INDIVIDUAL DIFFERENCES AND INSTRUCTIONAL DESIGN

Richard E. Snow
Stanford University

This paper is based on a presentation given at the Convention of the Association for Educational Communications & Technology, Miami, April 25-29, 1977. The research reported herein was supported by Office of Naval Research Contract No. N00014-75-C-0882. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Office of Naval Research, the Advanced Research Projects Agency, or the United States Government.

August 1977

One of the oldest facts about human learning in educational settings is that individuals differ, profoundly and multiply, in how they learn. Individual differences in school learning have been apparent since Greco-Roman times, but it is only in recent years (perhaps the last decade or so) that research has begun to show the real significance of this fact for education. Until now, information about individual differences has been used in education primarily to select people *out*, that is, to reject college applicants, or to identify students needing slower or special education, which often turns out to be no education at all.

However, three points about individual differences in learning from instruction now seem clear:

1. Individual differences are far more *complex* than the single rank order conception of intelligence usually manifest in popular personal thinking, and they are also more *fundamental* as human characteristics than usually assumed in popular social and educational policy.

2. Individual differences in various aptitudes not only predict individual differences in learning outcome; they also *interact* with alternative instructional treatments. That is, they relate differently to learning outcome under different instructional presentations or methods. This kind of interaction between individual differences and instructional conditions is called "ATI", standing for "aptitude-treatment interaction".

3. Individual differences (and ATI) can be used by the instructional developer to understand and *improve* instruction for everyone.

First, the popular misconception that biological differences do not exist and psychological differences can be easily erased is partly our own fault as instructional communicators. It stems in part from plagiarism among educational illustrators and audiovisualists. Roger Williams (1956;1967) stressed this point some years ago, but little notice seems to have been taken of it. He showed pictures of a variety of normal stomachs, for example, compared with a typical textbook version. Medical illustrators rarely show this kind of range of individual differences; when asked to make a new picture of a stomach for some instructional purpose, they just copy from existing textbooks. It is a bit frightening to think that our conception of the human stomach may be based on the shape of the stomach of a single 17th century murderer. Williams gives many other examples of striking individual differences in livers, kidneys, heart and brain tissue, nerve cells, spirograms, blood chemistries, etc. Beyond this, there are now bits of evidence of correlations between biological and psychological measures. One, noted by Cattell (1971) for instance, is between measured intelligence and cortical evoked potential of the brain. Time in milli-seconds from onset of the stimulus to the third wave crest is simply and inversely related to IQ. Rimland (1977) has recently noted several other psychobiological correlates.

In short, people are not created equal biologically or psychologically. It is their right to equal opportunity to learn, among other things, in spite of individual differences, that is created. And this makes adaptation of instruction to individual differences among students an imperative. Instructional development thus needs to aim at particular kinds of students, not at the mythical average student.

Now to the second point. Although all of the possibly thousands of individual difference variables are not relevant to instruction, some consistently correlate with learning and also give consistent ATI results. If ATI can be captured and understood, they will make possible the design of adaptive instruction. Only rarely, however, are these underlying ATI ideas properly evaluated in work on individualized instruction. All attempts to individualize instruction, it turns out, rest explicitly or implicitly on some kind of ATI idea.

But what does an ATI look like and how do we find one? Figure 1a shows the traditional outcome of instructional development attempts. Instructional Treatment A is judged better than B because average student achievement is higher after A than after B. A and B could be alternative instructional methods or media, or A and B might represent average effectiveness of the same course, film, program, textbook etc., both before and after some instructional development work. Student individual differences are not considered here.

