Action Research Project

Diego Diaz (Chemistry)

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Faculty Learning Outcome #1

FLO: Develop a mathematics competencies review module focused on logarithms, exponents, and single variable equations for chemistry students to improve the math skills necessary for success in CHM1045 (General Chemistry I).

Essential Competencies and Indicators Addressed:

1) Assessment
    - Employ formative feedback loops to assess student learning
    - Design activities to help students refine their abilities to self-assess their learning
    - Make assessment criteria public to students and colleagues

2) Outcomes based practice
    - Construct measurable learning outcomes (this performance indicator must be used in conjunction with at least one other Outcomes-based Practice indicator for demonstration in faculty portfolios)
    - Design assessments that demonstrate student growth in the student core competencies (Think, Value, Communicate & Act) and program learning outcomes
    - Use evidence of student learning to review and improve courses and programs (e.g., in classroom, counseling and library settings)

3) Scholarship of Teaching and Learning
    - Produce professional work (action research or traditional research) that meets the Valencia Standards of Scholarship

- Build upon the work of others (consult experts, peers, self, students)
- Be open to constructive critique (by both peers and students)
- Make work public to college and broader audiences
- Demonstrate relationship of SoTL to improved teaching and learning processes
- Demonstrate current teaching and learning theory & practice

Clear Goals

A. Abstract

A large segment of the student population taking chemistry classes is underprepared in terms of the mathematical skills needed to succeed in chemistry. Many students learned math concepts used in chemistry while they were in high school, while others may have never learned some of the concepts before beginning their journey through chemistry. In this FLO, the CHM1045 (General Chemistry I) students were presented with a pre-module, formative assessment test during the first day of lecture. The test assessed the students' math preparedness for chemistry. Following the test, the students were given a math self-study module to be studied during the first four weeks of classes. This module reinforces the math concepts needed for success in chemistry. The review module is divided in four basic units, and each unit contains a summative, take-home quiz about the module. After the module, the students re-took the same assessment test that they took during the first lecture and the before and after results were compared. Another way of determining the success of the modules was done by comparing the students' Exam #1 grades (which focused on the math skills) and overall class grades to those of previous semesters where the modules were not used.

B. Research Question

Will a comprehensive review of mathematics skills improve student learning of General Chemistry I?

Adequate Preparation

Background from Multiple Perspectives

1. Student Perspective

During the first class meeting of the semester, students were presented with a survey (**Artifact #1**) titled: *Perceptions of Preparedness for Chemistry*. In this survey, the students were questioned about the relevance that they think chemistry has for their careers, and the relevance that math has in helping them learning chemistry. The survey also questioned the students on how prepared they felt for solving typical mathematical problems in several areas like fractions, powers, logarithms, and algebra. The survey also attempted to gauge the students' interest in math and in chemistry, and their perceived relevance of chemistry for their careers. Their answers provided me essential insights on the students' perceptions of preparedness. A few of the most important findings are listed below:

a. 85% of the students agree or strongly agree that chemistry will help them be better professionals
b. 77% agree or strongly agree that chemistry will enhance their careers

c. 53% do not consider themselves properly prepared for a chemistry class (42% "Neutral" and 11% "Disagree")

d. The overwhelming majority (96%) consider that knowledge of math will help them with chemistry

e. 27% of the students reported fear of chemistry, while 50% were neutral

f. Interestingly, most students feel that they possess appropriate math skills for a chemistry class (several questions addressed different math concepts, while the answers were usually higher than 80% agree or strongly agree)

The students were also presented with a self-assessment test on the first day of lecture. The test addressed the same math concepts that they were surveyed about. The most interesting observation was that most students were lacking the same math skills that they felt knowledgeable about in the survey.

Supporting anecdotal information was obtained by talking with the students. I often get comments such as: "I am just not good at math." "Math is not my strength.", "I just took my last math class *X* number of years ago" (*X* being the actual number). There seems to be a fairly even distribution between students that (1) fear math and chemistry, (2) understand its importance, but are aware that they need to work on it, and (3) feel overly confident about their math skills. In all cases, most students realize that math is an essential component to learn chemistry and realize that they need to improve their math skills, but they often lack the resources to do so.

2. Colleague Perspective

During many informal discussions with my STEM colleagues (chemistry, engineering, and other science courses) at Valencia, at UCF, and at other institutions, we agree in the need to improve students' math skills and students' perceptions about math. Most colleagues agree that many chemistry students do not succeed in chemistry because their level of math is not adequate for them to visualize the chemistry concepts. While their classmates can apply their skills in math to understand the chemistry concepts, they are still trying to understand the math concepts by themselves, and fall behind on the chemistry aspects of the lesson.

A few exchanges and anecdotes with colleagues exemplify this concept.

Colleague #1: A physical chemist teaching chemistry at a 4-year institution. She mentioned to me at an American Chemical Society Meeting how a student in a Physical Chemistry class told her that he did not understood what the "S" means. The "S" was the calculus symbol for an integral while calculus is a requirement for the Physical Chemistry class.

Colleague #2: An analytical chemist. He always used to tell me how difficult it was for his classmates in high school to learn math when their teacher used to repeatedly tell them not to worry because "Math was difficult" when they did not perform well.

Therefore, by talking to several other chemistry faculty members, it further reinforced my belief that many students often struggle with the mathematical aspects in chemistry, hindering their success. Most colleagues also agree that a module to help students with math can be a great asset.

3. Expert Perspective

Many chemistry educators have questioned the correlation between success in chemistry and preparedness of the students. Some of the most commonly found factors that affect students' learning are: (a) "chemophobia" or fear of the subject, (b) anxiety, (c) and lack of preparedness. According to Nicoll and Francisco[1] one of the most common examples of lack of preparedness is their math skills. Often students do not remember concepts learned several years ago, or they just lack the necessary knowledge. Ozsogoonyan[2] found that the math SAT scores appear to be a good indicator of success in introductory chemistry. These suggest the correlation between the student's math skills and his/her ability to learn chemistry. Perkins[3] suggests that due to the correlation of math skills and success in chemistry, students should be surveyed at the beginning of the term and their math deficiencies should be addressed at the beginning of the term. In his words: "since mathematics skills appear to have a positive relationship to chemistry success, counselors and instructors should attempt to identify mathematics weaknesses early in the term." Geller Leopold, and Edgar[4] found a direct correlation between the math scores of a group of students and their overall grades in the chemistry course. Students that answered most of the math test correctly averaged an A grade on the chemistry class.

In general we observe that many educators are worried about the correlation between the math knowledge and the ability to succeed in chemistry. I want to extend this study to the General Chemistry I course at Valencia, and to offer the students a tool they can use to bridge the gap in math. It was my desire to follow up on R. Perkins suggestion to survey the students' math capabilities and to address the deficiencies at the beginning of the course.

References:

1. G. Nicoll, J.S. Francisco, An Investigation of the Factors Influencing Student Performance in Physical Chemistry, J. Chem. Ed., 78, 2001, 99
2. Ozsogomonyan, A.; Lotus, D.; Predictors of General Chemistry Grades, J. Chem. Ed., 56, 1979, 173
3. Perkins, R.; Do Community College Introductory Chemistry Students Have Adequate Mathematics Skills?, J. Chem. Ed., 56, 1979, 329
4. Geller Leopold, D.; Edgar, B.; Degree of Mathematics Fluency and Success in Second-Semester Introductory Chemistry, J. Chem. Ed., 85, 2008, 724

4. Self Perspective

I have been teaching chemistry courses for the past eight years. During that time, I have taught General Chemistry I, General Chemistry II, General Chemistry with Honors, Introductory Chemistry, and Analytical Chemistry, in addition to advising MSc. and PhD. students. Every year in my teaching career, I have made similar observations. I observe that many students have great difficulty in applying the learned concepts, or in understanding the main topics in the course. Of those students, I have found that a great number of the ones who struggle in chemistry share one of two trends: (1) Many students do well applying the learned concepts to chemistry problems (exams), but they show little understanding of the chemistry behind the concepts. (2) Many other students can describe the theoretical concepts in great detail, but fail to apply these concepts in problems. I have realized that both trends originate with the students' math skills. Students with a strong background in math are able to solve the problems, often without a good understanding of the chemistry theory. Moreover, students with weak math skills often have a hard time applying the learned concepts to chemistry problems. For these two groups of students I have a growing concern that they are not able to perform to their fullest capacity. The students in Introductory Chemistry and General Chemistry must develop knowledge and skills of chemistry concepts that they will need in their future coursework and careers. If we fail to enable these students to learn chemistry, it can potentially limit their success in their careers and in life.

Many of the students will realize their limitations in math skills, and even try their best to catch up after the first chemistry exam. However, once the semester is in full swing, it becomes too late to bridge the gap in their knowledge as the math material combines with the chemistry material that they are required to learn. I believe that if students are able to self-assess their math skills right from at the start of the semester, then they will have more time to overcome deficiencies and a higher chance to succeed.

In order to overcome such math deficiencies of the students in the shortest amount of time, a concise review needs to be applied. I believe that the review should ultimately provide them access to additional resources, be self-paced and combine different methods for assessment. Due to class limitations, the designed course was assessed via a set of homework assignments covering different topics. The compartmentalization of the work allows me to analyze specific areas of deficiencies to be addressed. In that way, I can use the classroom experience to enhance the module and the learning from it. Moreover, group work can also be incorporated in a way that different methods of learning are applied and students can help other students learn.

Appropriate Methods – Methods & Assessment Plan

A. Methods

1. Student Learning Outcomes

- Students will improve their ability to solve mathematical problems and to solve applied mathematical problems.
- Students will analyze a chemistry problem, understand the mathematical concepts to be applied, and be able to solve the problem.

2. Performance Indicators of Student Learning Outcomes

For SLO1

- Students will be able to solve mathematical problems involving logarithms, powers, and exponents.
- Students will be able to handle numerical expressions involving fractions, rounding, significant digits and scientific notation.
- Students will be able to solve algebraic equations.
- Students will be able to apply basic concepts of geometry.
- Students will be able to use a scientific calculator properly.

For SLO2

- Students will be able to identify the concepts needed to solve problems.
- Students will be able to apply the mathematical skills to chemistry problems.

3. Teaching Strategies of Student Learning Outcomes

1. The students were provided with a survey at the beginning of the semester in which they self-reflected on their math and chemistry. (**Artifact #1: Pre-survey**)
2. The students were given a pre-assessment test on the first day of lecture. (**Artifact #2: Pre-post assessment test**)
3. A math module was made available to students in BlackBoard titled: "A Math Review Module for CHM1045C" (**Artifact #3: Math Review Module**)
4. Four take home quizzes (summative assessment) on the math review module were given. (**Artifact #4: homework assignments**)
5. The students were given a post-assessment test to help them "auto-evaluate" their mathematical skills one week after finishing the module. (**Artifact #2: Pre-post test**)
6. The students were given problems to work in class, divided in small groups of students, to review the learned skills.

7. The students were provided with a survey at the end of the semester to reflect on the module and the relevance that math had in the class. (**Artifact #5: Post-survey**)
8. The students were given Exam #1 that was mostly based on mathematical concepts. (**Artifact#6 Exam #1**).
9. The students' grades on Exam #1 and in the course were compared to those of previous semesters (historical values) in order to evaluate the effectiveness of the modules for learning CHM 1045C.

B. Assessment Strategies

1. Formative Assessment – "Perception of Preparedness Survey". Students answer questions about how well prepared for chemistry they feel, and how relevant they feel that math is to chemistry.
2. Formative Assessment – Pre-module self-test. Students answer a short math test. It helps students self-assess their knowledge before studying the module.
3. Formative Assessment – Post-module self-test. It helps students evaluate their progress after taking the math module.
4. Formative / Summative Assessment – Work carried out in the classroom. The class is divided in small groups during lecture to work on math problems. It allows the students to share ideas and learn from each other. It also helps me to assess their progress and find common misconceptions and errors.
5. Formative / Summative Assessment – Module Quiz. Students complete four take-home quizzes related to the different sections of the module. These take-home quizzes (assignments) help students practice the concepts from the modules and offer me a better evaluation of their progress.
6. Summative Assessment –General Chemistry Exam # 1 tests the math concepts required for chemistry and can be used to measure the progress in the math skills.

C. Action Research Methodological Design

The Action Research Project was implemented via a Math Module that students were able to download from Blackboard on the first day of the Fall 2012 semester. The module contained very limited descriptions of the math modules as a review, and a list of different online resources for the students to visit as needed. The module did not aim to teach the students the concepts, but to provide a "refresher" of previously learned math concepts.

