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Anthony Oettinger could sell needles' eyes to camels. His critique of educational technology is entertaining, provocative, sarcastic, and witty. Hardly anyone could fail to be enthralled with it and find the reading of it a distinct pleasure, even though there are some infuriating misstatements and exaggerations.

Perhaps the most useful thing I can do in response to Oettinger's essay is to comment on some of the technical aspects of his critique. Oettinger carefully and explicitly insists that, in the long run, computers will play a very large role in education. He is, however, extremely pessimistic about the short run. My own view of the short run is more optimistic, and I will attempt here to give an alternative to Oettinger's position. In particular I shall concentrate on one of the two critical concerns considered by Oettinger—the problem of individualization of instruction.

I support much of Oettinger's criticism of the vague talk about individualization found in the educational literature. The theme of individualizing instruction had its first serious impact on American education when John Dewey

began the University of Chicago laboratory school just before the turn of the century. Throughout this century, talk about individualization of instruction has been widespread in American education. Like much discussion about education, it has had what I like to call a "second-story" character, meaning frequent use of general abstract terms with no particular reference to concrete experience or to the occurrence of actual events in the classroom. The nature of this second-story talk is exemplified by such phrases as "providing for each student according to his individual needs," and "adapting the curriculum to individual levels of ability and achievement." The second phrase is somewhat more definite than the first, because we can immediately visualize concrete measures of achievement and ability, but a major area of vagueness remains because we are not clear what is meant by "adapt."

I am not going to define individualization of instruction, or to fight a battle with the quotations cited by Oettinger or with his own comments on these quotations. A discussion of individualizing instruction is like a discussion about predicting the weather. For the main purposes at hand we don't need a precise definition of what we mean by "weather." We can simply resort to our intuitions, and we all recognize when these intuitions are violated by an example or a statement. We also recognize the difficulties of predicting the weather; the same is true of individualizing instruction.

Oettinger emphasizes the important point that achieving individualization of instruction is an heroic task and may be impossible in many situations. I agree that *only to a limited extent* can we expect *teachers* to carry the burdens of individualized instruction. I agree with Oettinger (p. 713) that the widespread use of computers for individualization of instruction seems a practical and feasible alternative. In order to bring a sense of concreteness to the discussion of individualization of instruction by the use of computers, I would like to review three programs now in operation at Stanford. The first is the drill-and-practice program in elementary mathematics, the second is the Brentwood tutorial program in elementary mathematics, and the third is the tutorial program in elementary Russian at the university level.

The drill-and-practice mathematics program has been run on a medium-size computer (the PDP-1) with more than 1000 students participating daily during the academic year 1966-1967, and with more than 2,000 during 1967-1968. The 2,000 students currently using the system live in California, Kentucky, Mississippi, or Iowa. The central purpose of this program is to provide a supplement to the teacher's regular instruction in elementary arithmetic. It is no news that a

regime of daily practice in arithmetic skills will contribute significantly to permanent mastery of these skills. The problem for the teacher is to find the time and energy to offer such a program on anything approaching a daily basis. And it is that much more difficult for the ordinary teacher to offer an individualized program to each student. In the drill-and-practice program, the computer consoles are ordinary teletype machines placed in the schools and connected by telephone lines to the computer at Stanford.

Individualization takes place in three distinct ways. First, under computer control, the teletype types out an exercise. The student responds with an answer that is immediately evaluated. The temporal pace of the problem presentation and the response of the system to the student's own answer is on an individual basis for each student. There is in no sense lock-stepping from problem to problem across students. If the student is wrong he is given a second chance. If his answer is correct, he is immediately given a new problem.

The second aspect of individualization is the organization of the problems in terms of difficulty. At each grade level the curriculum in arithmetic, or more generally in elementary mathematics, is broken up into somewhat more than twenty concept blocks. Work in each concept block covers seven days. On the first day the student is given a pretest, and on the basis of his pretest score, he is placed on one of five levels for five days of training. During the training he moves up and down in the five levels depending upon his daily score.

The third aspect of individualization is the selection of individualized review. While the student is working on a given concept block, he is also reviewing previous concepts on which his individual work was least satisfactory. For example, a fourth grader who is working on the twelfth concept block is concurrently reviewing the one concept block of the preceding eleven on which he scored lowest. For one student this review block might be multiple-digit multiplication; for another, problems of long division; and for another, solution of word problems. In addition, the review-block level of difficulty is selected at the level indicated by the numerical value of the student post-test score. At the end of the review block the student is given a review test on the review block and his score is used to update his record of achievement on this past block.

It is clear that a highly industrious and energetic teacher could just barely manage a program of individualization of this kind, although even the most energetic and able teacher would probably have difficulty in meeting the first requirement, that is, the "on-line" responsiveness to individual answers within a few seconds after the answers have been given by the students. It is also per-

fectly clear that under ordinary teaching circumstances it would not be easy or, indeed, practical for a teacher to maintain week after week and year after year such a complex program of individualized instruction.