Adding student aptitude scores (Figure 1b) gives the traditional picture an abscissa. Now we have a regression line, that is, a running average, showing the learning outcome level attained by students who come into instruction at different levels of aptitude. Pretest measures of general mental ability and of prior knowledge often give this kind of positive slope in conventional instruc-

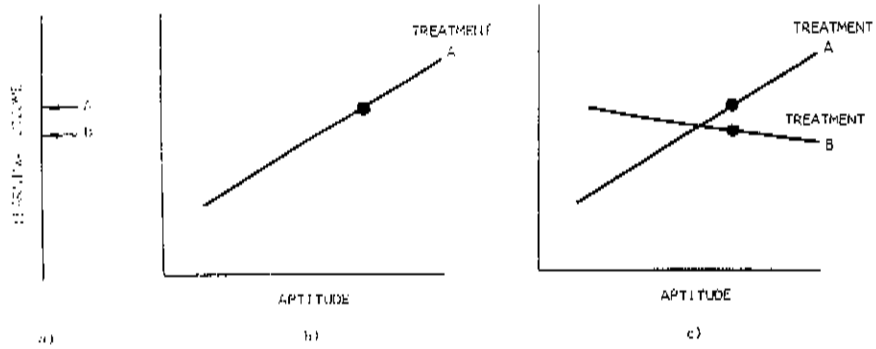

Figure 1. Hypothetical results of a) traditional instructional comparisons b) studies including an aptitude variable and c) studies testing for aptitude-treatment interaction.

tion. It is obtained simply by measuring an aptitude before instruction, achievement or some other valued outcome afterward, and then plotting each student as a point in the graph using his or her two scores. The line can be thought of as the running average across different aptitude levels, but it is usually estimated statistically. When results look like this, attempts at instructional improvement should concentrate on the lower aptitude students, i.e., the question is: What instructional changes will improve things *for them* particularly? It is possible that iterative instructional developments might raise the low end of the regression line, realizing more learning for the lower aptitude students while maintaining a high level of learning for high aptitude students.

But much research now suggests that Figure 1c is the more likely result. A new and different instructional treatment often gives a regression line that is sloped differently, even crossing the line for the first treatment. By improving instruction for one kind of student we have reduced its effectiveness for another kind of student. This happens often enough to suggest, only partly in jest, a first law of conservation of instructional effectiveness. It goes like this: "No matter how you try to make instruction better for someone, you will make it worse for someone else." Findings of this sort indicate ATI. If further attempts at instructional improvement fail to change this pattern, then the best one can do is to assign higher aptitude students to Treatment A and lower aptitude students to Treatment B. The two kinds of students do best with different instruction. This sort of adaptive classification of students into different instructional treatments is one important form of instructional development that can come from investigating student differences. And there are many variations on this theme, including periodic aptitude monitoring during instruction to decide when to switch each student from Treatment B to Treatment A as aptitude develops or knowledge accumulates. One can even imagine local instructional theories (Snow 1977a) built on such results, after much more research is done to understand the ATI phenomenon fully.

But the instructional designer-developer does not need to wait for an instructional theory of individual differences. His work can even be instrumental in creating such a theory. And this leads into the third and main point of this paper. Enough is now known about individual differences in aptitude and learning to allow the instructional developer to use individual differences to advantage in any instructional development project. At least three steps can be taken in such a project.

The first step would be to choose measures of the most important student aptitudes, based on the accumulated ATI literature as well as on whatever hunches are available about the kinds of students who seem to do well or poorly in the particular instructional condition of interest. A recent book (Cronbach & Snow, 1977; see also Snow, 1977b) that summarizes much of the voluminous ATI literature could serve as one guide, but there are several other summaries as well. The aptitude variables recommended for measurement at the start of almost any kind of high school or college instruction are the following:

G is a measure of general mental ability, otherwise known as intelligence (and sometimes divided into fluid, crystallized and visualization ability; see Horn, 1976). G seems to relate to learning increasingly as more of the information processing burden of learning is placed on the student. As the treatment is made to do things for the student that he cannot do for himself, G relations are often reduced. No instructional designer should today fail to include a measure of G in a formative or summative evaluation study, because instructional conditions almost always vary in cognitive processing demands.

$A_i + A_c$ stands for general achievement motivation or orientation, but the distinction between its two parts may be more important. A_i-A_c is achievement via independence vs. achievement via conformity. Many instructional treatments vary in the degree to which they encourage independent student action vs. conformity to instructor-set norms. Relative need for one or the other often turns out to be a critical student difference, particularly at the college level.