The results of the math module were compared by two different methods. First, the students were provided a pre-test of math concepts based on the module. At the end of the module, the students were presented with the same exam and their answers examined. The pre- and post-tests were given as formative assessments, and their scores had no effect toward the course final grade. A second evaluation is a comparison of Exam 1 results from the class with those of previous semesters. The first exam in the General Chemistry class is mostly based on the math concepts required for chemistry. All the results were compared and analyzed. It is important to note that in these comparisons there is no real control group, and that comparisons of different classes (groups of students) are difficult to evaluate. In this regard, the statistical analysis of the data is at best, empirical.

A formative assessment was carried out by a pre- and a post-survey given to the students. Through these surveys I was able to obtain information of the students' backgrounds, their interest in math, and the relevance they see in math for chemistry and their careers.

Significant Results

A. Pre-survey (Artifact #1)

On the first day of lecture the students completed a survey titled: "*Perceptions of Preparedness for Chemistry*". The results for the survey are analyzed. A total of 26 students answered the survey. The answers ranged using a Likert scale ranging from strongly agree to strongly disagree as follows.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
5	4	3	2	1

Relevant questions from the survey are summarized below.

1. Question #1: A good knowledge of chemistry will make me a better professional.

	Str. Agree	Agree	Neutral	Disagree	Str. Disagree
Total	13	9	3	1	0

Average response: 4.31.

A majority of students understand that chemistry will make them better prepared for their professional life, not only in their academic careers, but as full-fledged professionals in their respective fields.

2. Question #3: I will be able to use what I learn in chemistry to enhance my career.

	Str. Agree	Agree	Neutral	Disagree	Str. Disagree
Total	16	4	3	3	0

Average Response 4.12

Most students realize that learning chemistry can be a potential career enhancer. They seem to realize that chemistry is not a subject for the classroom only, but one that they will use in their careers.

3. Question #4: I feel prepared for a chemistry class.

	Str. Agree	Agree	Neutral	Disagree	Str. Disagree
Total	3	8	11	3	0

Average Response: 3.44

One student did not provide a response for this question. We can clearly see that the confidence drops considerably on this question. Almost half (54%) of the students feel "neutral" or not prepared for a chemistry class. It is an important observation that while they realize how important chemistry can be for their careers, they are also aware of the fact that they may not be properly prepared for learning chemistry

4. Question #5: Chemistry is a subject that I am afraid of.

	Str. Agree	Agree	Neutral	Disagree	Str. Disagree
Total	1	6	13	4	2

Average Response: 3.00

Another important observation is that not only they may feel unprepared for the course, but most students feel that they are afraid (27%) or "neutral" (not afraid nor at ease, 50%) with chemistry. The fear factor or "chemophobia" is a problem that also affects student learning.

5. Question #7: Having good math skills will help me learn chemistry.

	Str. Agree	Agree	Neutral	Disagree	Str. Disagree
Total	10	15	0	0	1

Average Response: 4.27

An overwhelming majority of students realize that math is essential to learn chemistry. When taken into consideration with the previous answers we can observe that students realize the importance of math in chemistry, and of chemistry for their careers. However, they feel unprepared for chemistry, or fear the course as a whole. The one outlier (strongly disagree) was an interesting case as in the open response, the student disclosed that he wants to be an engineer, showing that the student is either overly confident in his math, or fails to see the relation between math, chemistry and his future career.

6. Question # 10: You feel that your math knowledge prior to this class is adequate for your success in General Chemistry I.

	Str. Agree	Agree	Neutral	Disagree	Str. Disagree
Total	6	15	5	0	1

Average Response: 4.04

However, it is interesting to note that most students that fear chemistry seem to fear it for other reasons than their math skills. In general, this question suggests that students feel relatively confident of their math skills as required for a chemistry class. I believe that in general this only shows that most students are unaware on how the different science classes are related, but that they truly feel that their math skills are adequate for other subjects.

7. Questions #11-18

Total	Str. Agree	Agree	Neutral	Disagree	Str. Disagree	Average Resp.
11. I know how to properly use a scientific calculator.	10	12	4	0	0	4.23
12. I am confident in solving a problem involving logarithms.	4	3	16	3	0	3.31
13. I am confident in solving a problem involving powers.	8	14	3	1	0	4.12
14. I remember the proper mathematical order of operations.	9	16	1	0	0	4.31
15. I can easily solve a linear, 1-variable equation.	9	10	4	2	0	4.04
16. I remember how to solve a quadratic equation using the quadratic formula.	7	10	6	3	0	3.81
17. I can properly solve problems involving fractions.	5	18	1	2	0	4.00
18. I can calculate the area and volume of most basic geometric shapes.	4	14	7	1	0	3.81

One student did not respond to question # 15. The answers to these questions are related to question #10. The students were able to self-assess their math on several different areas. There are some general observations that can be made. First, it seems like logarithms is the concept where most students face the most difficulty. I can attest to that since I have observed in the classroom that students generally have the greater amount of problems dealing with logarithms and powers. The second observation that can be made from the survey is that most students are very confident in their math skills. It seems that most students believe that their math skills are adequate for work in chemistry. It is interesting as this is in stark contrast to common observations during my teaching. Many of the students that show great confidence in their math skills show great deficiencies in math.

Another interesting aspect of the survey was the students' answers to the open comments sections. Some of the most revealing answers offer a very good motive for a math module.

Some comments were:

- “Science is not my best”
- “Need a good refresher”
- “As of now its hard to remember past material but I pickup fast”
- “Math is not my strong suit”
- “last chemistry course in 9th grade”

All these comments show that many students are aware of their limitations and are conscious of their need to do a refresher prior to taking chemistry. It also shows that students believe that their greatest limitation to learning chemistry is the lack of a better background in chemistry, but fail to realize that their skills in math, and in other subjects can also affect their performance in a chemistry class. Also, I had some student responses like:

- “Enjoyed chem. Thought about it as a major”
- “I love science”

These comments justify that we must do something to motivate students in the sciences and in chemistry. By preparing them for success, giving them the tools they need, and increasing their confidence we can increase the number of students that succeed in STEM careers and help ease the fear of and apathy towards chemistry and the other sciences.

B. Pre- and post-test results (Artifact #2)

The students in CHM1045C took the pre-test on the first day of classes. They worked on the math module for the following four weeks. At the fifth week, the same test was administered again. I opted for the same exam to make sure that the concepts were refreshed.

For the pre-exam, an average score of 67 was obtained with a standard deviation of 20. The median for the pre-exam was 65. The scores varied broadly, and the results appeared to be very evenly distributed. Figure 1 shows the distribution of these results. More than a quarter of the students scored less than 60% on the exam, more than half scored no better than 70%. While a few students did very well, many students had relatively low grades.

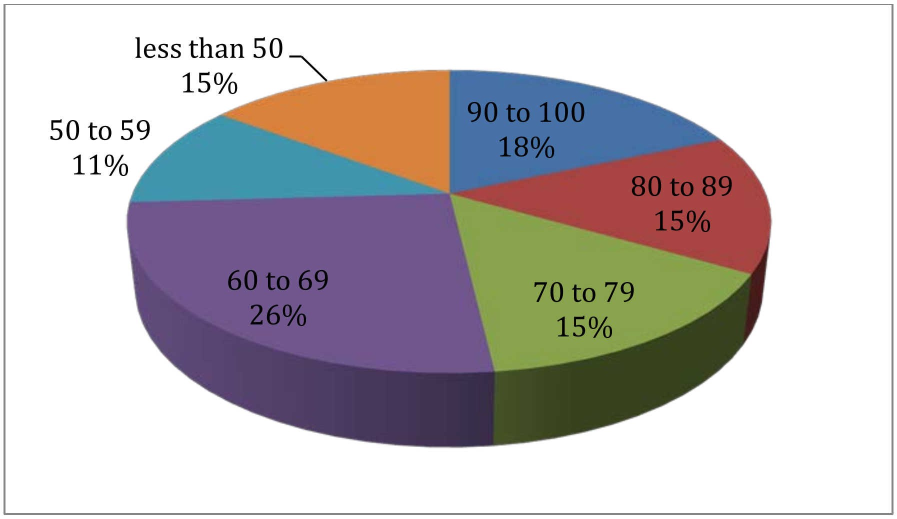


Figure 1. Range of results for the math exam (formative) prior the math module.

For the post-exam, it can be observed that the grades are vastly improved. Figure 2 shows the grade distribution. For the post-exam, the average score was 82 with a standard deviation of 16. The median for the post-exam was 85. The scores are almost a full standard deviation better than the pre-exam. The difference in the median was 20 points. The results suggest major improvement in student math comprehension and that although several students still did not perform well in math, most students were able to take full advantage of a refresher module for their math skills. Another important observation is that the results are greatly skewed to higher grades. Several students obtained a perfect score and few students had low scores. No students scored less than 50% (compared to 15% in the pre-exam), and only 22% (less than quarter of the students) scored less than 70%.

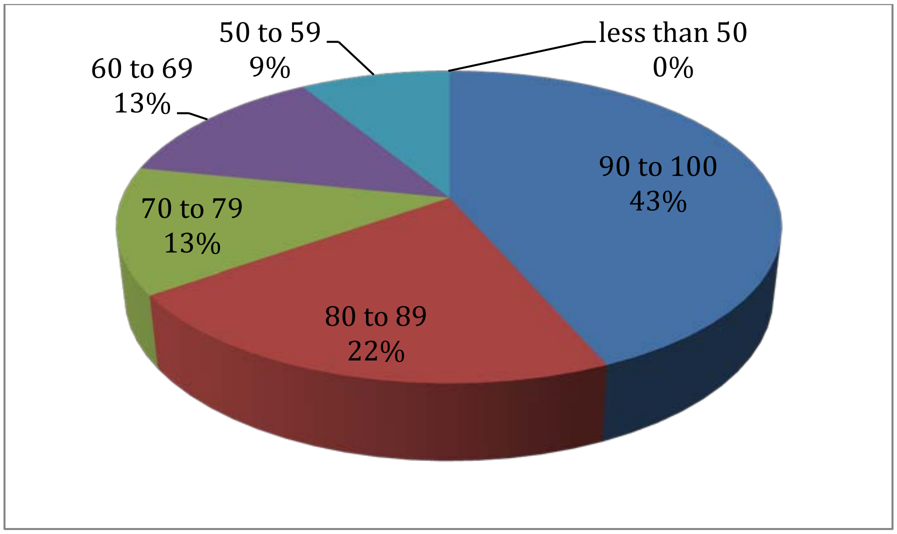


Figure 2. Results from the math exam after the math module (formative). The results are greatly improved showing higher scores as well as a very increased frequency of the results of 80% or higher.

When comparing the results side to side (pre- vs. post- tests) the improvement in the math skills appears more evident. Figure 3 shows the comparisons between different ranges of grades. It is important to note that the results of the post-test are skewed towards the highest ranges, while the pre-test appears more evenly distributed. One important note is that for the data on Figure 3 only students that took both tests were considered. Students missing the first day (did not take the pre-test), and students that dropped the course or did not complete the second test, were not considered. I wanted to be able to compare the students' performance in both exams and believe that students that only took one of the two exams may skew the results of the analysis. Of the 22 students that took both exams, only two students performed lower on the post-exam than on the pre-exam.

