Building Student Confidence with Chemistry Computation

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Abstract

I work in a liberal arts college as a chemistry professor. Not educated in the US, I have been welcomed into my adopted culture by being given the opportunity to teach that has allowed me to learn about a system I knew little about beforehand. At the college level, chemistry can be portrayed as applied algebra. In my experience algebra takes on a whole new level of difficulty and significance for students when the level they need to understand it underpins the comprehension of a subject it is a prerequisite for. This appears to be exacerbated by the following factors: the lack of continuity of the offering of high school algebra and chemistry prior to entering college, the increased emphasis of attaining confidence at the cost of learning content at high school, and the numbers of students attaining access to college who don't know how to study. This paper looks at attempts to redevelop the robustness of students' chemistry read-only memory (ROM) – their ability to identify and apply appropriate computational methods to solve problems without much thinking or hesitation. With the confidence of a reliable ROM, students are better able to learn chemistry at college.

Introduction

Many students in my first-year college chemistry classes struggle to solve chemistry problems. Sometimes it is not knowing where to start – what is the question actually asking? At other times, it is which data matter in formulating a response to a question. The most vexing to me the teacher are students who have a solution strategy, and when they try to execute it their math computation skills let them down. Not lacking in confidence outside of chemistry, the students rationalize the situation by informing me that they have not taken high school chemistry or that it was experienced too long ago, and in many cases the same goes for mathematics. However, when I show students the relevant math in the context of trying to address a chemistry question, even with the aid of non-programmable calculator they stumble doing the computation. I characterize this as students with rusty ROMs – or using the language of computer science, read-only memory. Since 2011 I have been experimenting in ways to make students' ROMs more reliable so they improve in their ability to identify and more importantly apply appropriate computational methods to solve problems without much thinking or hesitation. Students trained through positive reinforcement solve chemistry problems when they have confidence in the tools they have at their disposal to do so.

The main approach I have used is quite simple. I have required students to have a math workbook in addition to a standard first-year college chemistry text for my classes. Students who use the math workbook get to (re-)learn in a fundamental way math operations regularly applied to the context of chemistry that don't require them to use a calculator. This forces them to engage their brains to connect the numbers and units to the math operations to solve questions ideally in their heads. Such operations include working with exponents, significant figures, logarithms and undertaking dimensional analysis. Selected parts of the workbook are assigned as out of class work each week. I get the students to write up the assigned work in a notebook, and I provide an evening study session each week for students to do the work and get my help where needed. At the end of the week, I collect the notebooks and provide a grade based how complete it is and not on whether they did the work correctly. As I am grading their notebooks, the students undertake a quiz that contains a subset of the work assigned for that week – this is graded for working and correctness. Such math work parallels class work involving PowerPoint presentations, demonstrations and related class activities. In fact, taking a significant amount of problem solving out of regular class time frees up time to make the class work more interesting and memorable. Since 2011 I have incorporated such math work in my chemistry classes in much the same way as described above.

So are the ROMs of the students less rusty as a result? In the rest of this paper I report my findings in relation to student performance in the American Chemical Society (ACS) 2003 General Chemistry Examination.

Materials and Methods

Students were required to purchase the math workbook "Calculations in Chemistry", 1st edition, Dahm & Nelson, W.W. Norton publishers. For years before the workbook was published, or for class topics covered outside of those contained in the published workbook, related modules provided by chemreview.net were used instead. The ACS 2003 General Chemistry Examination was obtained from the ACS Exams Institute and used as received. Data was tabulated and graphed using Microsoft Excel. The *z*-test (and associated *p* value) calculator used for 2 population proportions can be found at http://www.socscistatistics.com/tests/ztest/Default.aspx

Results

Two research questions were posed. *Firstly, does a math emphasis (as described in the introduction) to the teaching of first-year college chemistry improve student test scores?*

I gave the same examination to students in my classes in 2006, 2007, 2008, 2010 and 2011. From 2006-2010, no math emphasis was provided (n = 114 students). In 2011, math emphasis was provided (n = 46 students). The graph of data obtained is given below (Figure 1):

