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Author(s): Underwood Dudley
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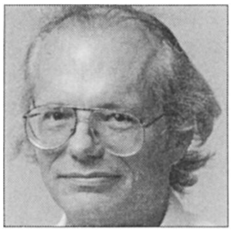
Underwood Dudley



Underwood Dudley (dudley@depauw.edu) taught his first calculus course in 1957 and is amazed that after all the years that he has been teaching them, students are still making the same mistakes. He hopes to see the new millennium in at DePauw University, where he has taught for 19% of the institution's existence. His last book, *Numerology,* was published by the MAA in 1997. Woody is the editor-elect of the *CMJ.*

Is mathematics necessary? Necessary, that is, for citizens of the United States to function in the world of work? You would get that impression from reading various recent documents, some coming from high and official places. For example, *Moving Beyond Myths*, published by the National Academy of Sciences, says so [**5**, p. 11]:

> Myth: Most jobs require little mathematics.
> Reality: The truth is just the opposite: more and more jobs especially those involving the use of computers require the ability to use quantitative skills. Although a working knowledge of arithmetic may have sufficed for jobs of the past, it is clearly not enough for today, for the next decade, or the next century.

The anonymous author of that item presumably had mathematical training and thus should know that theorems are not proved by assertion. But if we look in the document for evidence for this supposed reality, we look in vain, so an assertion is all that it is.

Here is an excerpt from *Everybody Counts* [**6**, p. 4], written anonymously for the National Research Council. (Do documents issuing from important national organizations gain more weight when their authors are not identified? Some members of important national organizations evidently think so.) This report too says that mathematics is a vocational necessity:

> Just because students do not use algebra anywhere except in algebra class does not mean that they will not need mathematics in the future. Over 75 percent of all jobs require proficiency in simple algebra and geometry, either as a prerequisite to a training program or as part of a licensure examination.

A quick reading of that passage might leave the impression that algebra and geometry are used in 75% of all jobs, but that is silly. Just look at the next eight workers that you see and ask yourself if at least six of them require proficiency in algebra to do their jobs. (If you are a teacher of mathematics, it is not fair to look at eight colleagues.)

The anonymous author was careful to add the qualification that the algebra and geometry may be necessary only for training or licensing. But I find even this claim, another bald assertion with nothing to back it up, unbelievable. Over 75% of *all* jobs? Incredible! I cannot imagine how that wildly inflated percentage was arrived at, unless the author was including having a high school diploma under "licensure examination." Authors who want to indulge in unsubstantiated percentages should be careful to have them consonant with common sense. For example, "99% of the mathematics done by the average person relates to money" [**2**]—now *that* I can believe.

Almost all jobs, I counter-assert, require no knowledge of algebra and geometry at all. You need none to be President of the United States, none to be a clerk at Wal-Mart, none to be a professor of philosophy, . . . the list extends indefinitely. Few jobs require knowing any mathematics beyond algebra. You might think that engineers, of all people, would need and use calculus, but this seems not to be so [**7**]:

> Why do 50% (probably closer to 70%) of engineers and science practitioners seldom, if ever, use mathematics above the elementary algebra/trigonometry level in their daily practice?
>
> My work has brought me into contact with *thousands* of engineers, but at this moment I cannot recall, on average, more than three out of ten who were well versed enough in calculus and ordinary differential equations to use either in their daily work.

If 70% of *engineers* don't need calculus to do their jobs, then how many of the 500,000 or so students that we put through calculus every year will? Minutely few, so we should not tell them how tremendously *useful* calculus is going to be to them when they go to work. If most engineers can do quite well with only algebra and trigonometry (or perhaps even less), is it not reasonable that non-engineers can survive and flourish with arithmetic, or even less? Yes, it is.

Were algebra necessary for 75% of all jobs, our algebra textbooks would be filled with on-the-job problems, since examples would be so plentiful. But they are not. Open any textbook at random—I will open a new one, just published—and what you find are problems like this:

> Through experience and analysis, the manager of a storage facility has determined that the function $s(t) = -3t^2 + 12t + 10$ models the approximate amount of product left in the inventory after t days from the last resupply. We want to find when the supply of the product will be exhausted and a new resupply needed.

Real inventories do not behave this way. For one thing, they do not *increase* after the resupply, from 10 at $t = 0$ to 22 at $t = 2$. For another, they usually decrease linearly, not quadratically. Besides, I doubt that warehouse managers, even 75% of them, use formulas to decide when to reorder.