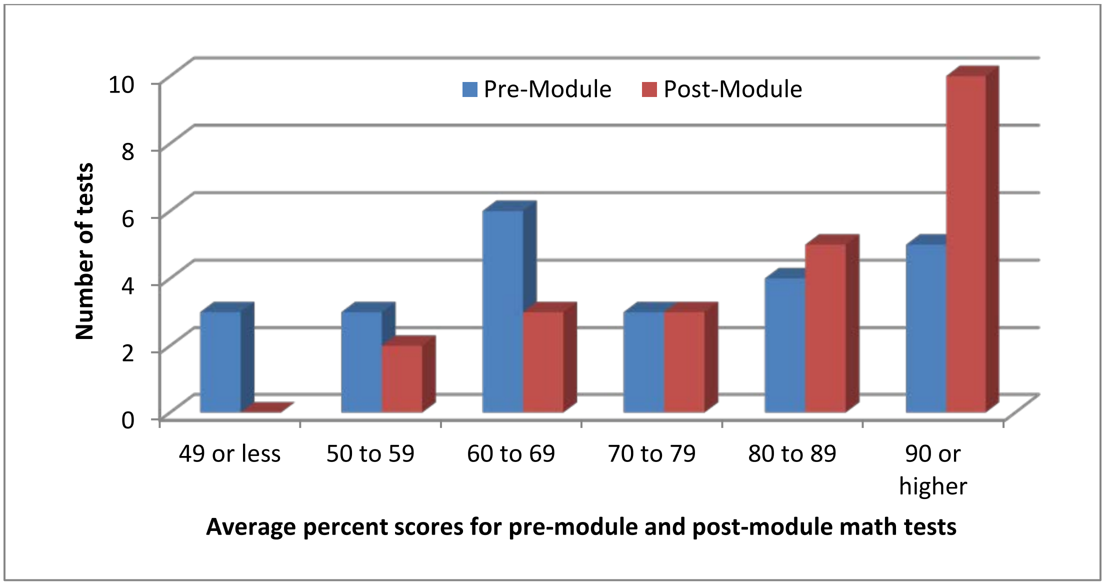


Figure 3. Comparison of results from the math exam prior and after the module. Notice the increase in frequency of higher grades and the drop in lowest scores. Note: Only students that took both exams are accounted in these analysis.

C. Post Survey (Artifact #5)

The students answered a second survey at the very end of the semester. The results of this "post" survey were compared to the results of the first survey. Some questions appear to provide great insights. For the post-survey 23 students provided their anonymous feedback. A few interesting observations can be made.

1. **Question #2:** The chemistry learned will help me with my other science classes.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
13	8	1	1	0

Average Response: 4.44

Most students that took the class were able to see that the chemistry that they have learned will be beneficial for their other science courses. It appears that the students are able to see some of the practical applications of chemistry, and realize that chemistry is an essential subject for their professional careers.

2. **Question #3:** The class made me redefine my future (career) goals.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
5	6	7	3	2

Average Response: 3.39

I think it is interesting that close to half of the students actually think that the chemistry class made them redefine their career goals. Unfortunately, the question does not tell the whole story as it can also mean that students were steered away from science. For example, a revealing comment in the comments section was: *"I just recently switched to journalism"*. One advantage is that even when it steers the students away from science careers, it helps the students truly define their goals.

3. **Question #4:** The class helped me ease my fears of chemistry.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
8	9	6	0	0

Average Response: 4.09

Most students, even those not admitting to fearing chemistry on the pre-survey, seem to agree that the course helped them overcome the "chemophobia" or fear of chemistry that often affects their performance. It is surprising how many times I hear my students explain concepts to me that they could not explain on the exam. This shows that they have learned the concepts, but that "chemophobia" truly affects their performance during exams. It seems like finding a way to increase the students' confidence in their chemistry knowledge prior to take an exam is also needed.

4. **Question #9:** The math module helped me realize the importance of math for this class.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
6	13	3	1	0

Average Response: 4.04

Although many students were well aware of how much math was needed in a chemistry class, it seems that the module truly helped them raise the awareness that math was an essential requirement to succeed in the class.

5. **Question #10:** The math module helped me refresh the math skills that I needed for the class.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
9	10	4	0	0

Average Response: 4.22

Not surprisingly, most students agree that the math module helped them refresh the skills needed for the course. No students disagreed with the statement. Some students were very competent in math, and they felt like their preparedness did not change ("neutral" responses), but for the vast majority of them, the module appears to have been helpful.

6. **Question #11:** The math module increased my confidence on being prepared for the class.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
5	10	7	1	0

Average Results: 3.83

Following the results from question #4, students taking the module are able to overcome their math limitations and can feel more empowered and prepared for a chemistry class. The students' confidence is an essential aspect of success. However, it is also interesting to observe that there is not a direct relation between one's fears of chemistry and one's math skills. It seems like many students fear chemistry on its own without realizing that their math skills are one of the most common challenges to face. The students mostly appear to fear chemistry for "being chemistry". I think that this is why the module is so important. The students are generally underprepared in math, but they also tend to focus on the wrong areas to overcome their limitations. Many students also fail to realize that their success in chemistry is linked to other fields of study such as math.

D. Comparison of exam results (Artifact#6)

Although there is no actual control group when comparing different classes (terms), the results for the CHM1045C class when the AR project was implemented (Fall 2012) are compared to the same courses during the Spring 2012 and Fall 2011 terms.

1. **Results from Exam #1**: Exam #1 in CHM1045C focuses heavily on the math skills used in chemistry, ranging from significant figures, order of operations and the basics of dimensional analysis. Comparing the results from these different exams #1 can offer some insights into the effectiveness of the math module. However, the results can't be directly compared as they present totally different student populations. Also, each exam #1 is a different exam although they cover the same material. In order to keep the integrity of the course, I do not offer the same exam in different semesters. Having different exams makes comparing the results more challenging, and the comparison is empirical at best.

Table 1. Comparison of exam #1 scores for semesters where students did not participate in the math module versus the Fall 2012 semester, where students participated in the math module.

Term	Fall 2011	Spring 2012	Fall 2012 – AR Implemented
Average Exam #1 Score	73	62	78
Standard Deviation	13	17	15
Median Score	73	61	74
Number of exams	19	20	24

We can observe that there is a slight improvement in the results from exam #1 after the implementation of the module. However, the improvement is rather small. For example, comparing Fall 2011 and Fall 2012 results gives a difference of only about a third of a standard deviation. Although a change is observed, the results are not statistically significant.

Although a straight comparison of the exam results is not easy, looking at the distribution of the results shows greater detail. Careful observation suggests that in all classes there are a small number of students greatly underperforming. However, we see that the Fall 2012 course after the math module, has a greater population of grades performing with C or better (at least 70%).

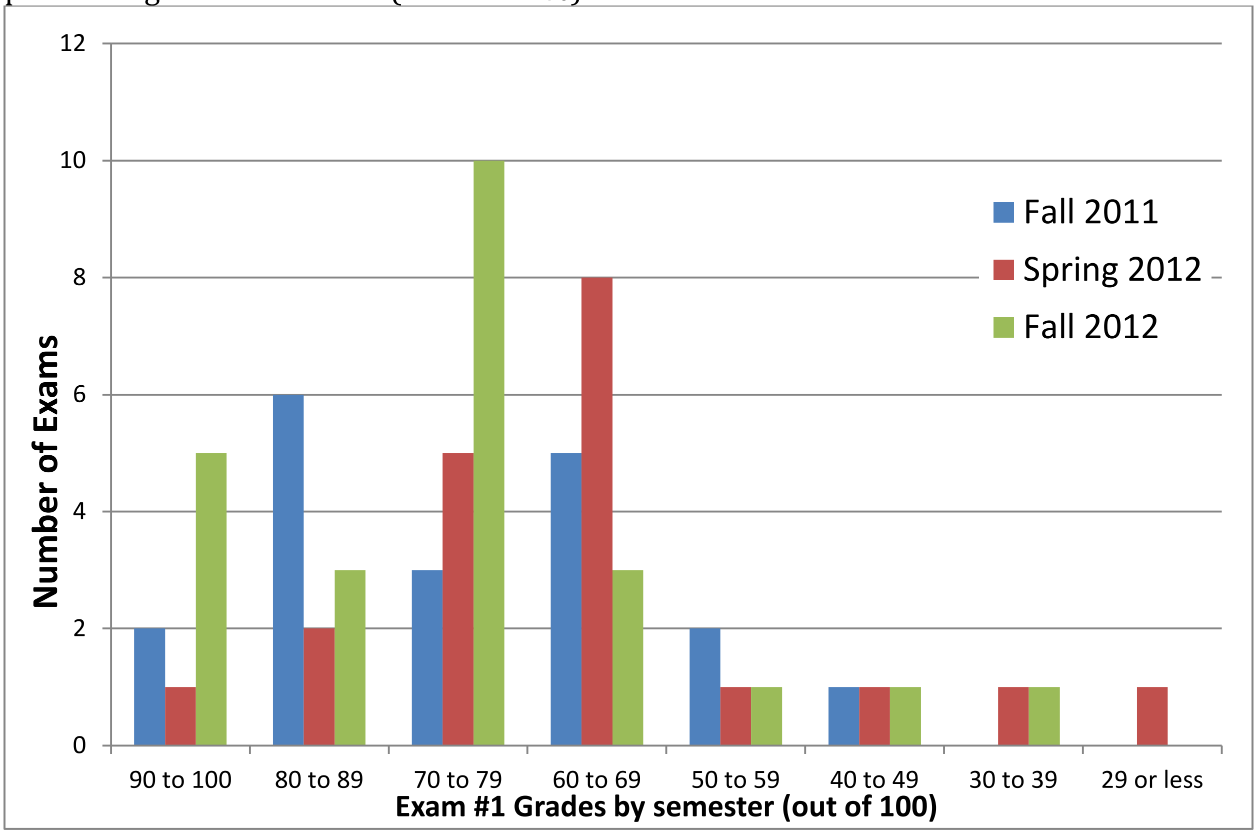


Figure 4. Grades distribution for exam # 1 for the Fall 2012 (after the math module) compared with historical data.

2. Results for the whole course

A comparison of the results for the whole course (not only exam #1) was also carried out. As the course relies heavily on math, it is desirable to also gather some empirical data to measure the module's effectiveness.

When comparing the students' scores, it was observed that there is no evidence of improvement for the students taking the math module. This was in stark contrast with the students' own perceptions (survey). I attribute this to comparing different populations ("apples to oranges") and suggest the need to collect more information.

Table 2. Comparison of the overall course grade for semesters before the implementation of the module to the Fall 2012 semester in which the module was implemented.

Term	Fall 2011	Spring 2012	Fall 2012 – AR Implemented
Average Course Grade	73.1	72.7	74.7
Standard Deviation	11.0	17.0	17.3
Median Score	73	76	78
Number of exams	19	21	25

Figure 5 shows the results from each class compared (ranges of grades). It is observed that quantitatively, there is almost no difference (as suggested by the tables). It can be argued that more data is needed. However, it is interesting to notice that for the course after the math module, a higher frequency of scores in the two highest ranges is observed again. The results are adversely affected by a few outliers in the course that brought the course grade considerably lower. Some of these outliers are students that are disengaged as they know they will fail, or students that miss one or two exams. Having some of these students can greatly change the overall grade distribution.

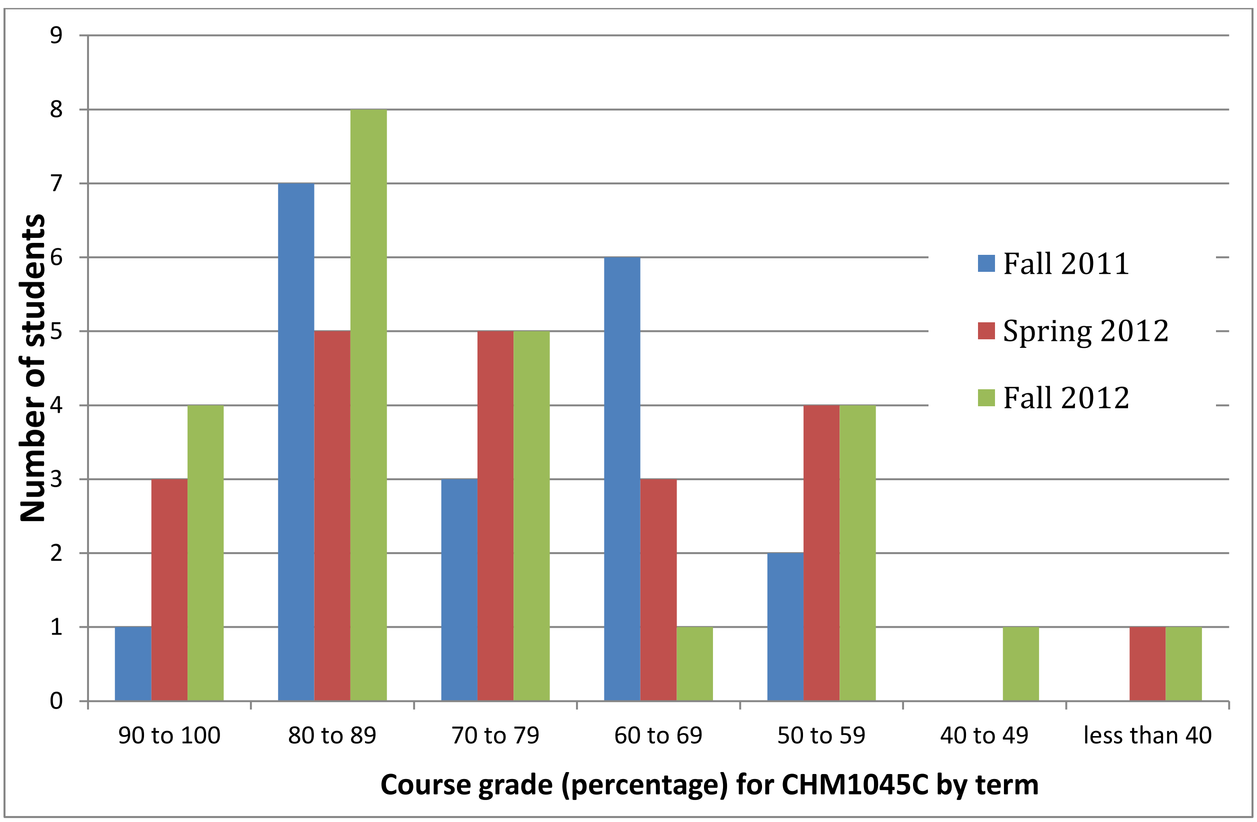


Figure 5. Grade Distribution comparison between CHM1045C with and without the math module being administered.

