Impact of Quick Review of Math Concepts in General Chemistry Courses: Engaged Student Learning

Jayashree S. Ranga
Department of Chemistry and Physics, Salem State University, 352 Lafayette Street, Salem, MA 01970.
Email: jranga@salemstate.edu

Abstract

Math proficiency is a vital skill for mastering concepts in General Chemistry courses. In this article, the author discusses simple yet powerful, pedagogical interventions implemented in General Chemistry courses to assist students with math. (a) A quick review of math concepts essential for solving chemistry problems has led to positive learning experiences in General Chemistry courses. This includes topics such as rearranging equations, exponents, etc. (b) A major challenge in General Chemistry courses include improper use of calculators. A quick discussion emphasizing the importance of parentheses/various function keys on calculators has led to efficient problem solving sessions. (c) Problem-solving skills are one of the most important skills acquired in these courses. Students learn how to read a problem, identify the given content, and then proceed to solve the problem. To alleviate stress during the problem solving sessions, pedagogies such as *pause method* were explored. Sample math review content, tips for using a calculator effectively, and problem solving strategies used in General Chemistry courses will be presented in this article.

Introduction

Math is an integral part of STEM courses. Applying math concepts to chemistry is extremely important while mastering problem solving skills in chemistry.[1,2] Math hinders some students from appreciating chemistry in chapters such as unit conversions, stoichiometry, kinetics, equilibrium, etc. Students struggling with math quickly develop a fear of these concepts and eventually lose interest in chemistry.[3] For some students, math makes problem solving a stressful experience in General Chemistry courses. Many books have served as valuable references to assist students with math for chemistry.[3,4]

There are multiple math concepts such as simple algebra, logarithms, etc. used in General Chemistry courses where students face challenges. Sample situations include use of calculators to plug in exponents correctly, use of calculators to divide numerators and denominators, rearranging equations, using logarithms to determine pH values, etc. When students solve chemistry problems using the aforementioned math topics, they determine incorrect values due to simple math mistakes. As an instructor, I have always explored ways to address math concerns in my General Chemistry courses.

Initially, I tried giving math quizzes/handouts before the start of the course/chapters, with limited success. Most students wanted to excel on these quizzes, and some of them actually did excel by seeking extra help during my office hours. This

inspired me to run quick math concept reviews in my classes. Currently, I review relevant math content just before the start of chapters or during the problem solving sessions. This has alleviated math phobia during problem solving. I have realized that this exercise is an investment, rather than an expenditure of my class time. The net result is, students are more confident about math content during the problem solving sessions.

Details regarding some of the helpful interventions in my classrooms are discussed in the next section. Interestingly, past studies have suggested that extended math courses might provide extra time for students to master math contents required for future STEM courses.[5] Here is an attempt to provide a quick refresher on math concepts before the introduction of chemistry concepts, thus preparing students for problem solving.

A survey was given to students in a General Chemistry course (Spring 2017). One of the questions asked during the survey was related to challenges in the course.

Question: "Describe the biggest challenge in the class" (read as course).

Some of the student responses are presented below.

"Use of calculator with larger problems."

"Math"

"I found the first few sections to be a challenge because of the rearrangement of formulas. If i rearranged it wrong, I got the answer wrong"

"The biggest challenge would be trying to remember what equation to use and how to completely understand the concept of it."

"My biggest challenge would have to be using the correct amount of sig figs"

Valuable feedback from students over the years has prompted me to invest my class time in reviewing math concepts. Various concepts reviewed during these courses are presented in the next section.

Review of math concepts in General Chemistry courses

As an instructor, I felt math reviews were a valuable use of my class time. Student misconceptions were identified either (a) through formative assessments and/or (b) during problem solving sessions.

(a) Formative assessments were simple multiple-choice problems on Canvas (Learning Management System). Students completed these problems (multiple choice questions) before the start of the chapter. They had one attempt to complete the simple homework problems and could not see the questions again. Based on the results from the homework, challenges/misconceptions were identified and addressed during class time. Problems similar (but not identical) to homework problems were discussed. The same problems were then assigned after the class to assess students' learning from class. Simple problems used during formative assessments were correlated to short-term learning.