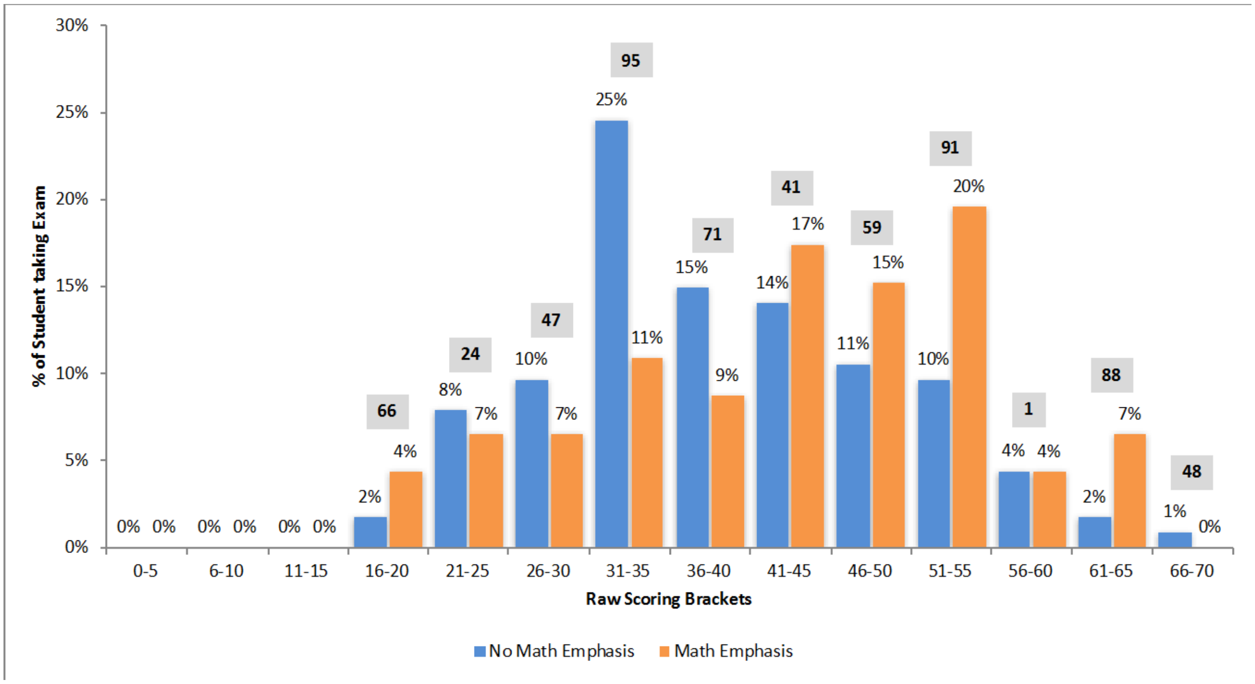

Figure 1: Impact of Math Emphasis on ACS 2003 General Chemistry Exam Results. The difference between these two proportions at each raw scoring bracket is statistically significant at the **x%** confidence level (p-values determined from http://www.socscistatistics.com/tests/ztest/Default2.aspx for two proportions (two tail) at the 0.05 significance level).

After 2011 at McDaniel, first-year college students taking chemistry classes were partitioned into Introductory Chemistry (included math emphasis) and General Chemistry (math emphasis was absent) sections. The section type differed in that students qualifying for General Chemistry placed out of arithmetic and algebra placement tests all take prior to entering the college. Both types of sections followed the same set of chemistry topics, only the depth of field in General Chemistry was greater owing to the documented higher math proficiency.

Secondly, does partitioning of first-year college chemistry students into Introductory (math emphasis) and General (no math emphasis) Chemistry sections improve test scores?

I continued to give the same examination to students in my classes in 2012, 2015 and 2017. In 2011, I emphasized the math to all students I taught (n = 46 students). For 2012-2017, a math emphasis was provided only to students in Introductory Chemistry sections I taught (n = 43 students). The graph of data obtained is given below (Figure 2):