Reflective Critique

A. General Reflection

The AR project proposed the general idea that the reason why many students fail or perform poorly in chemistry classes can be based on deficient or lacking math skills. It has been my observation during nearly eight years of teaching that many students seem to understand chemistry concepts in a qualitative way (i.e. the students can explain the concepts in their own words), but they fail the exams as they cannot interpret and solve a given chemistry problem. Often, the root of the problem is that the students do not have appropriate math skills. I often observe two trends in my courses: students with strong math skills and poor chemistry fundamentals, and students with a good grasp of the concepts, but weak problem solving skills. The former students tend to succeed in the course as they can apply good problem solving that compensates for the conceptual chemistry misconceptions. However, the latter group falls behind quickly, feels disengaged and performs poorly in class.

The students lacking the appropriate math skills often realize their deficiencies during the semester. Unfortunately, in my opinion, at the point when they realize their problem it may be too late for them to take the necessary actions to overcome their limitations. At that point, the students may have failed one or more exams, have a great workload with the course, or are busy with their other courses. For these students it may be impossible to catch up. It was my hypothesis that if the students were presented from day one with a self-assessment of their math as well as with options to correct their deficiencies (a review module), the students would be able to overcome their shortcomings and perform better in class.

I developed a math review module divided into four units. The module was designed as a very barebones (no theory) list of concepts, suggested practice and resources. In this way, the students would have to take ownership of their own shortcomings. The students were left with the responsibility of self-assessing and addressing their own deficiencies. In my attempt, I did not mean to teach them the subject, but to help them refresh previously learned concepts. I did not offer much explanation of the math concepts. I actually admitted that as a chemistry teacher, I may not be ideally qualified to teach them these math concepts and suggested that the students needed to seek any help as they needed.

The math module was evaluated by a pre-module test, then a series of four take-home quizzes, followed by a post-module test (the same as the pre-module). However, the main purpose of the graded quizzes was not to do a summative assessment, but to make students work on the concepts. It was my feeling that if not graded, the students would lack the motivation to work on the module. Therefore that summative aspect of the grades in the modules was not analyzed. In other words, I did not want to assess the students' success in refreshing the math concepts, but to engage the students in realizing the need to sharpen some of their math skills prior to doing work in chemistry. I analyzed the results of the pre-module and post-module tests. On the first day of class the students were presented a survey and the pre-module test. After four weeks each student completed the module, and on the fifth week the same exam was given (post-module test). I chose the same exam as I wanted to make sure that the students remembered the concepts, rather than testing for new learning. My desired outcome was that they could remember the concepts and apply them properly during the course.

The surveys and the exams showed me several interesting trends. First, there are a relatively high number of students that fear chemistry, and they consider that their skills are not the best to take a chemistry course. This finding correlated well with the number of students that felt like the module did help when asked during the post-survey. A second observation was that most of the students felt that the math module increased their confidence in their preparedness for chemistry; and most students felt that the refresher helped them ease the "chemophobia" or fear of chemistry. However, a third and most interesting observation (in my opinion) was that most students that feared chemistry appeared to be very self-confident on their math skills. Very few students initially appeared to correlate their math skills with their performance in chemistry. This was very striking when compared to the results of the math pre-test. It was observed that the students' performance in the math test prior to the module was not as good as their own perception of their math skills. The average grade was 67 with a median of 65 for a very basic math test. In my own perception, it was striking that the average was the equivalent of a D grade. It was observed that after the module, the test scores improved considerably. The students' performance in Exam #1 was compared to other semesters that did not use the module. A very small improvement in the performance was observed as compared to previous semesters. However, the difference in the outcome for the exam, as well as the comparison of their overall course grades to other semesters did not show any statistically significant difference. I believe that this may be a limitation of comparing the results of different student populations. Also, as the samples are rather small (the CHM1045C class can register only up to 28 students per session), a few outliers (too low or two high) will offset the averages. Looking at the median can help to rule out those outliers, and once again the results showed little improvement. However, based on my own observations and judgment in class, I think that the module was generally effective, but can be improved. I believe that the module actually served two purposes; help the students overcome their math deficiencies in a timely manner, and boost the students' confidence in being prepared for the chemistry course. I am currently working on improving the module for a "second version" to be deployed by the Fall of 2014. Among the changes that I can see are needed:

1. Develop the module fully online, where individual vs. collaborative work can be better controlled. In this module as they are working offline it is difficult to address students that may be copying their classmates and not actually doing the modules.
2. Increase the amount of group work activities based on the modules. I believe that students can help other students learn. Many students are more motivated to learn from their peers. Also, I believe that many students feel "ashamed" to not know some basic math concepts, and in those cases they do not seek help from faculty.
3. I plan to further expand some of the math discussions and try to explain a little of the concepts. I have realized that some topics such as logarithms and exponents tend to prove difficult for students even though they may have learned them earlier. I think that "teaching" some math skills is needed and a refresher may not be sufficient on these topics.

4. Use verbal chemistry problems directly incorporating the math concepts. Many students often lack the motivation to work on the math problems. The students feel like it is unrelated extra work if they signed up to learn chemistry. I want to incorporate problems that relate where the math problems can be applied on chemistry-related situations. This will help the students correlate the importance of the math concepts to the chemistry being learned.
5. Collect more data in order to make a more sensible comparison of performance. I believe that to effectively gauge the effect of the modules more data needs to be collected. I expect to gather more semester-to-semester data as the module progresses. This should help me make more sensible conclusions as to how and where the module can be improved. I see the module as a starting point, and as an ever-improving work to increase the rate of student success in chemistry.

I plan to exchange ideas with other chemistry faculty members and faculty members in math in order to properly address the student deficiencies in math. I want to "build" upon the work of others at Valencia and elsewhere to try to make the module a more valuable resource for students.

In general, I believe that the module is a promising tool, but that it needs more work in order to maximize the impact that it can have on the students.

B. Critical Evaluation of Each Essential Competency in this FLO

1. Assessment

- employ formative feedback loops to assess student learning

Starting on the first day of classes the students were provided a description of the class. In there, I stressed the importance of math for success in chemistry. After my introduction, the students were given the first sets of formative assessments (a survey and the pre-module test). The results of the tests were given back to the students within one week. Also, during the first lecture the students were told about the math module that they must download from Blackboard. As the students began to work on the module, they answered the assignments at the end of each of the four sections of the module. The students were also given some problems to work in groups during lecture. The problems given during lecture were used for students to share ideas and learn from each other. In lecture, I divided the class in groups of three to four students and gave them a problem to work on. I encouraged students to talk, move and share ideas. In the meantime, I stopped by each of the groups, helped them and asked them questions about their answers and thought processes. In this approach, the students were able to learn from their peers and self-assess their learning with little guidance from me. However, in order to assess their individual work, the assignments at the end of each section of the module provided me with a summative assessment, allowing me to measure the students' performance in the math modules. Finally, the students were able to self-assess their learning of the module by a post-survey and a post-test of the module. In this AR project, I implemented such variety of assessments as each one of these offered me as the instructor, and to the students a way to assess the students' skills and their progress. It offered me a way to provide the students with feedback as well as help them self-assess their limitations. The variety of problems (individual and group work) allowed the students to receive feedback from the instructor, from their peers and from their own self-assessment. I was able to use the results of the pre-survey to address their concerns and questions in a practical matter. Understanding the student fears, expectations and goals allowed me to have a more individualized, personal approach to teaching my students. It allowed me to reinforce their learning in math and to better prepare them for chemistry.

- design activities to help students refine their abilities to self-assess their learning

For this FLO the students were given several resources to do a self-assessment of their math skills. First, the students were able to self-assess their previous knowledge by a pre-module survey and pre-module test. These two resources gave the students the chance to gauge their math skills needed for the chemistry course before any chemistry material was covered. It also provided the students with tools that they could use based on their own assessment to overcome any limitations that they may have. After they worked on the module, they were also offered a self-assessment by a post-survey and post-test. The "post" assessments allowed the students to evaluate their own progress with the math skills. I believe that it is important that such self-assessments offer the students a relatively stress-free environment to learn, and enough time to overcome their limitations before they needed to use many of the math skills in the chemistry class. I believe that, in general, there is enough fear of chemistry to begin with, and being able to empower the students and boost their confidence as they self-assess their abilities is a great tool. It is in my opinion a stronger reinforcement of learning for this module than a summative assessment. The greatest asset of this self-assessment is that it shows the students that they have great control over their success. Many students will feel that their preparation is not adequate, but do not know what to focus on, or how to overcome their shortcomings. The pre-test, the pre-survey and the module provided to the students at the beginning of the semester a way to identify their shortcomings. Then, they are also provided with resources to overcome such shortcomings. When combined, I believe that the students can have a good idea of what they need to focus on and how to overcome their shortcomings for the class. One thing that I learned during this FLO is that one single approach to assessment does not fit all. In my teaching I have found that I often need to combine several approaches to assessment and evaluation. I have been able to see how several students benefited from one approach such as homework assignments, while other students benefited from exams, group work, or self-study. I felt it was necessary to expose students to several ways to self-assess themselves and other resources to complement their classroom learning. A thoughtful approach to assessment is needed in order for them to realize their shortcomings .

- make assessment criteria public to students and colleagues

Students were given access to the keys and answers to all of the assessments (summative and formative) in Blackboard. The rubric and grading were explained to the students. I make a great effort to present my students with all the evidence on how they will be evaluated. I make an effort to reward the students' work for accuracy as well as for completion and effort. I believe in openness of communication and that the student has the right to know about his own progress, his deficiencies, and the ways that he can improve his learning. I also believe sharing my ideas on assessment with colleagues can help me devise better ways to measure the students' learning. I strive to share my approaches to assessing student learning with my colleagues as well as my students and always try get feedback on their effectiveness. I plan to offer access to all information pertaining this FLO to all my science colleagues as the module undergoes its revisions, and the rubrics used will be included.

2. Outcomes Based Practice

- construct measurable learning outcomes (this performance indicator must be used in conjunction with at least one other Outcomes-based Practice indicator for demonstration in faculty portfolios)

Through the implementation of this FLO, great emphasis was given on helping students grow in the student core competency of "Think". As a science discipline, the students should be able to do some problem solving, and apply the learned knowledge to solve chemistry problems. In my opinion, students often face great limitations on their critical thinking skills. Many students arrive at Valencia being very apt with memorization of concepts. However, chemistry, as well as most science courses, makes them use the learned knowledge in a critical way: evaluating a given problem. As I teach, the students learn how to analyze and solve a problem ("Think"). With the use of the module, the students are aided in their math skills and how to apply them to solve problems. The work helped the students use facts, formulas and procedures of the discipline (chemistry) and other disciplines (math) and to integrate values from another discipline (math). The students as well as me as the instructor will be able to evaluate their progress during the course and the implemented module. The use of the different assessment methods discussed in the previous section can be used in order to measure the student progress in the student core competencies, especially "Think".