(b) Problem solving sessions: Class lectures were mostly problem solving sessions. Students were assigned problems and asked to work in teams. As teams performed the

calculations, I walked around the classroom. If students were struggling with math or calculators, I presented the calculation or the use of calculator to the whole class.

Key advantages of these math review sessions included:
(a) The review sessions took ***about five minutes*** of class time.
(b) Math review concepts were carefully picked based on student needs. The concepts were not predetermined. The concepts were identified from formative assessments before the start of the chapter or during problem solving sessions in class.
(c) Students incorporated their learning into their problem solving right away.

A number of instances when math reviews were helpful to students are presented below. In each of these cases, challenges faced by the students, the context of the chemistry content, steps presented to students as a part of math review, and impact on student learning through formative assessments (if available from Spring 2016) are presented. Towards the end of the semester, long-term learning was assessed using final exam scores (Summative assessments).

Case 1: Exponents (and Powers)

Math challenge: In problems similar to the given example, some students struggle how to input exponents into calculators. Which buttons should they use?

Problem: Solve $10^{-2} * (10^{-5})^2 = ????$

Intervention: During lectures on unit conversions, kinetics and/or equilibrium, I demonstrate the use of a calculator. I stress the (a) use of parentheses, and (b) how to plug in exponents etc. using TI 30X calculators (a common type of calculator among my students).

Steps:
- Use Shift or 2nd button in TI30X calculator
- Algorithm: (2ndEE-2)*((2ndEE-5)^2) =
- Highlight the importance of parentheses and Shift or 2nd button on the calculator

Formative Assessment Results: Before the lecture, 10% of the students were confused about exponents. After the lecture, almost all the students had a better understanding of exponents.

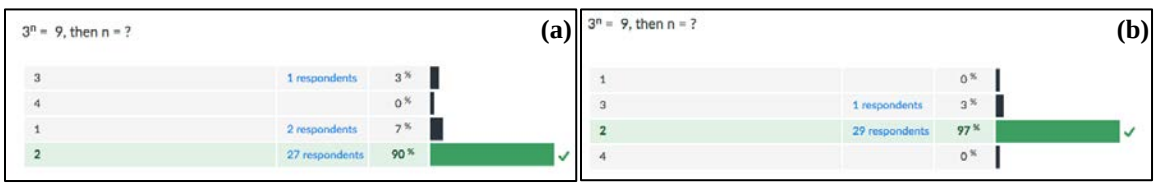

Figure 1: Formative assessment results related to exponents (a) before and (b) after the lecture during Spring 2016.

Case 2: Unit Conversions

Math challenge: In problems similar to the given example, my experience shows that students forget to plug parentheses into their calculators. This leads to wrong results due to incorrect handling of numerators and denominators.

Problem:

$$\frac{50\ \text{mg}}{} \left| \frac{1 * 10^{-3}\ \text{g}}{1\ \text{mg}} \right| \frac{1\ \text{ng}}{1 * 10^{-9}\ \text{g}} = ????$$

Intervention: During lectures on unit conversions, I demonstrate the importance of parentheses and isolation of exponents using colors. Elsewhere, I have discussed the use of colors chalks or pens during my teaching, which aids better visualization.[6]

Steps:

1. 1 mg = 1 * 10^{-3} g, 1 ng = 1 * 10^{-9} g
2. Pool numbers and exponents separately as demonstrated below
3. Add parentheses
4. Calculate numerator, then denominator, separately (especially helpful when numbers are *not 1*)
5. Divide numerator by denominator

$$\frac{(50 * 1 * 1)}{(1 * 1)} \frac{(10^{-3})}{(10^{-9})}$$

Case 3: Choosing the correct equation

Math challenge: When problems are presented to students, based on the given information, students find it difficult to identify the correct equation.

