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THE HUMAN/COMPUTER INTERFACE: THEIR SIDE OR OURS?

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The much touted user-friendliness of computers, like any other aspect of popular culture, has presuppositions underlying it. In particular, it presupposes that there is a human/computer interface and that humans are on the side opposite to the computers. This essay is concerned with this possibly erroneous presupposition.

Because I can think of no better way to introduce my subject, I am going to approach it chronologically. Two things happened to me at the beginning of February that prompted the considerations I am sharing with you. Let me tell you about them.

I was shown an examination question that was well worded but about unfamiliar material. It had to do with positions on the surface of the earth and the position of the rising sun on the horizon. The careful wording was spoiled by the accompanying diagram, which included a circle apparently representing a sphere. The sphere was not the surface of the earth, but rather the celestial sphere viewed either from an unnatural position outside it or from the almost equally impossible position on it opposite the zenith. The labels 'equator' and 'north pole' did nothing to distinguish the diagram from one of the earth. We are all familiar with badly posed problems, but I was struck forcefully by this one because I had not posed it badly myself.

Posing a problem badly is a standard way to make a problem difficult. It is notorious that problems that problem solvers are called upon to solve in the so-called real world are badly posed, but I do not offer this fact as an excuse for unintentionally making problems hard by posing them ineptly. Other reasons that one finds difficulty in interpreting a problem are that the mathematics or the area of application is unfamiliar or that one does not grasp what the problem states or asks. The student too can be inept. It is equally notorious that 'if Johnny has five marbles and loses two, how many marbles has Johnny left?' is more likely to produce an incorrect answer than '5 - 2 = ?.' Even when there is familiarity with the subject matter and the mathematics, the problem is well posed, and the student understands the problem, the hated 'word problems' are more difficult than five minus two.

My second jolt came from two students appealing grades of C and F in an applied-mathematics course. The student appealing the grade of C enclosed with her appeal a transcript of her high-school marks. It revealed steadily and substantially dropping marks in mathematics and low marks in English. She complained, as did the student appealing the grade of F, that she had worked very hard at the mathematics (induction, sequences, equations, trigonometry, and complex numbers) but that she had been hindered in obtaining the grade her effort deserved by her marks on term tests that had not been fair tests of 'mathematical principles' but instead had required 'interpretation.' I am enormously grateful for these students' causing me to focus on what precisely they were complaining of, which was that they — both native speakers of English — were required to understand a couple of English sentences, see what mathematics in the course was involved, and do it. Term tests in other sections of the course, they alleged, asked questions of a purely computational character, and these two students felt that they had been disadvantaged by the disparity in the term tests, having written a common final examination with the other sections.

These students were insisting — with some asperity — that it was unfair that I had demanded that they think as well as calculate. Not original creative thought, not even the less original creative thought of problem solving, but merely the thought of perceiving in some words an intelligible structure from a small list of intelligible structures on which they were being tested. They did not claim that it was not obvious what to do once they understood what the problems were about. They were claiming immunity on account of what I called above 'student ineptness.' They were claiming as a grievance that I had asked them to do the translation from Johnny's marbles to five minus two. This jarred me into considering seriously whether this was unfair.

If one takes the process that these students were unsuccessfully engaged in as being:

(1) extracting an intelligible structure from a context,
(2) calling upon a prior knowledge of that intelligible structure,
(3) engaging in routine ways of dealing with that structure,

then one can see one of the differences between teaching applied mathematics and teaching pure mathematics. In the latter, the structure is foremost and the others are there for the sake of learning about it; in the former, the structure is there to supply the necessary framework for the processes of extraction and solution.* In both cases, teaching is primarily about the structure, since the structure is logically prior to its extraction and to ways of dealing with it. If our tests and examinations test only the routine ways of performing calculations (3), perhaps intended to test a knowledge of content (2), but ignore 'applications' (1), then we are testing only what the students will do — after the examination is over — only by calculator or computer. We will be testing them solely on what they do not need to do and ignoring what it is increasingly important that they be able to do if they are not to be replaced by machines.

My students were complaining that I put them on the wrong side of the human/computer interface. At least I did! But I was not being up-front about it, just doing it automatically because they were my students. You can't get away from those presuppositions of popular culture.