- design assessments that demonstrate student growth in the student core competencies (Think, Value, Communicate & Act) and program learning outcomes

The FLO implementation of a math module truly addresses the student core competencies of Think, Value and Communicate. By applying their math skills in chemistry, the students are involved in "Think", reflected in the principles of: (a) analyze data, ideas, patterns, principles, perspectives, (b) employ the facts, formulas, procedures of the discipline, and (c) integrate ideas and values from different disciplines. This last one is reflected as the students need to use math to solve chemistry problems. The FLO reflects "Value" as students need to properly "employ values and standards of judgment from different disciplines". The FLO helps students grow in the Communicate competency as they will use the math to "communicate in different contexts, settings, and disciplines". In general, this FLO will not only help students improve on their math skills, but will help students grow in Valencia's student core competencies. It has the potential to help students grow in several areas. The combination of the formative and summative assessment methods (pre-test, post-test, module, and exam one) will help measure the students' growth in the aforementioned core competencies.

- use evidence of student learning to review and improve courses and programs (e.g., in classroom, counseling and library settings)

The results from this FLO will be used to further improve "version two" of the math module. My plan is that the math module will become an integral part of CHM1045C (General Chemistry I), and that it will also be eventually applied to CHM1025C (Introductory Chemistry). The analysis of the students' module and exams, and their answers of the post-evaluation can be used to further improve the module. I will be changing the implementation of the module as an online module. By permanently keeping this module in the course, I believe that the ability of the students to learn chemistry will improve. Incorporating a few concepts of applied math into the course can be beneficial for the students in chemistry and as well as for many of their other classes. Being able to address the student deficiencies in math can ultimately help all the chemistry faculty. It can also help us re-evaluate what the pre-requisites for our courses are, and how can we improve student preparedness prior to taking our courses. This FLO can help us learn where our students' shortcomings are, and help us solve them. It can also allow us to overcome some of our shortcomings as educators in chemistry.

3. Scholarship of Teaching and Learning

- produce professional work (action research or traditional research) that meets the Valencia Standards of Scholarship

In the development and implementation of this ARP (and FLO) I have taken special consideration of Valencia Standards of Scholarship at all times. Valencia Standards of Scholarship are based on Glassick, et. al,. *"Scholarship Assessed: Evaluation of the Professoriate"*. I paid close attention to all the aspects that they consider. I have very defined goals that can also be achieved: improve math skills as a way to improve learning of chemistry. I have strived to understand scholarship in the field following the Journal of Chemical Education. By reading the literature, I did realize that my concern with respect to students performing poorly in chemistry due to their limited math skills was shared by many colleagues. I tried to follow some of their recommendations and adapt them to the student population at Valencia. I implemented the AR using the best methods and tools at my disposition, considering the literature, the coursework, and what resources were available to my students. I carefully examined my results and analyzed their significance. Even when a direct statistical comparison is not possible, I have tried to present my results scientifically, concisely and precisely. Finally, I was very critical of my own work, trying to find the best ways to improve the AR going into the future. I want to see this project as just "starting" and see it grow in the near future instead of a "one-and-done" implementation. I have presented future modifications to the math module and to the AR project that may ultimately improve the students' outcomes. I truly believe that helping our students with their math deficiencies will improve their education and their careers.

- build upon the work of others (consult experts, peers, self, students)

The importance of math in learning chemistry has been debated extensively. I have consulted opinions from my colleagues at Valencia and at UCF. I have also consulted colleagues in physics and in math about their challenges with students. I searched extensively the Journal of Chemical Education. Last, I have considered the feedback I get from students, and my own observation of the students' challenges in order to build a body of work for this FLO. I tried to learn what the common shortcomings and the challenges experienced by the students are. I used all this information in the original ARP, and more importantly, I will be using this data in order to improve the module for future implementation. All the data collected allowed me to realize how necessary it is to overcome our students' limitations in math and enable them to learn chemistry. I will also use the data collected to consult with math faculty about how to overcome the students' deficiencies in math. I will use the data collected to consult with chemistry faculty on the best ways to incorporate the math concepts into conceptual problems that are related to chemistry as I envision making the module open to the general community where colleagues at Valencia and other institutions can download the module for their chemistry or other sciences coursework; I also plan to explore the idea that each use can contribute to improving the module. I believe that a type of "Wiki" project can be created, where I am able to accept input and implementations from other colleagues, while maintaining my intellectual property of the work.

- be open to constructive critique (by both peers and students)

It is my intent that the results from this work will be available to others for their use and critique. I plan to disseminate it to my colleagues at Valencia and use their feedback to make a better version of the module. I also plan to use the feedback offered by the students in the surveys to further improve on the module. I am a good listener and I like to engage my students in conversation during office hours, in the laboratory, and after lecture. I like to ask my students for their opinion on things and listen carefully to their opinions on math and chemistry. I value both the faculty and the students concerns and opinions and have used them, and will continue to do so in order to prepare a module tailored to their needs and concerns. I truly believe that this AR and the included math module are a work-in-progress, and I expect to implement new additions and improvements to the module taking into consideration all possible opinions from my peers and from my students.

- make work public to college and broader audiences

It has always been my intent that the results from this work, as well as the products from it (the math module) should be available to colleagues at Valencia, and at other institutions. It is my ideal plan that, in the end, the module will be offered as an open source product where others not only can benefit from it, but the chemistry community in general can make use of it, grow it, and improve it. I will first upload the project in the Action Research builder. Future revisions of the work will be released to other audiences following Valencia's protocols. I expect that in the future, other experts will offer their contribution to expand this module to help chemistry students in different institutions, as well as other science students that may be limited by their math skills It is my desire that in the future, chemistry or science faculty at Valencia or other institutions will be able to download the module, use it and contribute to it.

- demonstrate relationship of SOTL to improved teaching and learning processes demonstrate current teaching and learning theory & practice

In order to adequately follow Valencia Standards of Scholarship, and my own standards as a scientist, I followed the work of many experts in the field. I searched the Journal of Chemical Education. I also read Classroom Assessment Techniques (Angelo). One of the greatest challenges that I have faced, and that I think is common among us, is that we are trained as scientists, not as educators. As a scientist that loves education, I must follow the work of others, the experts in the field. I learned how to develop an Action Research Project (as opposed to a scientific research project). I followed the proper theories of learning and followed the lead of experts in the field. I worked hard on making a module that considered different ways of learning (individual vs. cooperative), different approaches to the subjects, various assessment tools, and in general how to approach students more efficiently. In order to grow as an educator I must learn how to better reach my students, and how to better communicate with my students. I have realized that I must become a better educator and I consider that I am currently learning more aspects of current teaching and learning theory and practice. Valencia's TLA is a great resource that I have been using in order to improve on my teaching skills. I am in the process of training myself as an educator, a journey that will never end while at Valencia.

C. Plan for Dissemination

This project will be presented to my panel as part of my year 2 portfolio (Y-2 meeting). The project will also be uploaded into the Action Research builder. Moreover, I plan to continue expanding this project and share it with colleagues in chemistry and other science disciplines. It is my ultimate goal that this module and the ideas behind it can be applied in a variety of science courses.

D. Supporting Artifacts for FLO#1

Artifact #1: Pre-survey

Perceptions of Preparedness for Chemistry

I. Briefly tell me about your career goals:

1. What is your major (or what is your planned major):____
____
____

2. Where do you see yourself in 5-10 years):____
____
____

II. General Perception of Chemistry:

Question	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)
1. A good knowledge of chemistry will make me a better professional.					
2. A good understanding of chemistry will help my everyday understating of the world.					
3. I will be able to use what I learn in chemistry to enhance my career.					
4. I feel prepared for a chemistry class.					
5. Chemistry is a subject that I am afraid of.					
6. I have no idea why I have to take a chemistry class.					
7. Having good math skills will help me learn chemistry.					
8. Having good math skills will help me learn other science subjects.					

III. General Preparedness for Chemistry

Question	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)
9. I feel that my science knowledge prior to this class is adequate for success in General Chemistry I.					
10. I feel that my math knowledge prior to this class is adequate for success in General Chemistry I.					
11. I know how to properly use a scientific calculator.					
12. I am confident in solving a problem involving logarithms.					
13. I am confident in solving a problem involving powers.					
14. I remember the proper mathematical order of operations.					
15. I can easily solve a linear, 1-variable equation.					
16. I remember how to solve a quadratic equation using the quadratic formula.					
17. I can properly solve problems involving fractions.					
18. I can calculate the area and volume of most basic geometric shapes.					
Additional comments:					

IV. Overall College Experience

Question	Selection	Comments
19. My last semester in college was:	1. Within 1 year 2. 1 to 3 years ago 3. 3 to 5 years ago 4. More than 5 years ago.	
20. I took my last science course:	1. Within 1 year 2. 1 to 3 years ago 3. 3 to 5 years ago 4. More than 5 years ago.	
21. I took my last chemistry course:	1. Within 1 year 2. 1 to 3 years ago 3. 3 to 5 years ago 4. More than 5 years ago.	

Artifact #2: Pre-post test (same test)

CHM1045 Name: ________________________

Math Self-Assessment Fall 2012 - I

Answer the following to the best of your ability. This test is not for grade, but to do an assessment of math background for the class.

1. Solve the following using the correct order of operations:

(a) 1 + 6 x (5 + 4) ÷ 3 – 9 =

(b) $\frac{31-6}{15+6} =$

2. Round each number as indicated

	Rounded to the nearest	Result
37	ten	
815	ten	
689	hundred	
1213	thousand	

3. Midterm exam scores for a small honors chemistry class are provided below. What was the average score on the midterm exam? Round to the nearest hundredth (two decimal places).

87, 99, 75, 87, 94, 78, 85, 88, 91, 93

4. Solve the following fraction problems. Express in simplest form possible (lowest denominators).

(a) $\frac{5}{8}\ x\ \frac{4}{7} =$

(b) $5\frac{1}{8}\ x\ 3\frac{1}{3} =$

5. A house which is assessed for $100,000 pays $3000 in taxes. What should the tax be on a house assessed at $155,000?

6. $\frac{(6x+5)^3}{(6x+5)^2} =$

(a) $(6x + 5)^3$ (b) $6x + 5$ (c) $(6x + 5)^{-1}$ (d) $(6x + 5)^5$ (e) $(6x + 5)^6$

7. Rewrite $7^{m} = n$ as a logarithmic equation.

(a) $\log_{n} 7 = m$ (b) $\log_{7} m = n$ (c) $\log_{m} 7 = n$ (d) $\log_{7} n = m$

8. $e^{\ln 7} =$

(a) ln 7 (b) 7 (c) e^{7} (d) (ln 7) e

9. A fence is being built around a dog pen that measures 16 ft by 20 ft. How many feet of fencing are needed?

10. Solve for x and check: $3x + 5 = 11$

Artifact #3: Math Module

Fall 2012
Dr. Diego J. Díaz
Valencia College
Rev 1. Aug 27, 2012

Chemistry, as the science that studies the properties and transformations of matter, is a science of observation and measurements. We cannot properly learn chemistry without math. This module will provide a quick refresher of some of the math skills that are needed to succeed in chemistry.

Introduction

Welcome to General Chemistry I (CHM1045). I hope that you will find chemistry an exciting subject, and one that you can see relate to everyday life and to your career. Chemistry will be present in many aspects of your life and of your career; from medicine (health sciences) to electronics, from engineering to power generation; there is no wonder why chemistry is often called "The Central Science". However, in order to properly understand chemistry, a good background in mathematics is needed. Many students have taken math classes a long time ago, or may have not learned all the necessary concepts. Perhaps some of you may just need a refresher in mathematics to facilitate learning the most in a chemistry course. This math module does not intend to be a full math course, but to help you, the student, to self-assess your math background and refresh some math skills that are essential to succeed in general chemistry. Notice that in this module there are little to no explanations of the concepts. There are two reasons for this. First, I expect that the concepts in these modules have already been taught, and that you just need to refresh them. Second, as a chemistry educator, I is not my intent to completely teach the math concepts. If you find yourself in the need to learn some of the concepts in greater depth, I strongly advice for you to search your old math textbooks again, use any of the many available online resources (some are listed at the end of this document), or to visit the math tutoring center on campus.

Module 1: Number Relations

I. Order of Operations

Solving a chemistry problem often involves a series of calculations. When a series of calculations is present, we must follow certain rules regarding in which order the calculations must be carried. Whether the calculations should be carried from left to right, top to bottom, etc. is determined by the *order of operations*.

All calculations should be carried in the same order. In High School, you should have learned the proper order of operations. A common technique for remembering the order of operations is the abbreviation "PEMDAS". PEMDAS stands for "Parentheses, Exponents, Multiplication and Division, and Addition and Subtraction". It means that you will first solve terms in parentheses, followed by terms in exponents. After that, multiplications and divisions should be solved in the order that they appear (from left to right, top to bottom), and finally, addition and subtraction should be solved also in the order that they appear.