Making fun of the "applications" that appear in textbooks is as easy as swatting mosquitoes in a swamp in midsummer, and as useful. What such problems actually illustrate is that the mathematics in the textbooks has no application to the world of warehouses and work. Does this mean that we should teach less mathematics? No; we should teach more. *Everyone* should learn algebra, but not because it is necessary for managing warehouses. Does it mean that we should stop assigning "applied" problems? Certainly not; we should assign more. Problems expressed in words are the best kind, but they should all start with "Suppose that. . . ." If we can't be realistic, we can at least be honest.

Those who know not history... Let us look at history. Those ignorant of history too often assume, knowing no better, that the world has always been much as it is now, which is seldom so. Today, with near-universal instruction in arithmetic and algebra, it is easy to suppose the curriculum has always been like that. But it has not. Algebra was not always taught to everyone. Not only that, even arithmetic itself is a relative newcomer.

Here is a report from Massachusetts in the early 1800s. Not the 1700s, nor the 1600s, the 1800s [**3**, p. 13]:

> Until within a few years no studies have been permitted in the day school but spelling, reading and writing. Arithmetic was taught by a few instructors one or two evenings a week. But in spite of the most determined opposition, arithmetic is now being permitted in the day school.

Opposition to arithmetic! How could anyone possibly be opposed to arithmetic? It is difficult for us to imagine.

The explanation is that arithmetic was a vulgar subject. As Patricia Cline Cohen tells us in *A Calculating People: The Spread of Numeracy in Early America*, a book that deserves to be more widely known [**1**, p. 26]:

> Those of high social rank, theoretically above the world of getting and spending, did not deign to study the subject. The most respectable English public schools, like Eton and Harrow, did not offer any instruction in arithmetic until well into the nineteenth century.

The English attitude was exported to the colonies [**1**, p. 49]:

> The founding generation arrived in Massachusetts in the 1630s with the highest number of university degrees and the highest rate of literacy of any migratory group. Within a decade they instructed towns to establish local grammar schools and had set up Harvard College to provide high-level training for home-grown ministers. But arithmetic was not among the subjects considered basic for Puritan children to learn.

Nevertheless, the colonies, and England, not only survived but thrived, economically as well as culturally. Some people believe that the eighteenth century represented a peak of civilization from which we have declined. I would not go that far, and I much prefer living in our time, with its plumbing and penicillin, computers and compact disks, anesthesia and even its automobiles, yet history clearly shows that arithmetic in the schools is not needed for a high civilization. How can that be? Easily enough: workers learn what they need *on the job*. What happens in the schools simply does not matter.

Here is a report on the situation in Boston in 1789 [**1** p. 131]. See if it does not sound familiar today:

> [There was a requirement] that boys aged eleven to fourteen were to learn a standardized course of arithmetic through fractions. Prior to this act, arithmetic had not been required in the Boston schools at all. Within a few years a group of Boston businessmen protested to the School Committee that the pupils taught by the method of arithmetic instruction then in use were totally unprepared for business. Unfortunately, the educators in this case insisted that they were doing an adequate job and refused to make changes in their programs.

Of course the students were unprepared for business, one reason being that it is neither wise nor practicable to try to prepare all students for all possible jobs. Another is that the "applications" in school books were just as phony as ours [**1**, p. 122]:

> Here is a typical word problem, typical in its complexity and in its use of current events to suggest the utility of arithmetic:
>
>> Suppose General Washington had 800 men and was supplied with provision for but two months, how many of his men must leave him, that his provision may serve the remaining five months?
>
> In this particular case the student mechanically applied the Rule of Three, writing $2 : 800 :: 5$ and and then dividing 5 into 2×800 to get a final answer of 320. Now, 320 is the number of men who can be fed for five months, not the number who must leave. So Washington's troops would have gone hungry if the schoolboy or his master had been in charge of provisioning.

As Professor Cohen pointed out, if Washington ran short of provisions, he would try to get more instead of telling part of his army to go away.

The conclusion cannot be avoided that school mathematics is not now, and never has been, necessary for jobs. There are a few exceptions, of course, most being for the jobs of teaching the subject. And of course science—both physical and social—cannot advance without a supply of scientists able to use mathematics. But most of these people did not need to be bullied or cajoled into learning the subject.