Problem: Choose the correct equation to solve the problem.

Intervention: During in-class activities, I designed something I call the *pause method*.[6] Students take a pause for a moment when they see a number, write it down, and continue working on the rest of the problem. Finally, they look for what needs to be calculated. Based on this exercise, they identify what is given and what they need to calculate, and determine the relevant equation to use.

Steps:

- Identify what is given and what needs to be calculated
- Find an equation that connects the given and to be determined parameters

Formative Assessment Results: Before the lecture, only 63% of the students were able to identify the correct equation. After the lecture, ~ 96% got the right answer.

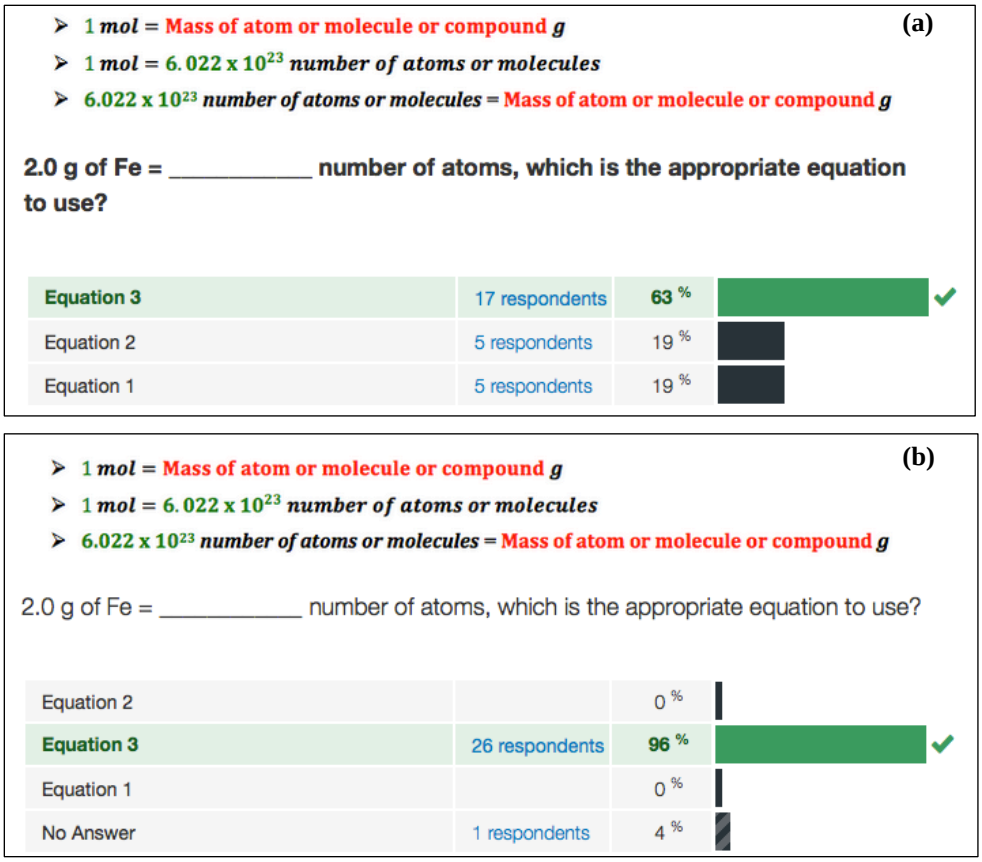

Figure 2: Formative assessment results related to choosing the correct equations (a) before and (b) after the lecture during Spring 2016.

Case 4: Rearranging equations

Math challenge: How should the equations be rearranged to determine unknown parameters?

Problem: Calculate n_1 in the given problem.

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Intervention: I use colors to distinguish between given and unknown parameters.

Steps:

- Rearrange equation as $V_1\ n_2 = V_2\ n_1$
- Next, rearrange the equation with known and unknowns on each side
- Plug in values

$$\frac{V_1\ n_2}{V_2} = n_1$$

Case 5: Logarithms, inverse logarithms and natural log

Math challenge: In the chapter on acids and bases, when working with the pH of acids and bases, there is a lot of confusion regarding the use of logarithms and inverse logarithms.

