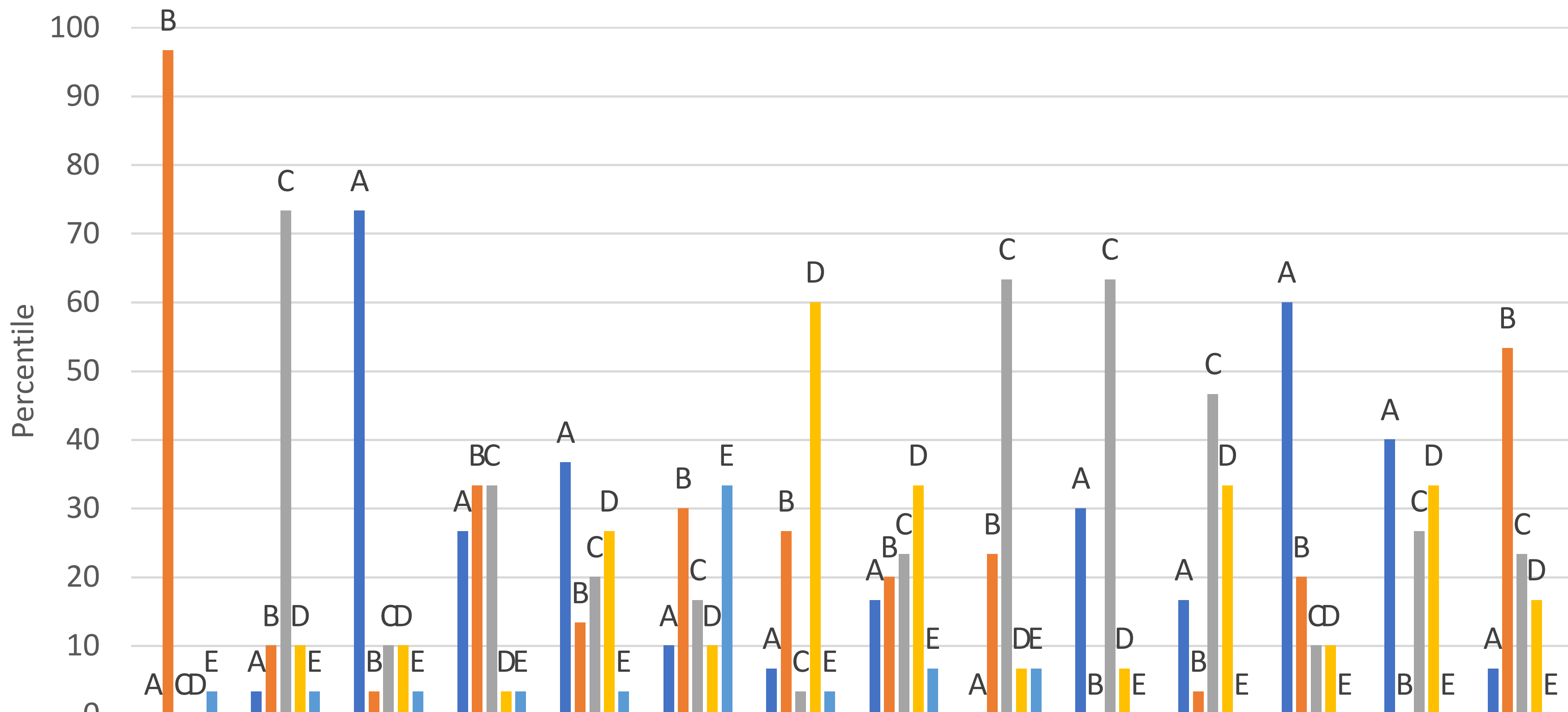
Final Exam Data Analytics (Chem 40 Fall 2019)



	25-B	26-C	27-E	28-E	29-D	30-D	31-C	32-C	33-C	34-C	35-A	36-E
A	3	7	3	0	13	3	0	7	17	7	40	17
B	83	27	13	7	13	7	10	13	0	3	0	23
C	7	47	7	13	10	7	13	73	60	50	20	23
D	3	20	7	7	50	77	10	3	13	30	3	17
E	3	0	70	73	13	7	67	3	10	10	37	20

Percentile Answer for Each Question

Final Exam Data Analytics (Chem 40 Fall 2019)



	37-B	38-C	39-A	40-B	41-A	42-B	43-D	44-C	45-C	46-C	47-D	48-A	49-A	50-B
A	0	3	73	27	37	10	7	17	0	30	17	60	40	7
B	97	10	3	33	13	30	27	20	23	0	3	20	0	53
C	0	73	10	33	20	17	3	23	63	63	47	10	27	23
D	0	10	10	3	27	10	60	33	7	7	33	10	33	17
E	3	3	3	3	3	33	3	7	7	0	0	0	0	0

Percentile Answer for Each Question

Abstract

As a result of this independent study, an Excel-based data analytics computational tool was developed to report student performances in each midterm assessment in a detailed way so that students can determine their strengths and weaknesses in a detailed and timely manner and make the necessary targeted improvements. The data analytics also provides detailed information on each exam question so that instructors can determine class strengths and weaknesses in order to make the necessary targeted improvements. Furthermore, the Excel-based data analytics application is integrated with over 200 clear and concise SLO statements for the Introductory Chemistry (Chem 40) organized in a 3-Level concept matrix. This model provides the necessary and targeted action that a course instructor and students need in order to make teaching and learning far more effective. It is expected that implementation of products developed in this independent study will take the usefulness of course level SLOs to the next level. Finally, this model can be adopted to any course on campus with clearly defined SLOs that are assessed through midterm exams.