Having returned now to the human/computer interface, I should say the little I want to say about computers: my subject is human. In the past decade, there has been a movement to take account of the availability of computers, especially in calculus and especially in the U.S.A. There has been a ICMI conference on the topic [1, 7], and a number of books have been written that make a gesture or more toward the fact that some students of calculus have access to a computer. This is inevitable, and with time it may become more generally not just a marketing gimmick but something more substantial, as for instance with David A. Smith's *Interface: Calculus and the computer.* Not being in the U.S.A. and not teaching much calculus, I have been more concerned with getting students on top of the capabilities of their pocket calculators and have been thinking that the availability of computers is far more significant to algebra than to calculus. It is in algebra particularly that Jon Barwise [2] has drawn attention to the problem of Miles, namely 'that symbolic mathematics packages may make it even harder for our students to understand the meaning of mathematics.' As Miles put it [9],

> Use of an algebra utility can eliminate the need to know the words and usage of algebra — the core of the language of applicable mathematics. Unquestionably one can persevere in calculus on this basis — many students already do so without benefit of algebra utilities. Whether one can find meaning in doing so is doubtful. And it is a serious question whether colleges can prosper without imparting a greater sense of meaning to their curricula.

In the terms I introduced above, computer power renders one's routine ways of dealing with mathematical structure possible without knowing that intelligible structure, but without that knowledge one cannot seek and find the structures in their non-mathematical contexts. This renders the structures invisible as well as meaningless. Applied mathematics becomes impossible to a human for the same reason as it is impossible to a computer: the mathematics has been reduced to software. The human has slipped across the human/computer interface. I see this as a danger to be combatted. (On meaning in mathematics, see [8] and [12].)

On a more humane side, another educational movement has spawned meetings and now a book, *Writing to learn mathematics & science* [4]. Both the Humanistic Mathematics Network and other organizations have been exploring ways of engaging students in the learning of mathematics, including writing about it. Three recent papers [6, 10, 11] have drawn attention to the benefits — even if only to their ability to write — of having students write about what they are doing when they are doing mathematics. By embedding mathematics in prose a large step is taken toward making it meaningful and something that can be recognized outside the classroom. In the context of teaching mathematics to first-year engineering students at the University of Manitoba, it might be possible to combine efforts with their technical-writing course in a way not wholly unlike Duke University's course, Introductory calculus with digital computation, which, as the title indicates, involves computers, but also involves weekly lab reports including from one to three pages of expository writing along with the data and graphs [6]. The possibility of benefits to both courses — and ultimately the students — merits investigation.

More universally, my students' complaint has brought home to me, as well intentioned things I have read have not, that we need to encourage the hated interpretation.

I can fairly claim that I have always done this, and I have the student complaints to prove it. But I have done it only on tests and examinations. I have never talked about it, warned them of it, pressed them to practise it, helped them with it (except individual difficulties). As Clement and Konold demonstrate with the scarcely mathematical problem ([3] adapted from [14]),

> What day precedes the day after tomorrow if four days ago was two days after Wednesday?

the difficulties are enormous even without any mathematical complexity at all. In the above taxonomy, difficulties with this are purely student ineptness, and whose job is it to help them with it but ours? Not only have I been remiss in expecting interpretation only under testing circumstances, but also I have neglected to influence my colleagues not to pose trivially mathematical questions on their tests and examinations. What I have done has been seen as my way of doing things and therefore tolerated (by colleagues) or complained of (by students). I have now realized that I think that what I have been doing is right — though far too limited — and I am prepared to defend it. (I am not prepared to defend wording questions badly.) The terms in which I defend it are those of the human/computer interface. It is easier for students to respond to keystroking than to the presentation of what is intelligible but not yet converted into ASCII codes. Students, like the rest of us humans, prefer what is easier. But computers respond to keystrokes far more dependably, powerfully, and quickly than they can; they cannot compete. What they must learn to do is extract intelligible structure and frame it in such a way that they can do the keystroking. In order to do this, they need help.

As a first step toward influencing my colleagues, I have suggested three things that I think I and others should do:

> shun meaningless manipulation,
> engage students in verbal expression of meaning,

and

> insist that students cope with verbal presentation,

all to teach them some mathematics usefully and by contributing to their education to keep them from slipping across the human/computer interface.

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* Two quotations from respondents to the survey reported on in [5] illustrate this.

"Applied departments use math as a tool. An individual topic is analogous to a hammer perhaps. They wish to 'hammer' with it. On the other hand, math departments often become more interested in its description and generalization of the 'hammer' itself."

"I cannot take it for granted that [students from calculus] are able to use their mathematical skills in problem solving. What appears to be . . . lacking is the ability to formulate a problem quantitatively and then to solve it using the tools they learned in their calculus course."