The exception to the rule is when the problem involves a fraction bar. In that case, you must perform all calculations above and below the bar using the aforementioned rules, and then divide the numerator by the denominator.

For example, what is the "right" answer to:

$25 - 3 \times 4 + 2^2 \times (6 - 1) =$

The proper order of operations state that we will solve $(6 - 1)$ first, followed by 2^2.

$25 - 3 \times 4 + 4 \times 5 =$

The multiplications will follow, finally taking care of the addition and subtraction.

25 – 12 + 20 = 33

II. Rounding

Often we find that after we perform operations, the resulting number has a large number of digits after the decimal point (decimal places). We are usually asked to round the number to a pre-determined number of decimal places. For example, if we look at the operation

5/11 = 0.45454545454

If we are required to round the number to a specific number of decimal places, three for example, we look at the number following the last decimal place of interest.

0.4545454545… =

If the number that follows the last decimal place of interest is a five or larger, then we increase the number in that decimal place by one. If the number that follows the last decimal place is smaller than five, we drop the extra decimal places. In our example, the number after the third decimal place is a 5, the answer then would be: 0.455.

III. Fractions

Fractions are related to decimal numbers. One way to look into fractions is as a division. In a fraction, the top number (numerator) is divided by the bottom number (denominator). In other words, the numerator tells us how many “parts” do we have, and the denominator tells us in “how many parts it was divided”.

Within the scope of a chemistry class, it is very important to consider that we often have to convert a fraction to a decimal and vice-versa. As stated, in order to convert a fraction to a decimal, we just divide the numerator by the denominator and round as appropriate.

Converting decimals to fractions involves more labor. In order to accomplish just that, we need to remember place value. The first decimal place after the decimal is the "tenths" place. The second decimal place is the "hundredths" place. The third decimal place is the "thousandths" place, and so on. For example, if you want to convert 0.35 to a fraction we realize that there are two decimal places, or a place value in the hundredths. We can write our number as 35/100. After we accomplished this, the next step is to simplify our fraction by looking a common factor (if any) that we can use to simplify our fraction.

$$\frac{35}{100} = \frac{7\,x\,5}{20\,x\,5} = \frac{7}{20}\,x\,\frac{5}{5} = \frac{7}{20}$$

The last step of this process is to make sure the fraction is reduced (simplified) all the way. Our fraction is not reduced, so we need to reduce it by finding the largest common denominator, that is, the largest number by which both numerator and denominator can be divided.

IV. Ratios and Proportions

A ratio is a comparison of two similar quantities obtained by dividing one quantity by the other. A ratio can be written by separating the numbers by a colon (:), or written as a fraction. For example, in your chemistry class, out of 28 students, we may have 12 men and 16 women. Then, the ratio of men to women is 12:16 or 12/16. The ratio of women to men would them be 16:12. A ratio, like a fraction, can be simplified by looking for a common denominator. In this particular case, both numbers can be divided by 4, giving a ratio of men to women of:

$$\frac{12}{16} = \frac{3\,x\,4}{4\,x\,4} = \frac{3}{4}$$ or 3:4.

V. Averages

When making an observation or a measurement, we often made several experiments or trials of the same measurement. In those cases, we obtain several numbers with values relatively close to each other. In those cases, we need to find a good representation on how to present the values. We can use the arithmetic mean, more commonly known as average, as a way to present the central tendency of the value. The average can be easily calculated by applying the following formula:

$$Average = \bar{X} = \frac{Sum\ of\ all\ values}{Number\ of\ values} = \frac{S}{N}$$

Practice Problems Module 1.

1. Solve the following using the correct order of operations:

(a) 7 + (3 - 5) + 2 × 8 × 7 =

(b) 1 + 6 x (5 + 4) ÷ 3 – 9 =

(c) $\frac{31-6}{15+6} =$

(d) 25 - 6 ÷ 2 + 6 =

(e) log 1500 – log 125 + 12 x 2^3 =

2. Solve the following and round as instructed.

(a) 0.0577/0.753 = ____________ rounded to three decimal places, or _____________ rounded to four decimal places

(b) $\frac{\sqrt[3]{257}}{3^2} =$ _________ rounded to three decimal places

(c) Round each number as indicated

	Rounded to the nearest	Result
37	ten	
815	ten	
689	hundred	
2481	hundred	
3956	thousand	
3956	hundred	
1213	thousand	

4. Over the course of a week, Luke spent $32.49 on lunch. What was the average cost per day?

(a) $16.24 (b) $3.25 (c) $6.50 (d) $4.64 (e) $5.41

5. Midterm exam scores for a small honors chemistry class are provided below. What was the average score on the midterm exam? Round to the nearest hundredth (two decimal places).

87, 99, 75, 87, 94, 78, 85, 88, 91, 93

6. Solve the following fraction problems. Express in simplest form possible (lowest denominators).

(a) $4\ x\ \frac{3}{7} =$

(b) $\frac{5}{8}\ x\ \frac{4}{7} =$

(c) $5\frac{1}{8}\ x\ 3\frac{1}{3} =$

7. You are going on a trip of four miles, and you have gone two thirds of the way. How far have you gone?

8. A slot machine at a casino paid 93 quarters. How much money is that?

9. There are 7 cupcakes, 2 brownies, and 6 tarts in an oven. What is the ratio of cupcakes to brownies?

10. A house which is assessed for $100,000 pays $3000 in taxes. What should the tax be on a house assessed at $155,000?

11. The length of a highway is 200 miles. If 0.5 inch represents 50 miles in a map, what is the length of the highway on the map?

Module 2. Powers, Exponents and Logarithms

I. Exponents

An exponent can be seen as a repeated multiplication. For example, in 5^3 the three represents the number of times five is multiplied by itself, or 5 x 5 x 5 = 125. In general, the format for using exponents is: $(\text{base})^{\text{exponent}}$, where the exponent tells you how many of the base are being multiplied together. Another way to refer to numbers involving exponents is as a number raised to a power. For example, 5^3 can also be referred to as five to the third power. When working with exponents, we should remember some basic rules for their use.

Rules for the use of exponents:

1. $x^1 = x$
2. $x^0 = 1$
3. $x^{-1} = \frac{1}{x}$
4. $x^{-m} = \frac{1}{x^m}$
5. $x^m x^n = x^{m+n}$
6. $\frac{x^m}{x^n} = x^{m-n}$
7. $(x^m)^n = x^{mn}$
8. $(xy)^m = x^m y^m$
9. $\left(\frac{x}{y}\right)^m = \frac{x^m}{y^m}$
10. $x^{\frac{m}{n}} = \sqrt[n]{x^m} = \left(\sqrt[n]{x}\right)^m$

II. Logarithms

To an extent, logarithms are exponents. A logarithm of a number is the exponent of a base number that equals the original number raised to that exponent. In other words, $\log_a b = x$ means that $a^x = b$. The number represented by the variable "a" is referred to as the base of the logarithm.

The most typically found logarithms are either common logarithms (base 10) or natural logarithms (base e, an irrational number close to 2.72). A common logarithm is usually represented just as log, while the natural logarithm is usually expressed as *ln*. In chemistry you will find two main types of problems involving logarithms. You may have to determine what the value of a specific logarithm is, for example:

$$\log 1000 = 3\ , or \qquad \qquad \ln 125 = 4.83$$

In other instances, you will need to find the number if the logarithm is provided. You will do this by applying the anti-log. For example,

$$\log x = 5\ , \qquad \qquad then\ antilog\ 5 = 10^5 = \ 100{,}000.$$

Similar to exponents, there are some basic rules that apply to logarithms.

Table 1. Rules for the use of logarithms

Common Logarithm	**Natural Logarithm**
$\log xy = \log x + \log y$	$\ln xy = \ln x + \ln y$
$\log\left(\frac{x}{y}\right) = \log x - \log y$	$\ln\left(\frac{x}{y}\right) = \ln x - \ln y$
$\log x^y = \mathrm{y} \log x$	$\ln x^y = \mathrm{y} \ln x$

Although the common and natural logarithms are the most commonly found, a logarithm can exist with any real number as the base. When solving a problem involving different logarithm bases, a change of base is needed, where the base of the logarithm can be changed. To change the base of a logarithm, we use the relation:

$$\log_a x = \frac{\log_b x}{\log_b a}$$

For example, if we want to change the base from natural logarithm to a common logarithm:

$$\ln x = \log_e x = \frac{\log_{10} x}{\log_{10} e} = \frac{\log_{10} x}{0.4343} = 2.303 \log x$$

Practice Problems Module 2

1. Are the following statements true sometimes, always, or never for a, b, c, d, k, l > 0 ?

(a) $(a + b)^2 = a^2 + b^2$

(b) $ca^2 + da^2 = (c + d)a^2$

(c) $a^k a^l = a^{k+l}$

(d) $a^k a^l = a^{kl}$

(e) $(a^k)^l = a^{kl}$

(f) $a^{-2} < 1$

2. Simplify $(5x)^2 + (x^3)^2 + (5x)(2x^3) =$

Which one is true for the following relations:

3. $\frac{(6x+5)^3}{(6x+5)^2} =$

(a) $(6x + 5)^3$ (b) $6x + 5$ (c) $(6x + 5)^{-1}$ (d) $(6x + 5)^5$ (e) $(6x + 5)^6$

4. $(xy)^2\ (xy)^{9}$ =

(a) xy^{11} (b) $(xy)^{18}$ (c) $(xy)^{11}$ (d) xy^{18}

5. $6x^2\sqrt{x} =$

(a) $6x$ (b) $\sqrt{36\,x^3}$ (c) $6x^{5/2}$ (d) $(6x)^{5/2}$

6. $\left(\frac{2}{x}\right)^{-1} =$

(a) $\frac{x}{2}$ (b) $\frac{x^{-1}}{2^{-1}}$ (c) $\frac{-x}{2}$ (d) $\frac{-2}{x}$

7. $[x(y-x)]^{-2} =$

(a) $\frac{x^2}{(y-x)^2}$ (b) $\frac{-x^2}{(y-x)^2}$ (c) $\frac{1}{x^2(y-x)^2}$ (d) $\frac{x^2}{x^2-y^2}$

7. $(3x^2y^4)^3$ =

(a) $3x^5y^7$ (b) $3x^6y^{12}$ (c) $9x^5y^7$ (d) $27x^6y^{12}$

8. Rewrite $\log_a x = w$ as an exponential equation.

(a) $a^w = x$ (b) $a^x = w$ (c) $x^a = w$ (d) $w^a = x$

9. Rewrite $7^m = n$ as a logarithmic equation.

(a) $\log_n 7 = m$ (b) $\log_7 m = n$ (c) $\log_m 7 = n$ (d) $\log_7 n = m$

10. $e^{\ln 7}$ =

(a) ln 7 (b) 7 (c) e^7 (d) (ln 7) e

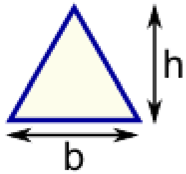
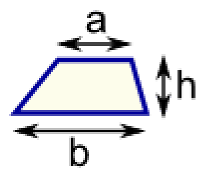
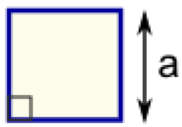
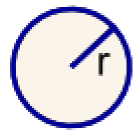
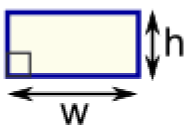
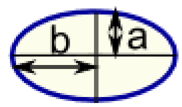
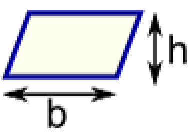
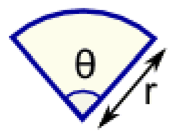
Module 3: Geometry

Geometry can be generally defined as the branch of mathematics that deals with the shape, size, and spatial position of objects. Considering that chemistry is a science of measurements and observations, geometry can take a very important role. From observations of physical phenomena and properties, to the shapes of atoms and molecules in a very small scale, geometry is evident.

I. Volumes and Areas

One of the most important applications of geometry is in the measurement of physical spaces (area and volume) that make up a system under study. The area of a regular shape can be important in instances where for example, a surface must be coated. The area is easily determined from several equations. The volume of regular-shaped containers can also be determined by using several geometric formulas. In the case of irregularly shaped objects, the volume can be determined by measuring the volume they displace in a regular shaped container. For example, if you fill a pool to the top and then get inside the pool, water will spill overboard. The amount of water displaced will equal the amount of space (volume) that you occupied.

