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In [2], R. P. Driver's book Why Math? [1] is reviewed. In that review, the reviewer alleges that he gives "the right answer" to the question "Why Math?" (which he states in full as: "Why should students who are going to be neither mathematicians, scientists, nor engineers study some topics in precalculus mathematics?"). Let us agree to call such students non-technical. Before giving "the right answer", the reviewer disposes of (or, at least, says that he disposes of) the way in which the question has been answered in the past, the way in which it is answered now, and the way in which Professor Driver answers it. This note is a reply to the reviewer's remarks.

The reviewer's "right answer" is: "[The value of mathematics]...is exactly the same as the value of any other game. ...for most students it will never be more than a game. ... Let us present mathematics, as mathematics. Why math? Because."

The reviewer's "right answer" isn't. (The other answers he discusses are all better answers than his--though none of them is the right answer, either.) That we should present mathematics as a game, and as such of intrinsic interest to human beings, can be suggested only from the myopic viewpoint of the specialist. That specialist, although he asserts the utility of mathematics, has no first-hand knowledge of that utility; he is ignorant of the historical and cultural context which affect the development of mathematics and have in turn been affected thereby.

But beyond the specialist's ignorance, the reviewer's "<u>right answer</u>" displays the specialist's arrogance as well. His "<u>right answer</u>" may well be the reason why many colleges and universities no longer impose universal mathematics requirements: For too long, we have arrogantly asserted the value of our discipline for non-technical students, arrogantly accepted their enrollments in our courses, and then arrogantly refused to deliver anything of value--even the value of a game. That we ourselves find the game interesting has no bearing on other people's findings. We should recall that games (of the non-circus variety) are of compelling interest only to players who are gifted with high "limits imposed by talent and application" (the reviewer's phrase).

Scholarship is always a game <u>to the scholar</u>. Our students are not yet scholars, and some--most?--never will be. To them, mathematics is not "only a game". They very clearly do "mind...the unreward of losing since it is, after all" a grade they are thinking about. And it is frequently their advisee's grades that our colleagues in other disciplines are thinking about when they advise their non-technical students and when they weigh potential general education requirements before voting thereon. And recall that the reviewer purports to justify, both to us and to those colleagues, a universal mathematics requirement. But the "right answer" he gives serves just as well to justify universal college requirements in bridge and chess.

If the reviewer's answer is wrong, so is his question. To most professional mathematicians, the phrase "precalculus mathematics" means not just mathematics that requires no background in the calculus, but a specific body of mathematics intended to provide the tools the student will need in the study of calculus. If one takes the question in this sense, and if one does not believe that calculus is appropriate for all undergraduate students, then the answer to the question is probably, at best, "Why, indeed?". Let us ask instead whether non-technical students should be required to study mathematics at some level below that of calculus, but not necessarily directed at preparation for a calculus course. The answer to this question is "Certainly!". And the reviewer's reason is the least of the reasons why.

Consider Driver's book and the approach it represents. I have no quarrel with the reviewer's analysis of this work--which I have not actually seen. If the remarks the reviewer directs at the book are correct, then I can safely say that I have seen many books of its ilk. These books reflect the current standard approach to General Education Mathematics courses.

The standard approach to General Education Mathematics courses is characterized by three conditions. The first of these conditions is that the mathematics must be trivial; if it isn't, then our audience--of whose stupidity we are firmly convinced--won't understand it. The second condition is that the mathematics must be of "intrinsic" interest to mathematicians; if it isn't, we won't be able to get anybody to agree to teach the courses. The third boundary condition is that the mathematics must be "applicable". Now, given the first pair of boundary conditions, it isn't very surprising that the third condition is almost impossible to satisfy. But we don't let that stop us. If we can't find real applications, we just <u>contrive</u> some. The reviewer's criticisms of the problems in Driver's book make this very point: Driver's (<u>i</u>.<u>e</u>., the standard) approach advertises these problems as demonstrating the applicability of the mathematics that he has presented. The point is not, as the reviewer seems to think, that the problems are worthless. It is that the advertising is false.

One thing is certain about the standard approach: We aren't fooling anyone. Except possibly ourselves. We assuredly aren't fooling our students--who aren't anywhere nearly as stupid as we think they are. Nor have the defects of this approach gone unnoticed until now. See Chapter 6 of [4] for a tirade on these matters.