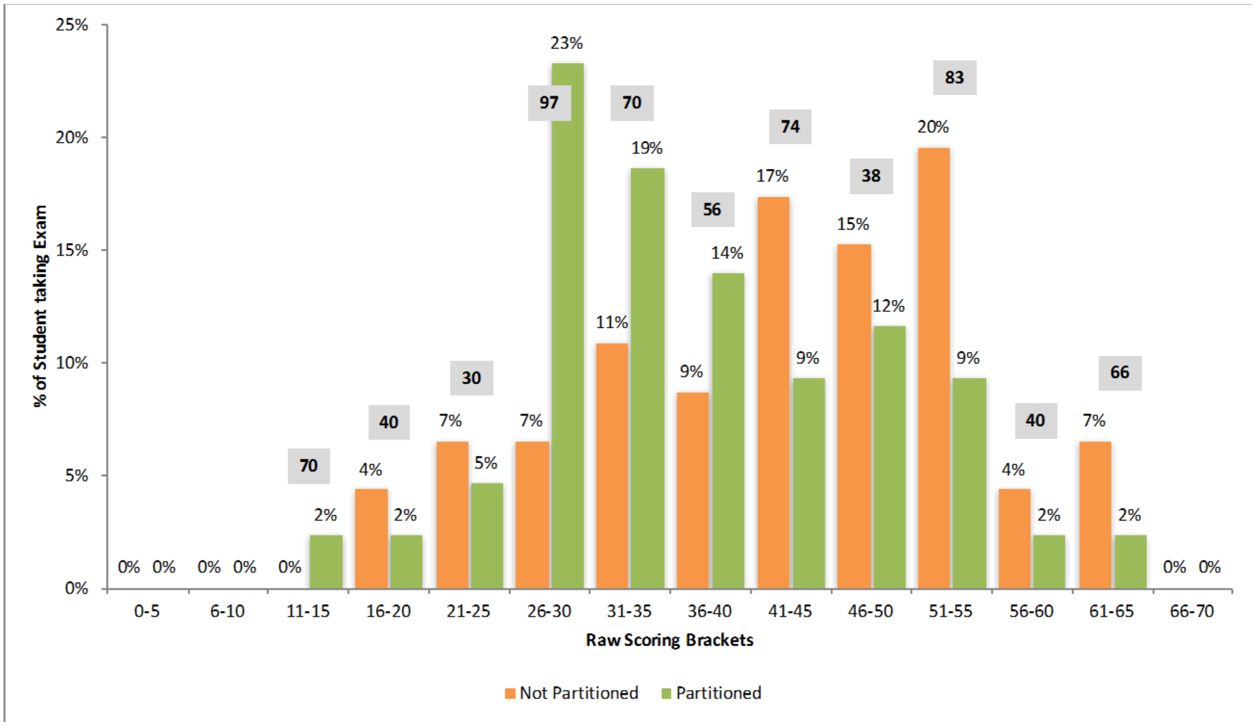

Figure 2: Impact of Partitioning Students into Introductory (Math Emphasis) and General (No Math Emphasis) Chemistry sections on ACS 2003 General Chemistry Exam Results. The difference between these two proportions at each raw scoring bracket is statistically significant at the **x%** confidence level (p-values determined from http://www.socscistatistics.com/tests/ztest/Default2.aspx for two proportions (two tail) at the 0.05 significance level).

Discussion

In comparing the two histograms of data related to the impact of applying a math emphasis to teaching first-year chemistry students (Figure 1), the relative proportion of those who now occupied higher raw scoring brackets definitely improved. The gray boxes above the two-colored sets of data for each raw scoring bracket signify the confidence level where the two proportions are statistically significantly different. The raw scoring brackets where this is the greatest are the 31-35 (95%), 51-55 (91%) and 61-65 (88%; all out of 70 possible questions correct). This clearly indicates that teaching with a math emphasis in the manner described in the introduction has a positive impact on first-year chemistry student test scores. It also suggests that it helps students who score in the 50% range as well as those scoring in the 75 or 90% range: it helps both the challenged and smart students.

In comparing the two histograms of data related to the impact of partitioning first-year chemistry students into Introductory (math emphasis) and General (no math emphasis) Chemistry sections (Figure 2), the picture is also pretty clear. More students proportionally score in lower raw scoring brackets when in separate Introductory and General Chemistry sections. This is particularly evident for the 26-30 and 31-35 raw scoring brackets. This reverses in the higher raw scoring brackets (especially in the 51-55 and 61-65 raw scoring brackets). This indicates that the students in General Chemistry who routinely score in these higher raw scoring brackets would still benefit from a math emphasis to the teaching in their section.

Conclusions

Having a math emphasis to the teaching of first-year chemistry students clearly benefits them from a test score perspective. Separating the students (based on math placement test scores attained when entering college) into Introductory (math emphasis) and General (no math emphasis) Chemistry sections doesn't appear to improve the situation. These results put into question the benefit of partitioning students into the two types of sections offered at McDaniel, or at least suggests that another type of metric be used to do the partitioning. A chemistry placement test may be a better option. The results also suggest that even first-year chemistry students proficient in math can still benefit from a math emphasis to their learning that will make their ROM more reliable.