In terms of Oettinger's essay, I emphasize that this is the drill-and-practice program which he confuses with the tutorial program at Brentwood. In addition, there are no specialized technical personnel from the Stanford staff in any of the schools in which this program operates on a regular basis. We do not have Stanford personnel in Mississippi, in Kentucky, or in Iowa, or even in the schools relatively close to Stanford. The consoles are placed in ordinary schools and run by the local school personnel.

This drill-and-practice program began in the spring of 1965, with one class of 40 students. In the academic year, 1968-1969, the number will exceed 7,000. (For the increase from 2,000 to 7,000 we are adding a PDP-10 and additional memory.) The point to emphasize here is that this program does represent a strict operational implementation of individualized drill-and-practice in elementary mathematics.

The program at Brentwood, which Oettinger badly confuses with the drill-and-practice program that I have just described, is more radical. In the tutorial programs at Brentwood, we have attempted to carry the main load of instruction in elementary mathematics (and also in reading, under the direction of Professor Richard C. Atkinson). A certain amount of the curriculum is handled in a classroom setting, but teachers and proctors are used primarily to help students who are having trouble with the tutorial program. For example, the student is presented with material on a given concept; if he passes the criterion test he moves on to new material. If he does not pass he is given a remedial loop. If he fails the remedial loop he will be given a second try at another loop, and if he still fails, a proctor-call is automatically made. This call brings a teacher to the console to provide individualized instruction for that student. It is certainly true that the Brentwood tutorial program is far too expensive for widespread use. As Oettinger notes (p. 713) there are an abundance of technical personnel including specialized teachers in addition to the regular school personnel at the Brentwood Laboratory. Although I agree with Oettinger's remarks about the difficulty of using the Brentwood configuration on a broad basis, the Brentwood tutorial program could not possibly be more different from the drill-and-practice program. Oettinger's remarks are primarily directed at the Brentwood tutorial program, not at the drill-and-practice program with which he is perhaps not familiar.

The three kinds of individualization described as part of the drill-and-practice program are also part of the Brentwood tutorial program. In addition, a main feature of the Brentwood system is that students are not required to work on the same concept block at the same time. The faster students will be considerably separated in terms of curriculum material from the slower students. In this sense an important feature of individualization at Brentwood is that students can determine their own progress through the curriculum. This is possible in a tutorial setting because what is offered at the console is not tied directly to the teacher's work in the classroom, as it is in the drill-and-practice program.

A second additional aspect of individualization at Brentwood is that all students do not eventually progress through the same curriculum material. Segments are reserved only for the students who are making fast progress. In addition, remedial loops and blocks for the maintenance of skills are given only to students who indicate on the basis of pretests that such additional work is needed.

Again, I want to emphasize that in the first two operational years at Brentwood we have taken only the first steps in constructing an adequate tutorial system.

In his discussion of the Brentwood Program (p. 715), Oettinger notes the number of teachers is not reduced when individualized instruction is offered at computer consoles. I offer the computer-based Russian course at Stanford as a counterexample to this claim. (This course was prepared under the direction of Professor Joseph van Campen.) In the elementary Russian course the regular classroom teacher has been totally eliminated. There are three main components of a secondary-school or college-level language course. These components include regular classroom sessions on a daily basis, several hours a week in the language laboratory, and regular homework assignments. Because we have now had considerable experience in preparing computer-based courses, we decided to replace only the first major component, regular classroom sessions, with daily sessions at computer consoles. The students continue to go to the language laboratory and they continue to do homework, but the regular teaching function of the classroom has been eliminated.

At the present time the elementary Russian course has all the features of individualization mentioned for the drill-and-practice system. Again, this is only a first step toward individualization of foreign-language instruction. The computer-based instruction at consoles does not include an attempt to deal seriously with pronunciation. For example we do not ask the students to verbalize orally many Russian words and sentences at the computer consoles; rather, the real

evaluation and drill in pronunciation takes place in the language laboratory. Apart, however, from pronunciation and the teaching of Cyrillic cursive, all the other standard functions of a first-year course are handled at computer consoles; these include comprehension of written Russian, comprehension of spoken Russian, and mastery of grammar and syntax.

The evaluation of the Russian program has been strikingly positive. It is difficult even for the most disciplined person to pay attention, at an appropriate level of concentration, to group instruction in a language, even when the teaching sections are as small as ten to fifteen students. It is easy to drift, to day-dream, or to move back into English when some other student is being called upon to perform. By teaching Russian at a computer console, however, the situation is individualized in a most important sense. Every single response is required from the student sitting at the console. No questions are directed at anyone else. No responses from any other student enter the picture. The level of concentration and effort required is intense, but it is also rewarding. The student inevitably feels that his time is being efficiently used. In my judgment, at the tutorial level probably the first successful application on a broad basis of computer-assisted instruction will be at the secondary and college level of elementary foreign-language teaching. The psychological facts that I am hinting at in these brief remarks have not been properly set forth as yet, but I have a strong conviction that what I am saying about these matters is correct. (I don't always feel so certain about my views!)

I hope this short essay has helped to clarify some of Oettinger's broad, and occasionally misleading, statements about individualization. Even though our work at Stanford is in its earliest stages, we feel that it shows how computers will be able to improve education by "individualizing instruction" in the several important interpretations of that phrase described above. In contrast to Professor Oettinger, we believe this improvement will not be long in coming.