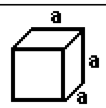
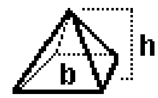
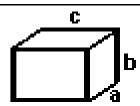
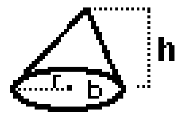
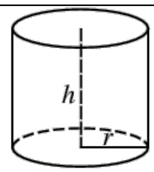
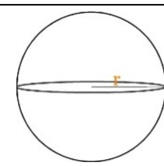
Table 2. Areas of basic geometrical shapes

Geometric Shape	**Formula for Area**	**Geometric Shape**	**Formula for Area**
	Triangle Area = $\frac{1}{2} \times b \times h$ b = base h = height		Trapezoid Area = $\frac{1}{2}(a+b) \times h$ h = vertical height a, b = lengths of parallel sides
	Square Area = a^2 a = length of side		Circle Area = $\pi \times r^2$ r = radius
	Rectangle Area = $w \times h$ w = width h = vertical height		Ellipse Area = $\pi \times a \times b$ a = minor radius b = major radius
	Parallelogram Area = $b \times h$ h = height b = base		Sector Area = $\frac{1}{2} \times r^2 \times \theta$ r = radius θ = angle in **radians***

Source: http://www.mathsisfun.com/area.html

* The radian is the ratio between the length of an arc and its radius. The radian is the standard unit of angular measure.

Table 3. Volumes of basic geometrical shapes

Geometric Shape	**Formula for Volume**	**Geometric Shape**	**Formula for Volume**
	Cube $V = a^3$ a = length of side		Pyramid $V = (1/3)\ b \times h$ b = length of base h = height
	Rectangular prism $V = a \times b \times c$ a,b,c = width, length and height		Cone $V = (1/3)\ b \times h$ $V = 1/3\ \pi \times r^2 \times h$
	Cylinder $V = b \times h = \pi \times r^2 \times h$ r = radius h = height		Sphere $V = (4/3)\ \pi \times r^3$ r = radius

Source: http://math2.org/math/geometry/areasvols.htm

These concepts are of importance when for example you have to answer questions like: How much water is required to fill a pool? How much helium is required to fill a balloon? How much Teflon® is required to coat a non-stick frying pan? How much gauze is needed to cover up a wound? Area and volume measurements are present in everyday situations, and are two of the most common calculations needed in geometry.

When measuring the volume, the SI (International System of Units, abbreviated SI from French: Système international d'unités) uses the cubic meter (m^3). However, more commonly used units are the cubic centimeter (cc, or cm^3) which is equal in magnitude to a milliliter (mL); or the liter (1000 mL).

Another application of geometry that is important in chemistry is that of angles and shapes. We need to realize that molecules exist in 3-D space, and thus the location of atoms in a molecule is important. Are molecules linearly organized? Or are they at an angle? In order to answer those questions, we need to apply the concepts of geometry.

II. Lines, Angles and Planes

Most of the described shapes are created by the combination (intersection) of lines. In order to understand the concepts properly, we should refresh the definitions of a few concepts:

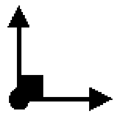
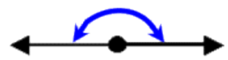
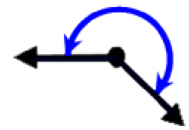
(a) point - a point has no dimension (the point has no length, width, or thickness).

(b) line - has no thickness but its length extends in one dimension and goes on forever in both directions. A line can extend in both directions, or extend from a point towards one direction only (ray).

(c) plane - a plane has no thickness but extends indefinitely in two directions (akin to a piece of paper)

The intersection of two rays creates an **angle**. When the angle measures less than 90°, we call that an acute angle. A 90° angle is a right angle, and one that measures more than 90° is an obtuse angle. A full circumference measures 360°. An angle of 180° is a straight angle, and more than 180° makes a reflex angle.

Table 4. Different types of angles

shape					
name	acute	right	obtuse	straight	reflex
angle	< 90°	= 90°	> 90°	= 180°	> 180°

Source: http://www.regentsprep.org/Regents/math/geometry/GG1/undefinedterms.htm

Practice Problems Module 3

1. Find the area of a circle with radius of 9 cm.

2. A fence is being built around a dog pen that measures 16 ft by 20 ft. How many feet of fencing are needed?

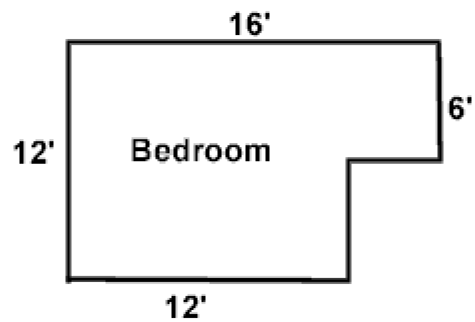
3. An art project requires a triangular piece of paper. The paper is 8 inches in height, and measures 6 inches at the base. What is the area of the paper?

4. Calculate the volume in liters of a cubic container 0.500 meter tall.

5. Soda is sold in aluminum cans that measure 6 inches in height and 2 inches in diameter. How many cubic inches of soda are contained in a full can?

6. When buying a room air conditioner, it is important to purchase a unit that is neither too big nor too small for the room. If the unit is too large, it will cool too quickly and will not remove humidity from the air, thus wasting money and energy. If the unit is too small, it will run continually without ever cooling to the desired temperature, again wasting energy and money.

(a) Find the total cubic feet of living space for the bedroom below. The ceiling is 7 feet high.



(b) Which of these 3 air conditioning models would be the best purchase for this bedroom?

Model A: for rooms 900 to 1100 cubic feet
Model B: for rooms 1100 to 1300 cubic feet
Model C: for rooms 1300 to 1500 cubic feet

Module 4: Basic Algebra

Solving many problems in chemistry will require carrying different types of algebraic manipulations of some mathematical expressions. Algebra can help us simplify mathematical expressions, and to solve for an unknown.

I. Understanding numbers

When numerical representations are used in chemistry we should remember that numbers can be classified into different categories. We must often deal with **real** numbers made up of a series of decimal digits. Real numbers are classified into:

1. natural numbers - are the numbers 1, 2, 3, 4, 5, 6, . . . , 100, . . . , 1000, . . .

2. integers - consist of the natural numbers, the negative natural numbers and 0; or more succinctly: . . . ,−4,−3,−2,−1, 0, 1, 2, 3, 4, . . .
3. rational number - is a number of the form p/q, where p, q are integers and $q \neq 0$
4. decimals - each rational number has a decimal representation (carrying the division). Some rational numbers have a finite decimal expansion whereas other rational numbers have an infinite repeating decimal expansion.
5. irrational numbers - all other numbers that are not rational. These have infinite decimal expansions that are nonrepeating.

II. Solving for an unknown

One thing that we must realize is the meaning of equality on an equation. Both sides of the equal sign will always have equal value. As long as **any operation that you do to one side of an equality is also done at the other side of the expression, the equality will remain.** Using this rule the two sides of the expression remain equal. You can add, subtract, multiply, divide, rise to a power, or take the logarithm and the overall expression will remain equal

Algebraic manipulations of mathematical expressions are mostly based on three basic laws:

1. Commutative Law: $a + b = b + a$, or $ab = ba$
2. Associative Law: $(a + b) + c = a + (b + c)$, or $(ab)c = a(bc)$
3. Distributive Law: $a(b + c) = ab + ac$

Table 5. Examples of algebraic manipulations

Example 1	$x + 6 = 10$ $(x + 6) - 6 = 10 - 6$ $x = 4$	To solve for x, it is necessary to subtract 6 from both sides of the equation
Example 2	$2x - 6 = -3$ $(2x - 6) + 6 = -3 + 6$ $2x = 3$ $x = \frac{3}{2} = 1.5$	To solve for x, you need to add 6 to both sides of the equation and then divide both sides by 2.
Example 3	$\frac{5x + 2}{6} = 2$ $6\left[\frac{5x + 2}{6}\right] = (6)(2)$ $5x + 2 = 12$ $(5x + 2) - 2 = 12 - 2$ $5x = 10$ $\frac{5x}{5} = \frac{10}{5}$ $x = 2$	To isolate x, you need to (1) multiply through by 6, (2) subtract 2 from both sides, and (3) divide both sides by 5.
Example 4	$\frac{2x + 3}{4} = \frac{x + 7}{3}$ $(3)(2x + 3) = (4)(x + 7)$ $6x + 9 = 4x + 28$ $6x - 4x = 28 - 9$ $2x = 19$ $\frac{2x}{2} = \frac{19}{2}$ $x = \frac{19}{2} = 9.5$	Multiply the numerator of one side of the equality by the denominator of the other side of the equality. Use the distributive law, by adding and subtracting, move the x terms to one side, and the non-x terms to the other side in line 5. Use the associative law to simplify and divide both sides by 2.

Source: http://www.chem.tamu.edu/class/fyp/mathrev/mr-algeb.html

III. The quadratic expression

When solving problems in chemistry, we often need to solve a quadratic equation in the form:

$$0 = ax^2 + bx + c$$

where a, b, and c are real numbers. For solving a quadratic equation we must use the quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

When solving an equation using the quadratic formula two answers or roots are obtained (due to the ± in the equation). When dealing with a quadratic formula in experimental data, it is often found that only one of the answers will make physical sense, and thus be used (the other root may give negative concentrations, negative sizes, etc).

IV. Dimensional Analysis

When solving problems we can often apply our learning of algebra into a problem solving technique named “Dimensional Analysis” or the “Factor-Label Method”.

Dimensional analysis relies on the fact that multiplying an expression by “one” will not change the value. We can use unit factors (conversion factors) that allow us to change one unit to another, without changing the value.

For example: How many centimeters are in 10.00 inches?

First, we need to determine a unit factor (equality) that will help us change the units. In this case, we know (given) that 1 inch is equal to 2.54 cm. We can write this as a unit factor:

$\frac{1\ in}{2.54\ cm}$ or $\frac{2.54\ cm}{1\ in}$; and, as we are interested in cancelling the inches, we will choose the unit factor as written in the later form:

$$10.00\ in\ \left(\frac{2.54\ cm}{1\ in}\right) = 25.40\ cm$$

This technique is commonly applied to many types of chemistry problems.

Practice Problems Module 4

1. Which statement is *not* true for the set of integers?

(a) The set of integers is closed under multiplication.

(b) The set of integers is closed under division.

(c) Every integer has an additive inverse.

(d) Every integer has a multiplicative identity.

2. Operation * is defined to be a * b = | b - 2a |. What is the value of 8 * 5?

(a) 11 (b) -11 (c) 2 (d) -2

3. Which of the following is not true?

(a) 16.701 < 16.71 (b) 53.23 = 53.2300

(c) 25.500 > 25.5 (d) 5.225 > 5.215

4. If x = -2 and y = 8, find the value of x^2y^3

5. Find the value of $(2x - 6)^0$ when *x* does not equal 3.

(a) 0 (b) 1 (c) 3 (d) it varies

6. Solve for *x* and check: $3x + 5 = 11$

7. Solve for *x*: $2x + 1.8 = 4x - 4.4$
8. Solve for *x*: $2x^2 + 4 = 9x$

9. Solve for x:
$$\frac{x-2}{x-1} = \frac{x+4}{2x+2}$$

10. Solve for *x* : $\log_6 (x - 1) = 2$.

(a) $x = 3$ (b) $x = 37$ (c) $x = 13$ (d) $x = 65$

Additional Resources

The internet provides innumerable resources for you to refresh your math skills. One quick search on Google will yield a great number of excellent resources. In this module, I wanted to suggest a few of those online resources where you can learn some additional math concepts that will help you in chemistry, as well as in any other science class.

General Math and Chemistry

http://faculty.ccbcmd.edu/~cyau/TutorialMathReviewForGenChemISp2006.pdf
http://www.files.chem.vt.edu/chem-ed/general/math.html
http://www.shodor.org/unchem/math/index.html
http://www.chemtutor.com/numbr.htm
http://www.chem.tamu.edu/class/fyp/mathrev/mathrev.html
http://www.tutor-homework.com/notes_exams_quizzes.html
http://chemistry.about.com/od/homeworkhelp/Chemistry_Homework_Help.htm
http://www.khanacademy.org/
http://www.mathsisfun.com/

General Math

http://www.opensourcemath.org/
http://www.chemreview.net/download_instructions.htm
http://www.mathgoodies.com/lessons/vol7/order_operations.html
http://www.cottonchemistry.bizland.com/mathreview/Math%20Review.ppt
http://proton.csudh.edu/Math_Review/mathreview.html

Geometry

http://math2.org/math/geometry/areasvols.htm
http://math.about.com/od/formulas/ss/surfaceareavol.htm
http://www.mathsisfun.com/area.html
http://www.regentsprep.org/Regents/math/geometry/GG1/undefinedterms.htm

Algebra

http://www.math.uakron.edu/~dpstory/mpt_home.html
http://www.chem.tamu.edu/class/fyp/mathrev/mr-algeb.html
http://www.stewartcalculus.com/data/default/upfiles/AlgebraReview.pdf

http://regentsprep.org/Regents/math/ALGEBRA/AO5/LExp.htm
http://linear.ups.edu/curriculum.html

As mentioned, these are just a few of the many excellent resources available to you on the internet. Please, feel free to explore and do not let math get in the way of your success in chemistry or any science course.

