Letters

Programmed Instruction

In his proper concern ("What are professors for?", 18 June, p. 1545) with aspects of education that only a meeting of minds between student and teacher can provide (guidance, motivation, sense of values), Abelson mentions programmed instruction, probably unintentionally, in a way that makes it appear as one of the *causes* or *symptoms* of depersonalization of education. It may be that it is one of the *remedies*, if used in its place. The most precious part of education is the nurture of the spirit; we need good teachers to convey the pleasures of learning and of continuing to learn, the joy of discovery, the satisfaction of duty well done. But good teachers are few; one important virtue of programmed instruction for higher education is that it helps conserve one of our valuable and limited resources, the time of competent teachers.

Programmed instruction does not replace a good teacher; it amplifies his teaching powers, making him more effective and more efficient, enabling him to teach more people more things with no more effort and with better quality control. It makes it easier for the student to learn "facts"; by teaching recognition of recurrent patterns, it may also help him develop his faculty of abstract reasoning. Programming no more replaces teachers than the printing press replaced storytellers 500 years ago; printing a story or programming a course merely helps to spread existing values. Young people of all ages need both *education* and *instruction*, knowledge of the world around them and the ability to judge it and change it where it needs to be changed. A pupil is both a vessel to be filled and a candle to be lit; he is a lamp. Knowledge of facts is oil for the lamp, and programmed instruction is a good way to provide it without effort. This makes it ready to receive the light from the teacher and spread it.

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. . . At the start of his editorial Abelson says, "Large classes and the use of television films and programmed instruction have tended to make teaching impersonal and mechanical," and at the end, "Television and programmed instruction are here to stay"—announcements which will be read with some surprise on many campuses. In their context, the statements make these media and techniques sound like lowly vegetables indeed in the flowery groves of academe. I would argue that it is not these technological developments which help make teaching impersonal and mechanical but rather the failure of many teachers to seek ways of making creative and rewarding use of them. Do poor textbooks tend to make teaching impersonal and mechanical? Do lectures based on yellowing and crumbling notes tend to make teaching impersonal and mechanical? Do graduate assistants teaching basic courses while pursuing their own studies tend to do so? Of course they do. And they also tend to make large numbers of potentially first-rate students discontented and often even rather contemptuous of the professed aims of higher education.

Advances in educational technology will scarcely replace the good teacher, but they will be no better than the use he makes of them. Properly prepared and used, programmed instruction material can provide that teacher with the kind of classes he has always claimed he wanted—classes composed of students who have absorbed the necessary information about the subject matter to enable him to make his own unique pedagogical contribution. In most cases, there is no reason why a good program cannot be written to offer the student a stimulating learning experience that will motivate him to look further into the subject. A good program, after all, is the result of a close collaboration between author (it is to be hoped, an excellent teacher) and many students, each learning from the other as the material is tested and revised until it meets its objectives. Good programs do, in fact, exist, and use of them has indicated that students have enjoyed them and learned from them, sometimes even when these materials were not very wisely used. A film, a book, or a program which impresses its audience as being the product of a teacher who is interested in his subject and, most important, who cares that his students learn, certainly offers more to the cause of good education than does the academic time-server or professor who sees his students as simply so many hurdles to be leaped on the way to the laboratories or the stacks.

If, as Abelson says (and I hope he is right), television and programmed instruction are here to stay, one might infer that they are providing some benefits to education. The responsible commercial producers of films, TV, programmed instruction, and textbooks are deeply involved in the cause of better education at every level. What is needed from others who are similarly concerned are suggestions, comments, and criticisms directed toward improving these instruments of instruction and the uses to be made of them.

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Political Principles and NIH

I too have been awaiting comments on the Wooldridge Report, as has Arthur Gellhorn (2 July, p. 6). Gellhorn's comments are interesting and may appear biased in favor of NIH's intramural program because of omission of an American political principle. No one who has had contact with the intramural scientists of NIH will deny their competence and contributions or their continuing valuable relations with the rest of the scientific community. I have personally received needed assistance from my friends in government service, and I hope I shall continue to do so.

Two philosophical considerations inevitably color attitudes toward the intramural programs. The first, and weaker, is the unspoken feeling that government service tends to prostitute, to weaken moral standards. We all recognize that less than devotion to government service may be associated with other loyalties, for instance to pressure groups or political parties. Also, we are aware of the present and potential political usages of science and scientists. The weakness of this consideration is the failure to account for the generally high integrity of scientists.

