Connecting Theory and Practice

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The case statement argues that quantitative literacy is not merely a euphemism for mathematics but is something significantly different—less formal and more intuitive, less abstract and more contextual, less symbolic and more concrete. Would quantitative literacy as thus described be particularly helpful to physics students, or are they best served by mastery of traditional mathematics?

The quantitative literacy described in the case statement would serve as an outstanding foundation for all students, regardless of their potential major in college or their avocation should they decide to directly enter the workforce. Although the traditional mathematics curriculum has served the physics community well, I don't believe that quantitative literacy as defined in the case statement precludes a student's mastery of traditional mathematics. Furthermore, there is a real possibility that quantitative literacy as here defined might increase the yield of physics students from the pool of those who currently take the introductory course (about 1 in 32).

For example, quantitative literacy might give students a better understanding of the difference between change and rates of change, leading to a better conceptual grasp of the difference between velocity and acceleration. In addition, QL might sharpen the proportional reasoning skills of students, leading to a better grasp of density. Many students struggle to understand the differences between linear density, surface density, and volume density, often using the three quantities interchangeably. Students' inability to build a conceptual model of these ideas is reflected in their difficulty understanding and applying follow-on principles. Far too often, many of these students drop out of the program, never taking another course in physics.

Too many students (and instructors) link students' difficulty in the physical sciences to their lack of understanding of mathematical concepts. Far too frequently, faculties tie an understanding of physical science concepts to the ability to manipulate mathematical equations. Quantitative literacy as defined in the case statement could assist in changing this status quo.

Mathematics is indeed the culprit in many of the problems students have in science. It is a subject students love to hate. Can an emphasis on quantitative literacy help resolve this age-old dilemma? Should schools give greater emphasis to quantitative literacy than to the more formal aspects of mathematics?

The question is, Why do students love to hate mathematics? If the answer is that too many mathematics teachers hide behind the formalism of the subject, then emphasis on quantitative literacy may well help resolve the dilemma. Given the mounting evidence that students learn better when they can relate to a subject, when they can see the "big picture," it makes sense that a greater emphasis on quantitative literacy in the early years will help students understand and relate to the more formal aspects of mathematics when they come along later.

Furthermore, I believe that an emphasis on quantitative literacy will appeal to a broader cross section of the student population, thus giving them a better understanding of mathematical concepts while not eroding the level of understanding of those who thrive under the current system. I see QL not as watering down or otherwise changing the basic content of the subject but rather as raising the expectations we have for all students. Ideally, both faculty and students would believe that students can learn, understand, and use mathematics. An emphasis on quantitative literacy may help reduce the widespread perception that some people are born to do mathematics while others are not.

That's a very important point. Too many people see mathematical ability as an inborn characteristic that determines students' future *options. Indeed, mathematics has been called a "critical filter" that blocks students with weak backgrounds from rewarding careers. Just how important is it that all students master formal mathematics? Might context-rich quantitative literacy be a more reasonable expectation? Does it make sense for students with different interests, say in grades 10–14, to study significantly different kinds of mathematics?*

I have difficulty drawing the distinction between formal mathematics and context-rich quantitative literacy as an either-or scenario. I think we would all agree there exists a subset of formal mathematics that all students, regardless of what they choose to do in life, should master. I believe we would also agree that there are certain habits of mind that we want all students to exhibit.

It does not make sense to me that students in grades 10–12 should study significantly different kinds of mathematics, but it does make sense that those in grades 13–14 perhaps should do so. My feeling is that fundamental algebraic, geometric, trigonometric, and probabilistic concepts coupled with a strong sense of logic will stand all students in good stead and provide the support that all subjects requiring a mathematics foundation can and should build on.

I would reiterate, though, that the "what" that is taught is not nearly as important as how that material is taught. I don't underestimate how difficult it will be to change the habits, beliefs, and pedagogical practices of a significant fraction of the teaching workforce. But a fundamental change must occur to reach the point where everyone truly believes that all students can learn mathematics and science. The question is, How do we move beyond the rhetoric?

Suppose for the moment that we have moved beyond rhetoric and that all students study the same core in high school. What level of quantitative literacy should be required to enroll in a four-year degree program? How much more, if any, should be required for all bachelor's degree recipients?

Every student enrolling in a four-year degree program should have a basic understanding of the arithmetic, geometric, algebraic, and trigonometric concepts taught in most, if not all, high school mathematics programs. Additionally, every college graduate should have a fundamental understanding of statistical and probabilistic concepts. Students should be required to demonstrate their understanding of those concepts by using them in a variety of real-life situations.