Even more advanced mathematics turns out to be all too often not needed for work [**8**]:

> Presumably, with degrees in mathematics and statistics [students with mathematical majors] could pursue careers in their disciplines. But, for mathematicians and statisticians who would seek employment in commerce, i.e. in business, industry, or government, this presumption is not presently valid. In fact most, if not virtually all, such mathematical scientists currently employed in commerce do not work in their fields of expertise.

This holds even for those with higher degrees. The National Research Council "reports that at least 90 percent of nonacademically employed mathematical scientists who received master's degrees in 1986 do not work as mathematical scientists" [**8**].

A few years ago I heard an interesting talk at an MAA section meeting on the use of mathematics by employees of the Florida Department of Transportation. The department needs to calculate many things, including areas, and its method of finding the area of irregular shapes was surprising to me. When I asked the speaker how the department copes with new workers with varying degrees of mathematical training, the answer was that it doesn't: it had found that the only safe assumption is that new workers know nothing about mathematics, so they are taught what they need as it is needed. This is satisfactory to everyone. It does not imply that the time that new employees had spent in school trying to do problems in arithmetic, algebra, and geometry was wasted, but it had nothing to do with their jobs. Boston, 1789; Florida, 1993: some things do not change.

A way of thought. Despite the initial opposition and continued irrelevance to jobs, mathematics instruction spread in the United States in the nineteenth and twentieth centuries. As the *History of Mathematics Education* [**3**] tells us, Harvard in 1816 required "the whole of arithmetic" for entrance. Until then addition, subtraction, multiplication, division, and the Rule of Three had been enough. After 1865, geometry was required as well. As the country was settled, secondary education expanded, and "arithmetic moved from the academies and high schools to become an elementary school subject by the end of the nineteenth century" [**3**, p. 27]. Algebra was an optional subject in some high schools, and it became possible to study calculus in the upper reaches of some colleges. Today years and years of mathematics is compulsory for all, and calculus has become a high school subject.

How come? Because parents, school boards, and society as a whole think that mathematics instruction is worth doing. On account of applications and jobs? Certainly not. The reason, I think, is that one of the tasks of schools is to do their best to teach students to think, and of all subjects none is better suited to this than mathematics. In no other subject is it so clear that reasoning can get results that are right, verifiably right. When you solve $x^2 + x = 132$ and get $x = 11$ you can then calculate $11^2 + 11$ and know that you are correct. No other subject has this capacity at the elementary levels. Mathematics increases the ability to reason and shows its power, all at the same time.

It is not fashionable these days to assert that mathematical training strengthens the mind, perhaps because that proposition is as impossible to prove as the proposition that music and art broaden and enrich the soul. But it is still believed by many people, including me. Some of our forebears had more confidence, as did John Arbuthnot (1667–1735), whose *On the Usefulness of Mathematical Learning* (c. 1700) proclaimed: "The mathematics are the friends of religion, inasmuch as they charm the passions, restrain the impetuosity of the imagination, and purge the mind of error and prejudice" [**4**, p. 70]. Even better, "mathematical knowledge adds vigour to the mind, frees it from prejudice, credulity, and superstition" [**4**, p. 67]. Though we no longer say such things out loud, the belief that they hold quite a bit of truth goes a long way toward explaining why people have supported and continue to support the mass teaching of mathematics, though many of them did not enjoy the experience when they underwent it.

Once a graduate of my school, a mathematics major, came back to campus to visit. I said to him, after finding out that his job was running a television station in Knoxville, Tennessee, "Well, I guess all that mathematics you learned hasn't been very useful." "Oh no," he replied, "I use it every day." I found this claim incredible (soap operas have no partial derivatives), so I pressed him. It turned out that he meant that he believed he used the *mathematical way of thinking* every day.

That is impossible to quantify and impossible to prove, but we cannot tell him that he is wrong. Nor should we.

It is time to stop claiming that mathematics is necessary for jobs. It is time to stop asserting that students must master algebra to be able to solve problems that arise every day, at home or at work. It is time to stop telling students that the main reason they should learn mathematics is that it has applications. We should not tell our students lies. They will find us out, sooner or later.

Besides, it demeans mathematics to justify it by appeals to work, to getting and spending. Mathematics is above that—far, far above. Can you recall why you fell in love with mathematics? It was not, I think, because of its usefulness in controlling inventories. Was it not instead because of the delight, the feelings of power and satisfaction it gave; the theorems that inspired awe, or jubilation, or amazement; the wonder and glory of what I think is the human race's supreme intellectual achievement? Mathematics is more important than jobs. It transcends them, it does not need them.

Is mathematics necessary? No. But it *is* sufficient.

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