The second consideration, which smacks of "political conservatism," is nonetheless founded on our Constitution—that is, that only problems found difficult of solution on local levels may be referred to the central government. The federal government should fill clear and present needs, where local authorities—state governments, universities—are not able to supply the requisites.

Perhaps the future of the intramural programs could be most satisfactorily sought in this second consideration. These programs could be directed toward problems where the strength of the federal government can fill a need beyond the capacity of weaker institutions. Let us do what we can, and let Uncle do what he must for all our benefit. There should be no competition, but rather complementation.

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Emotional Perils of Mathematics

People are turned aside from being mathematicians—by which I mean "pure" mathematicians—far more by temperament than by any intellectual problems. There are certain emotional difficulties which are intrinsic to the mathematical life, and only a few people are able to live with them all their lives.

First of all, the mathematician must be capable of total involvement in a specific problem. To do mathematics, you must immerse yourself completely in a situation, studying it from all aspects, toying with it day and night, and devoting every scrap of available energy to understanding it. You can permit yourself occasional breaks, and probably should; nevertheless the state of immersion must go on for somewhat extended periods, usually several days or weeks.

Second, the mathematician must risk frustration. Most of the time, in fact, he finds himself, after weeks or months of ceaseless searching, with exactly nothing: no results, no ideas, no energy. Since some of this time, at least, has been spent in total involvement, the resulting frustration is very nearly total. Certainly it seriously affects his attitude toward all other affairs. This factor is a more important hindrance than any other, I believe; to risk total frustration, and to be almost certain to lose, is a psychological problem of the first rank.

Next, even the most successful mathematician suffers from lack of appreciation. Naturally his family and his friends have no feeling for the significance of his accomplishments, but it is even worse than this. Other mathematicians don't appreciate the blood, sweat, and tears that have gone into a result that appears simple, straightforward, almost trivial. Mathematical terminology is designed to eliminate extraneous things and focus on fundamental processes, but the method of finding results is far different from these fundamental processes. Mathematical writing doesn't permit any indication of the labor behind the results.

Finally, the mathematician must face the fact that he will almost certainly be dissatisfied with himself. This is partly because he is running head-on into problems which are too vast ever to be solved completely. More important, it is because he knows that his own contributions actually have little significance. The history of mathematics makes plain that all the general outlines and most of the major results have been obtained by a few geniuses who are not the ordinary run of mathematicians. These few big men make the long strides forward, then the lesser lights come scurrying in to fill the chinks, make generalizations, and find some new applications; meanwhile the giants are making further strides.

Furthermore, these giants always appear at an early age—most major mathematical advances have been made by people who were not yet forty—so it is hard to tell yourself that you are one of these geniuses lying undiscovered. Maybe it is important for someone to fill in the little gaps and to make the generalizations, and it is probably necessary to create an atmosphere of mathematical thought so that the geniuses can find themselves and thrive. But no run-of-the-mill mathematician expects in his heart to prove a major theorem himself.

I wonder how much of this psychological difficulty is present in other scholarly fields. I suspect that no other field suffers so acutely from all four problems. The experimental sciences in particular, I think, are pretty well preserved from the second and third difficulties. An experimentalist can perform an experiment and, at the end, will have a set of data; and these data at least will indicate that such-and-such either is or is not significant. He knows before he starts the experiment that, except for equipment failure, he will finally have *something*. He is not faced with nearly certain frustration. Furthermore, publication standards permit experimentalists to describe details of procedures followed and difficulties encountered.

I also think the experimentalist has a reasonable hope for personal satisfaction. Experimental advances are frequently made by unknowns; in fact, there aren't many experimentalists in history who have consistently made important discoveries, if we don't count those who have been lucky enough to head active research organizations for long periods.

Whether other speculative disciplines are immune from the four emotional problems I've outlined isn't clear to me. But I feel that differing standards of precision may ease the problem of frustration, in the sense that it is often possible in these other fields to hide the fact that you don't have anything to say. A mathematician who says nothing in an obscure manner is usually caught quickly—but, alas, not always.

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Force-Free Body: A Thought Experiment

Hanson's interesting essay, "Galileo's discoveries in dynamics" (29 Jan., p. 471), stresses the point that, even in a purely conceptual universe, a particle can never be totally free from unbalanced external force; therefore the law of uniform rectilinear motion (the law of inertia) can never, even in principle, be tested. This conclusion results from the evident need for a measuring rod, a clock, and an observer as the minimum furniture in an otherwise bare conceptual universe in order to demonstrate uniform rectilinear motion, but these material bodies exert an unbalanced gravitational force on the particle under test.