Artifact #4(a): First Assignment on Math Module

1. Solve the following using the correct order of operations:

(a) $7 + (3 - 5) + 2 \times 8 \times 7 =$

(b) $1 + 6 \text{ x } (5 + 4) \div 3 - 9 =$

(c) $\frac{31-6}{15+6} =$

(d) $25 - 6 \div 2 + 6 =$

(e) $\log 1500 - \log 125 + 12 \text{ x } 2^3 =$

2. Solve the following and round as instructed.

(a) 0.0577/0.753 = ____________ rounded to three decimal places, or _____________ rounded to four decimal places

(b) $\frac{\sqrt[3]{257}}{3^2} =$ ________ rounded to three decimal places

(c) Round each number as indicated

	Rounded to the nearest	Result
37	ten	
815	ten	
689	hundred	
2481	hundred	
3956	thousand	
3956	hundred	
1213	thousand	

4. Over the course of a week, Luke spent $32.49 on lunch. What was the average cost per day?

(a) \$16.24 (b) \$3.25 (c) \$6.50 (d) \$4.64 (e) \$5.41

5. Midterm exam scores for a small honors chemistry class are provided below. What was the average score on the midterm exam? Round to the nearest hundredth (two decimal places).

87, 99, 75, 87, 94, 78, 85, 88, 91, 93

6. Solve the following fraction problems. Express in simplest form possible (lowest denominators).

(a) $4\ x\ \frac{3}{7} =$

(b) $\frac{5}{8}\ x\ \frac{4}{7} =$

(c) $5\frac{1}{8}\ x\ 3\frac{1}{3} =$

7. You are going on a trip of four miles, and you have gone two thirds of the way. How far have you gone?

8. A slot machine at a casino paid 93 quarters. How much money is that?

9. There are 7 cupcakes, 2 brownies, and 6 tarts in an oven. What is the ratio of cupcakes to brownies?

10. A house which is assessed for \$100,000 pays \$3000 in taxes. What should the tax be on a house assessed at \$155,000?

11. The length of a highway is 200 miles. If 0.5 inch represents 50 miles in a map, what is the length of the highway on the map?

Artifact #4(b): Second Assignment on Math Module

1. Are the following statements true sometimes, always, or never for a, b, c, d, k, l > 0 ?

(a) $(a + b)^2 = a^2 + b^2$

(b) $ca^2 + da^2 = (c + d)a^2$

(c) $a^k a^l = a^{k+l}$

(d) $a^k a^l = a^{kl}$

(e) $(a^k)^l = a^{kl}$

(f) $a^{-2} < 1$

2. Simplify $(5x)^2 + (x^3)^2 + (5x)(2x^3) =$

Which one is true for the following relations:

3. $\frac{(6x+5)^3}{(6x+5)^2} =$

(a) $(6x + 5)^3$ (b) $6x + 5$ (c) $(6x + 5)^{-1}$ (d) $(6x + 5)^5$ (e) $(6x + 5)^6$

4. $(xy)^2 (xy)^9 =$

(a) xy^{11} (b) $(xy)^{18}$ (c) $(xy)^{11}$ (d) xy^{18}

5. $6x^2 \sqrt{x} =$

(a) $6x$ (b) $\sqrt{36\, x^3}$ (c) $6x^{5/2}$ (d) $(6x)^{5/2}$

6. $\left(\frac{2}{x}\right)^{-1} =$

(a) $\frac{x}{2}$ (b) $\frac{x^{-1}}{2^{-1}}$ (c) $\frac{-x}{2}$ (d) $\frac{-2}{x}$

7. $[x(y - x)]^{-2} =$

(a) $\frac{x^2}{(y-x)^2}$ (b) $\frac{-x^2}{(y-x)^2}$ (c) $\frac{1}{x^2(y-x)^2}$ (d) $\frac{x^2}{x^2 - y^2}$

8. $(3x^2y^4)^3 =$

(a) $3x^5y^7$ (b) $3x^6y^{12}$ (c) $9x^5y^7$ (d) $27x^6y^{12}$

9. Rewrite $\log_a x = w$ as an exponential equation.

(a) $a^w = x$ (b) $a^x = w$ (c) $x^a = w$ (d) $w^a = x$

10. Rewrite $7^m = n$ as a logarithmic equation.

(a) $\log_n 7 = m$ (b) $\log_7 m = n$ (c) $\log_m 7 = n$ (d) $\log_7 n = m$

11. $e^{\ln 7} =$

(a) ln 7 (b) 7 (c) e^7 (d) (ln 7) e

Artifact #4(c): Third Assignment on Math Module
1. Find the area of a circle with radius of 9 cm.

2. A fence is being built around a dog pen that measures 16 ft by 20 ft. How many feet of fencing are needed?

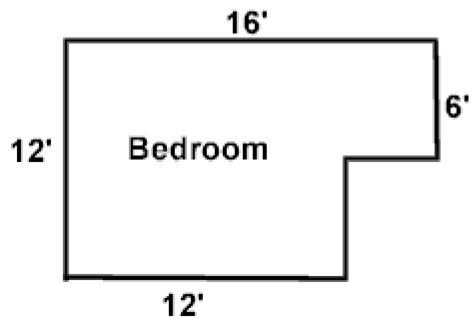
3. An art project requires a triangular piece of paper. The paper is 8 inches in height, and measures 6 inches at the base. What is the area of the paper?

4. Calculate the volume in liters of a cubic container 0.500 meter tall.

5. Soda is sold in aluminum cans that measure 6 inches in height and 2 inches in diameter. How many cubic inches of soda are contained in a full can?

6. When buying a room air conditioner, it is important to purchase a unit that is neither too big nor too small for the room. If the unit is too large, it will cool too quickly and will not remove humidity from the air, thus wasting money and energy. If the unit is too small, it will run continually without ever cooling to the desired temperature, again wasting energy and money.

(a) Find the total cubic feet of living space for the bedroom below. The ceiling is 7 feet high.



(b) Which of these 3 air conditioning models would be the best purchase for this bedroom?

Model A: for rooms 900 to 1100 cubic feet
Model B: for rooms 1100 to 1300 cubic feet
Model C: for rooms 1300 to 1500 cubic feet

Artifact #4(d): Fourth Assignment on Math Module

1. Which statement is *not* true for the set of integers?

(a) The set of integers is closed under multiplication.

(b) The set of integers is closed under division.

(c) Every integer has an additive inverse.

(d) Every integer has a multiplicative identity.

2. Operation * is defined to be a * b = | b - 2a |. What is the value of 8 * 5?

(a) 11 (b) -11 (c) 2 (d) -2

3. Which of the following is not true?

(a) 16.701 < 16.71 (b) 53.23 = 53.2300

(c) 25.500 > 25.5 (d) 5.225 > 5.215

4. If x = -2 and y = 8, find the value of x^2y^3

5. Find the value of $(2x - 6)^0$ when *x* does not equal 3.

(a) 0 (b) 1 (c) 3 (d) it varies

6. Solve for *x* and check: $3x + 5 = 11$

7. Solve for *x*: $2x + 1.8 = 4x - 4.4$

8. Solve for *x*: $2x^2 + 4 = 9x$

9. Solve for x:

$$\frac{x-2}{x-1} = \frac{x+4}{2x+2}$$

10. Solve for *x* : $\log_6 (x - 1) = 2$.

(a) $x = 3$ (b) $x = 37$ (c) $x = 13$ (d) $x = 65$

Artifact #5: Post-survey

1045 Post-Survey – Preparedness for Chemistry

I. Briefly tell me about your career goals:

1. What is your major (or what is your planned major):

____

____

II. General Perception of Chemistry:

Question	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)
1. In the class I developed an understanding of chemistry that will help my career.					
2. The chemistry learned will help me with my other science classes.					
3. The class has made me redefine my future (career) goals.					
4. The class helped me ease my fears of chemistry.					
5. Chemistry now seems relevant to my goals.					
6. Chemistry now seems relevant to my life.					

III. General Preparedness for Chemistry

Question	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)
7. My prior knowledge of **chemistry** was adequate for this class.					
8. My prior knowledge of **math** was adequate for this class.					
9. The math module helped me realize the importance of math for this class.					
10. The math module helped me refresh the math skills that I needed for the class.					
11. The math module increased my confidence on being prepared for the class.					
12. The math module did not provide me any benefits for the class.					

Additional comments:

Artifact#6 Exam #1
(Note: Spacing is reduced on the Artifact compared to actual exam)

CHM1045C
Exam # 1 (Chapters 1-3)

Name: ______________________
Fall 2012

Please follow instructions carefully. Show your work to receive full credit. Answer questions to the correct number of significant figures.

1. Average measurements show that one gram of carbon contains 50,200,000,000,000,000,000,000 atoms.

(a) How many significant figures are in the number? __________

(b) Express the number in scientific notation. __________________

(c) The total attendance to the UCF vs. Ohio State football game on Sept. 8 was 104,745. How many significant figures are in the number? (Think carefully!)

2. Perform the following mathematical operations and express to the correct number of significant figures (don't forget the units if present):

(a) 7.214 + 1.602 – 2.2 =

(b) 3.152 ÷ 12.310 x 12.0 =

(c) $\frac{158.95 \ x \ 0.7128}{30.15 \ x \ 9.13} =$

3. Convert the following measurements as indicated:

(a) Your favorite cookbook is from the French Culinary Institute. If a recipe calls for the oven to be at 163°C, but your American-made oven has temperatures in °F, to what temperature do you need to heat the oven in °F?

(b) Mount Everest, the highest elevation on Earth is 29, 029 feet high. What is the elevation in meters?

(c) If an automobile airbag inflates in 25 μs, what is the time in seconds?

(d) An economy car has an EPA highway mileage rating of 22 km/L. What is the mileage rating in miles per gallon?

4. Bromine (used to make silver bromide, the important component of photographic film) has two naturally occurring isotopes, $^{79}_{35}Br$ and $^{80}_{35}Br$. $^{79}_{35}Br$ has a mass of 78.918 amu and a percent abundance of 50.69%. The other isotope ($^{80}_{35}Br$)has a mass of 80.916 amu and a percent abundance of 49.31%. Calculate the atomic mass of bromine. Show your work to receive credit!!

5. How many electrons, protons, and neutrons are present in the following isotopes:

(a) $^{80}_{35}Br$

(b) $^{23}_{11}Na^{+}$

6. Naming compounds:

(a) What is the name for the following ionic compound: NH_4Cl? ________________________

(b) What is the formula xenon hexafluoride? _____________________________

(c) What is the name for $Fe_2(SO_4)_3$? _______________________________

(d) What is the formula for nitric acid? _____________________________

(e) What is the name for SiF_4? _____________________________

7. Balance the following chemical equation:

$$\_\_\_ \ C_4H_{10}O_{(g)} + \_\_\_ \ O_{2\,(g)} \longrightarrow \_\_\_ \ CO_{2\,(g)} + \_\_\_\_ \ H_2O_{\,(g)}$$

Bonus:
Calculate the length of a copper wire having a diameter of 0.200 cm and a mass of 15.620 g. The density of copper is 8.92 g/cm^3. (Given: volume = $\pi d^2 L/4$, where $\pi = 3.14$, d = diameter, and L = length)

Unit Factors and Conversions

°F = 1.80 (°C) + 32
°C = (°F – 32) / 1.8
°K = °C + 273

1 m = 1.0936 yards
1 yard = 3 feet
1 inch = 2.54 cm
1 mile = 1.609 km
1 feet = 12 inch

1 quart = 0.94635 L
1 quart = 32 ounces
1 gal = 3.785 L

1 kg = 2.205 pounds (lbs)
1 pound = 453.6 g
1 pound = 16 ounce