Problems:
1. Calculate the pH of 1.0×10^{-2} M HCl.
$pH = - \log [H_3O^+]$

2. If pH = 3.3, Calculate $[H_3O^+]$
$[H_3O^+] = 10^{-pH}$

Intervention: I quickly demonstrate how to run *log* and *inverse log* using calculators. I highlight the power of the shift button on the calculator.

Steps:
Problem 1:
- Algorithm -log (2^{nd} EE-2) =
- Highlight the importance of parentheses

Problem 2:
- For inverse log use the shift button
- Algorithm is 2nd 10^x (-3.3) = OR 10 ^ (-3.3)
- Highlight the importance of parentheses

Note: When we discuss thermodynamics, some students get confused between ln (natural logarithm) and log (common logarithm). I demonstrate how to use LN button on calculators.

Natural logarithms (ln): use LN function on your calculator.

Case 6: Word problems

Math challenge: Word problems! When problems are presented to students as sentences, students feel overwhelmed by the problems. Students struggle to break down the problem and proceed with the calculations.

Problem:
My car travels 40 miles per gallon. I drove from Boston to New York and back in my car. Distance between Boston and NYC is about 220 miles. If the gas price is $2.30/ gallon of gas, calculate the gas cost for the round trip. Choose the closest answer!
(a) $ 25.3
(b) $ 0.41
(c) $ 3800
(d) $ 12.7

Intervention: Pause method was used in class. Students pause for a moment when they see a number, write it down, and look for what needs to be calculated.

Steps:
When this problem was assigned before the lecture, a significant number of students did not bring me back from NYC! Once the pause method was discussed in class, they started paying attention to the problem and the right answer was obtained.

Formative Assessment Results: Before the lecture, only 59% of the students got the right answer. After the lecture, 96% of the students got the right answer.

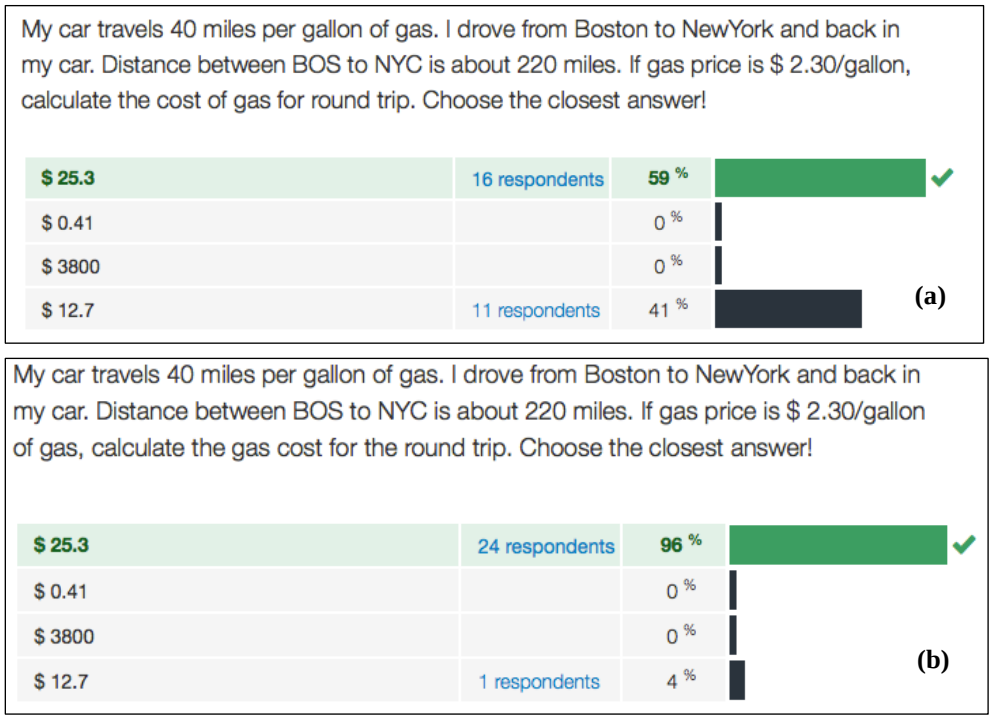

Figure 3: Formative assessment results related to word problems (a) before and (b) after the lecture during Spring 2016.