This sounds pretty much like requiring the traditional precalculus mathematics sequence for everyone who plans to go to college. Yet the case statement suggests a rather different vision of high school mathematics. Help me understand how you see the balance between traditional mathematics and quantitative literacy playing out in the high school curriculum. How can both aims be achieved at the same time?

Maybe I read the case statement incorrectly, but I did not see it calling for fundamental changes in content itself. Rather, I saw it calling for moving beyond content. My belief is that the traditional precalculus mathematics sequence suggested for those who plan to go to college will serve all students well and hence should be required of all students. I agree that the high school curriculum is short on statistical concepts. Although it would be desirable to introduce those concepts in high school, it is essential that they be part of every college graduate's portfolio.

We need, however, to move beyond the goal of teaching students a set of skills that is nice to have to teaching a set of competencies that students feel comfortable using on a daily basis. Students should see their mathematical skills as tools that are important to use on a daily basis. They should be as comfortable with the language of mathematics as with the language of English. The threads of mathematics should be present and exploited in every course in the high school curriculum. Logical thinking is as important in history and social science as it is in mathematics and science. All mathematics taught in high school should be seen as "mathematics for life" for all students. College preparatory mathematics has, I believe, become a misnomer. Hence, I really resonated with the "Elements of Quantitative Literacy" section of the case statement.

Some critics worry that a focus on quantitative or scientific literacy weakens students' backgrounds by providing only vicarious experiences—a distant observer's knowledge about science or mathematics. Do you see a distinction between traditional lab-based science and science literacy, or between traditional skills-based *mathematics and quantitative literacy? Which is more important for students in grades 10–14?*

If done well, I don't believe that a focus on quantitative or scientific literacy weakens students' backgrounds. On the contrary, students' scientific and mathematical understanding and ability to extend what they have learned to the next level is only enhanced.

I have always felt that teaching a conceptual physics course is far more difficult than teaching the so-called traditional physics course that is steeped in mathematics. Far too often, the instructor writes an equation on the blackboard that embodies the essence of a physical law without ever getting the student to see the subtleties that are clear to the instructor. What makes matters worse is that often neither the student nor the instructor recognizes that there has been a communication gap. This same gap appears between traditional skills-based mathematics and quantitative literacy. Hence our most important goal is quantitative literacy for all students.

Is it reasonable to teach quantitative literacy "across the curriculum" as writing often is taught, or does it require special expertise? Or might it be the case that science teachers in fact are better able to teach quantitative literacy because they, in contrast to mathematics teachers, also deal with real contexts in which quantitative issues arise?

Ideally, it would be great to teach quantitative literacy across the curriculum, for in my view this is the only way that students can see the connection between school mathematics and the mathematics of real life. It is not clear, however, that science teachers hold any special edge when it comes to the ability to provide the context for the use of mathematics within a particular subject.

I have some real concerns about the communication gap between science and mathematics teachers that often leads to student confusion, such as when similar quantities are called by different names in different subjects. The silo structure that separates disciplines at the college and graduate school levels unfortunately perpetuates itself at the school level.

I would claim that mathematics teachers, like all teachers, deal on a daily basis with the real context in which quantitative issues arise. Yet for some reason, the paradigm is that in school mathematics this context is often removed. The result is that students often walk out of the classroom making a distinction between theory and practice when they should really be seeing the connections between theory and practice.

Why is context so often removed from school mathematics? We constantly hear stories of students who learn mathematical formalities without any accompanying sense of meaning. Is this a problem of pedagogy, or is it perhaps inherent in the nature of mathematics? Does it also happen in physics?

To answer the last part of the question first, yes, this also happens in physics. My belief is that in both subjects, this disjunction is not inherent in the nature of the subject but is a problem of pedagogy. Although there is a growing body of knowledge on how students learn, it is my sense that most faculty are unaware of this research and hence do not incorporate it into their daily teaching practice.

My sense is that most instructors teach their subject using techniques they believe make the material most understandable. Unfortunately, they frequently use younger versions of themselves as the model for their students and expect their students to supply many of the missing steps, just as they did when they were students. Moreover, many instructors do not remember the difficulty they had mastering these same concepts when they were first exposed to them. The end result is that much of the context is eliminated. Finally, putting in the context is often perceived as taking time and is thus ignored so that more "content" may be covered. We must somehow overcome the deep-seated conviction that content is king, that if we can get the content correct, the rest will take care of itself.