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I read the well-written article *Gresham's law: algorithm drives out thought* by Sherman Stein in the first issue of the *Newsletter*. It documents once more that rote memorization of algorithms does not teach our students how to think, communicate, or solve problems. In it some authorities are quoted who rail against courses in mathematics that demand little more than that students reproduce procedures that differ only trivially from ones the student has seen before many times. He exhorts teachers of mathematics to change their ways and gives some constructive suggestions on how to prevent the dominance of algorithms from driving out thought. No reasonable mathematician could disagree with Professor Stein, so why does this problem persist?

I have been teaching college-level mathematics since 1948 in publically supported, as well as private institutions and have yet to meet any college teacher of mathematics who likes to teach by rote or who thinks this is good pedagogy. As we all know, most of our teaching efforts go into "service" courses that are taken by students who enroll in them because they are required or advised to do so by nonmathematicians. They are told to take these courses to learn <u>how</u> to solve certain kinds of problems that arise in the subjects in which they are really interested. They are told that they need to know how to do specific things such as solve annuity and compound interest problems, linear programming problems, calculus problems, solve linear partial differential equations with the aid of Fourier series, or calculate correlation coefficients. An assignment to teach a "service" course is usually accompanied by a densely packed course outline which allows little or not time to teach why the algorithms to which the students are being exposed work. If one persists in trying to teach "why" in addition to "how", most of the students resent it and feel you are adding an unnecessary burden for them to bear, and if they complain vigorously enough to their advisors, you may hear from your department chairman or dean that your students feel you are spending most of your time on "theory" instead of teaching them what they need to know. The faculty from department X are dissatisfied, for, after all, most of the students that come back to them from such "service" courses can't cope with the mathematical problems that arise in X-ology, so you must be spending your time teaching them irrelevancies; worse yet "pure" mathematics. Whatever the reason, I learned early in my teaching career to be leery of burdening the students in "service" courses with too many "whys" and that failing to "finish" a course outline was much more likely to promote dissatisfaction than turning out a class of students almost none of whom had a real understanding of the subject matter. In short, I learned how to "process" students so I could survive and spend my time on better things such as my own research or teaching students who were not hostile to mathematics.

Professor Stein is addressing the wrong audience. Our natural instincts and desires as college teachers of mathematics is to teach for understanding to help our students to solve problems in their areas of interest besides the illustrative examples in the text. It is harsh reality that forces us to accept impossibly crowded course outlines and anti-intellectualism.

Indeed reality gets harsher all the time as increases in tuition and fees make college administrators more and more nervous to the point that they know less and less that there is any possible difference between keeping students happy and having them learn

the nonsuperficial. Any non-tenured faculty member who follows Professor Stein's advice may be playing Russian roulette with his career. As for the speeches by college presidents and other leaders of society that learning computational skills without understanding is of little value, quoting them never seems to help a mathematics department under attack for rebelling against teaching algorithms by rote. If we won't do it, the department of X-ology will drop the mathematics requirement and we will lose positions. This is not just a rationalization; I can cite chapter and verse on how many a mathematics department got reduced in size in this way. These lofty speeches on the importance of understanding remind me of the passages in William Whyte's *Organization Man* that described how many a president of an influential company would address college students urging them to get as broad and general an education as possible, while his own personnel department refused to interview any job candidate who didn't have a laundry list of highly specialized skills.

In summary, Professor Stein is carrying coals to Newcastle even as the bottom is falling out of the coal market. It is the "consumers" of mathematics he has to convince, not the teachers; a monumental task indeed.

Yet the situations is not hopeless. First of all, despite the odds and the difficulties, there always seem to be a small number of individuals (e.g., Professor Stein) who persist in trying to teach students registered in "service" courses what the need to know as opposed to what they want to know when they enter the classroom. Even though the best selling texts are those whose size approximate that of big city telephone directories, there are still a few that encourage their readers to think. The torch is kept burning even if only a few students benefit from its light and the teachers who keep it lit at the expense of an extraordinary expenditure of time get the usual reward for virtue. One experience I had many years ago may give a way to make a dent in the problem on a larger scale.

In the early 1960's, the mathematics department at Purdue University was moved for a couple of years into the School of Engineering. Its Dean, the late George Hawkins had grown weary of the bickering between the mathematics department and the various departments of engineering over the contents of mathematics service courses. He appointed a committee consisting of three mathematicians and a lot of mathematically knowledgeable engineers with the charge to decide what kinds of mathematics should be taught by mathematicians and what should be made a part of various engineering courses. It met weekly for an academic year, its proceedings did not always go smoothly, and we never really settled the problem posed in our charge. Yet serving on that committee taught all of us invaluable lessons. Engineers do want their students to understand mathematics, but they don't see how $\in$-δ proof techniques help and they know little about the real problems of mathematical pedagogy. I still remember a chemical engineer who made sophisticated use of partial differential equations in his research, but didn't know why we had to spend time teaching solid analytic geometry to students before teaching them how to evaluate multiple integrals. He accepted our explanation readily and my initial shock at such ignorance was replaced by a realization of my own naivete at assuming that professors that had never taught any mathematics would have any idea of the problems of mathematical pedagogy. I also learned that when a professor of engineering says, our student need to "know" how to solve linear differential equations of the second order, they mean something rather different from what a mathematician would mean by that assertion, and the differences

are not easy to describe. What did emerge from our deliberations was an understanding of both the similarities and the differences in educational goals between the two groups, an increase in mutual respect, and direct communication between individuals instead of formal communications from faculty members in department X to his chairman to his dean to another dean to the chairman of the mathematics department to a faculty member in the mathematics department. I left Purdue a few years later, and the "era of good feeling" there lasted for 7 or 8 years. But personnel changes and a failure to renew the old efforts eroded away the good will that had made communication possible, and the old hostilities resumed.

I think it will take this kind of effort between departments to even begin to solve this problem, which, of course goes back to the students first introduction to mathematics in grade school. The impetus will have to come from the top; unless college administrators prove by their actions that they want mathematics courses for the bulk of the students to be more than a series of memorized rules. They will have to reward those who are willing to spend time on these problems and stop avoiding their real responsibility by pretending to a false neutrality in departmental disputes. I hope also, that "humanistic" mathematicians will spend less time exhorting the mathematical community and more time talking to people who might be able to do something about the problem. Remember also, that it is possible to overemphasize the "why" over the "how" as was pointed out years ago by Alfred North Whitehead when he said *It is a profoundly erroneous truism, repeated by all copy books and by eminent people when they are making speeches, that we should think about what we are doing. The precise opposite is the case. Civilization advances by extending the number of important operations we can perform without thinking about them.*

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