That is not to say that G. Chrystal, M.A., whose nineteenth-century algebra book the reviewer cites approvingly, had the right approach either. Chrystal's approach ("Here it is. Take it or leave it.") was acceptable a century ago for a number of reasons that no longer obtain. (We are back to the matter of historical and cultural context here.) I will mention only that modern pedagogy recognizes, as last century's did not, the futility of an appeal to authority in support of an effort to inculcate the habit of critical thinking.

The reviewer's justification of General Education Mathematics courses reflects the specialist's ignorance and arrogance. It merits little attention outside of the mathematical community, and that is precisely what it gets. The current standard justifications (Beauty and Utility) for these courses are misleading. Each of them is in fact a good reason to study mathematics. But both together do not justify a universal requirement for the study of mathematics. After all, chess is beautiful. Auto mechanics is utilitarian. And bookbinding, rug-weaving, and a thousand other crafts are both.

The old standard justification (that one learns transferable skills) for the study of mathematics is, as the reviewer grudgingly admits, unproven. Now, as mathematicians we all know very well that unproven and false are quite different things, and it may well be that we wrongly ask for "scientific" evidence in this complicated arena of human capabilities. (The quotation marks are the reviewer's; they betray his agreement here.) At the very least, it is certainly also unproven that the skills do <u>not</u> transfer. And if not the skills, what of the <u>habits</u> of precision and skepticism that one learns to practice in mathematics? One could argue, at some risk, that we have in these unproven possibilities already better reason to study mathematics than any we have considered so far. Fortunately, we need not take this route; for there are much better reasons than these for the study of mathematics.

The reviewer's "<u>right</u> answer" begs the question "Why must we justify the study of mathematics?", which we must now consider. As I hinted earlier, we must convince our non-technical colleagues, because they, ultimately, are the ones who decide which students will and which students will not undertake the study. Any justifications we give them must be extrinsic ones, and not the intrinsic ones that suffice for us. We are thus led back to the utility of mathematics--which we have already discarded as justification for a universal mathematics requirement.

But we were then speaking of the trivial utility that we commonly see in today's General Education Mathematics courses. There is a great deal more to the utility of mathematics--at all levels--than this trivial utility. There is in fact an essentiality to mathematics that it shares with language. Mark

Van Doren [8] has written:

> "'Language and mathematics are the mother tongues of our rational selves'--that is, of the human race--and no student should be permitted to be speechless in either tongue, whatever value he sets upon his special gifts, and however sure he may be at sixteen or eighteen that he knows the uses to which his mind will eventually be put. This would be like amputating his left hand because he did not seem to be ambidextrous. It is crippling to be illiterate in either, and the natural curriculum does not choose between them. They are two ways in which the student will have to express himself; they are two ways in which the truth gets known."

Other authors (see, e.g., [5]) have written of language and of mathematics each as "a calculus of thought". (It is a telling comment on the coequality of language and mathematics that the metaphors these authors chose to describe their mutual essentiality are those of "mother tongue" and "calculus".)

We ourselves appear to be re-awakening to the value of our discipline. See [3] for a refreshing new approach to General Education Mathematics that implicitly recognizes the tremendous essentiality of mathematics by giving real applications of mathematics below the level of calculus. It is to be hoped that others will follow the trail Prof. Growney has blazed.

If this were all that one could say in support of mathematics for non-technical students, it would surely be enough. But it isn't all. Consider the famous quotation of Arnold Toynbee, taken from [7], that appears in [6]:

> "...I chose to give up mathematics, and I have lived to regret this keenly after it has become too late to repair my mistake. The calculus, even a taste of it, would have given me an important and illuminating

> additional outlook on the Universe... ...the rudiments, at least, of the calculus ought to have been compulsory for me. One ought, after all, to be initiated into the life of the world in which one is going to have to live. I was going to have to live in the Western World at its transition from the modern to the post-modern chapter of its history; and the calculus, like the full-rigged sailing ship, is...one of the characteristic expressions of the modern Western genius."

Toynbee keenly regretted the amputation of which Van Doren wrote and to which he had submitted himself. He explicitly mentioned the "...outlook on the Universe" that mathematics provides. And then he went further: "One ought, after all, to be initiated into the life of the world in which one is going to have to live." Here is compelling justification for the study of meaningful mathematics, and not least because it has been given by a man whose accomplishments gave him the literary, historical, and cultural perspectives that our accomplishments tend to deny us.

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