Case 7: Significant figures in General Chemistry II

Math challenge: Significant figures and retention of content from General Chemistry I during General Chemistry II courses.

Problem:
The pressure in a boiler at a chemical plant is 2.00 atm. Express the pressure in psi.
(a) 29.40 psi
(b) 760 psi
(c) 29.4 psi
(d) 29 psi

Intervention: In class we quickly review the rules for significant figures for various mathematical operations.

Steps:
- For addition and subtraction, the least number of significant figures after the decimal place decides the number of significant figures.
- For multiplication and division, the least number of total significant figures decides the number of significant figures.

Formative Assessment Results: Before the lecture, 16% of the students did not pay attention to the number of significant figures. After the lecture, ~ 97% of the students got the correct answer.

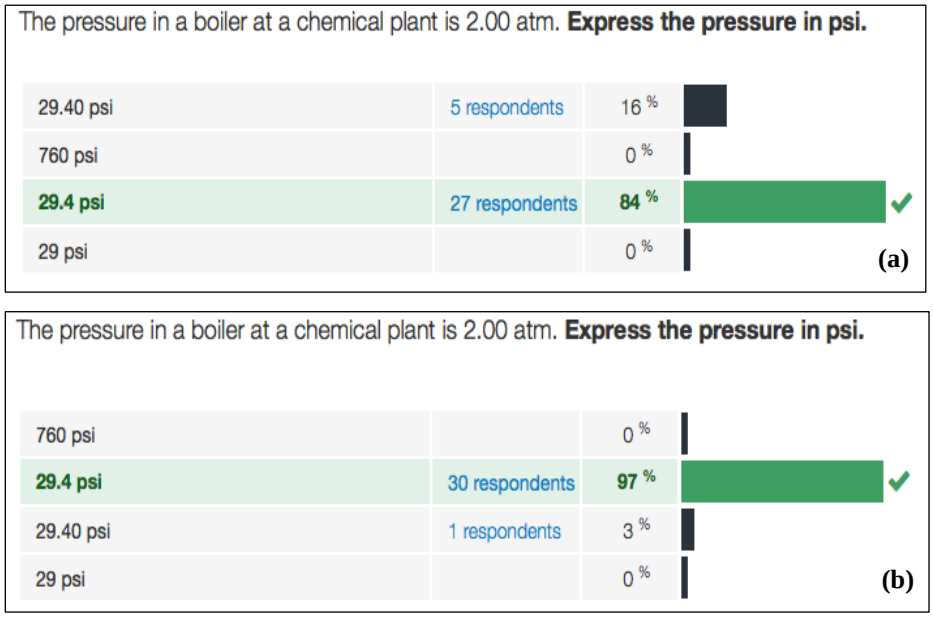

Figure 4: Formative assessment results related to significant figures (a) before and (b) after the lecture during Spring 2016.

Summative assessments:

Summative assessments were challenging, cumulative, and open format problems (not multiple choice questions) as opposed to simple problems assigned during formative assessments. Students were assessed during the final exam of the course. Student performance during the final exam in the aforementioned topics is presented below. As one would expect, many parameters influence the performance of students during the final exam. Regardless, good retention of material was observed at the end of the semester. Similar results were observed in teacher developed CPT (Chemistry Progress Test) in 10^{th} and 11^{th} grade chemistry courses.[7]

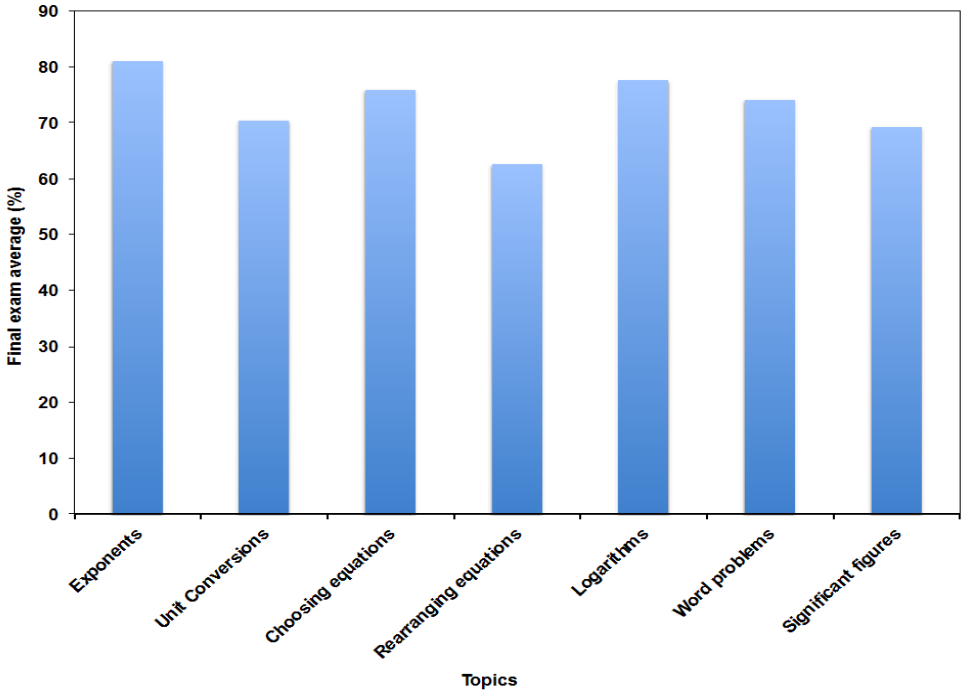

Figure 5: Summative assessment results during the final exam in the aforementioned topics (Data from Spring 2016).

Student feedback on Math reviews:

A survey was sent out to students regarding the usefulness of math review in class. Students were asked the following questions:

Question 1: "Rate the helpfulness of quick review of math topics and use of calculators during lectures."

From 25 responses, 100% of the responses indicated these quick reviews to be *useful or very useful* during the course. The data is very small, as the class size was small during Spring 2017.

Question 2: Describe how math review helped you with learning chemistry."

Student responses are presented below:

"prior to reviewing these topics I didn't know how to use the calculator correctly."

"Since the last time I took a math course was a couple of years ago, it was really helpful just to touch on the quick math topics that we need to know for this course. "

"I myself am proficient at math and use of calculators, but I have learned some new calculator tips from class so far this semester"

"I feel like the topic I really got used to using from your class was using parenthesis more while plugging full equations into our calculators. It made solving problems quicker and more accurately."

"Very helpful she gave me pointers on how to rearrange the formulas. I had an issue before on how to do it."

"Made math concepts less challenging and less scary overall"

"It was helpful because we need to know the stuff before we start doing harder things that stem from this basis. This was definitely extremely helpful."

Conclusions:

Simple and quick math concept reviews have led to the transformation of a stressful math phobic classroom to an engaged-learning environment. One of the key limitations with this endeavor is the time spent during class reviewing the math content. Alternatively, an instructor can create videos and post them before the start of chemistry content in class. Also, these topics can be presented to students during SI sessions (Supplemental Instruction) or help/review/discussion sessions. As students report, after the math reviews they are more proficient with the use of calculators, feel less overwhelmed about math, and more ready to apply math to chemistry problems. It is a worthwhile experience to see students performing calculations related to chemistry problems more confidently without worrying about the math. In sum, the math reviews are a valuable investment of my class time to engage students in learning chemistry.

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