A_x is anxiety, another student difference that seems to be fundamentally involved in learning, both on its own and in combination with G. That is, there are higher-order ATI between A_x, G, and Treatment.

These four aptitude constructs deserve to be included in all instructional evaluations. Measures exist for each, and test administration time totals about one to two hours. There are also other individual differences of special interest. Among these are: MS (memory span), PS (perceptual speed), MV (visual memory), and CS (for various undifferentiated cognitive style measures). These aptitude variables may be important for some kinds of instruction; they deserve attention, but are optional in this general list.

Finally, a measure of prior achievement is obviously a requirement; one simply has to know what students already know, in order to develop instruction further. These measures may be pretests specific to the content to be taught, or they may be measures reflecting achievement in earlier courses, or even past grade-point-averages. One would hope, in any event, that they reflected not only variations in factual knowledge but in knowledge organization. All such differences in prior knowledge are differences in aptitude.

These are recommendations, but it should be clear that they are only hypotheses. While supported by some strong prior research, they remain to be tested anew in each new instructional situation. For reasons too numerous to detail here, generalizations across diverse instructional settings are difficult, perhaps even impossible to make. Nor should measures of such aptitudes be taken blindly. While measures of G and A_x have been fairly well-developed, any specific test may not always fit the student population of local interest. Measures of A_i and A_x have seen less development and validation, and are thus even less trustworthy. But progress should come from cautious iterative exploration. One should not throw out an aptitude measure after a single failure, nor should one institute a rigid instructional prescription after a single success.

The second step is to evaluate instructional effects by drawing scatterplots and regression lines as demonstrated earlier, to determine which students do well and which students do not in a given condition. Take each aptitude-outcome pair and investigate it separately as before. Or, use two or more aptitudes at once in multiple regression. Statistical methods for this are discussed by Cronbach and Snow (1977).

Some example pictures of results involving two aptitudes in each of two or more instructional treatments are given in Snow (1977b) and so are not reproduced here. Each shows a bivariate regression plane for G and A_x, or for A_i+A_c and A_i-A_c, as joint predictors of achievement in each of several treatments. The findings represented are those of Peterson (1976) and Porteus (1976). They are complicated, but they do make sense. The results suggest that high school students who are able, conforming and anxious, seem to need more step-by-step structure in the progress of instruction. They do better when teachers provide explicit objectives and sequences of instruction, with clear outlines, reviews, and emphases of the essentials. Students who are able, independent, and non-anxious seem to need less teacher structure of this sort. They seem to provide their own organization for learning. So also, apparently, do less able students who can nonetheless work on their own and are motivated (anxious) to do so.

Consider a hypothetical next step now. Suppose that an instructional designer pursues these earlier findings, administering the same aptitude measures in evaluating a new audio-visual tutorial course in college science. A study is conducted in which the new course is compared with the conventional lecture-demonstration format. Some student sections receive the individualized treatment, going to stalls in the AV library for work with films, tapes, and slides to guide their own study and lab work. Others get the regular treatment. (Or perhaps aptitude and outcome data are available from the conventional treatment of previous years.)

Figures 2 and 3 give the hypothetical results. The ordinate in each case is end-of-course achievement. The aptitudes in Figure 2 are A_i+A_c and A_i-A_c; in Figure 3, they are G and A_x. Comparison with the previous results shows our instructional developer that his data in the first figure conform closely to Peterson's (1976) and those of the second are only slightly different from some of Porteus's (1976).

With these results, one might think of establishing both kinds of courses and assigning students to whichever course their aptitude scores suggest will be best for them. But our instructional developer is mainly interested in improving the new course. The ATI results also give clues to help understand instructional effects because they focus attention on particular kinds of students who seem not to be well served by some particular condition. Why is the new course not effective for students high in achievement via conformity or either low or high on *both* ability and anxiety? Students in these groups have aptitude scores falling in the shaded regions of the aptitude base planes of Figures 2 and 3. Notice that in these regions the traditional course is better (higher) than the new course on the achievement outcome. Task analysis can then focus on these groups, and on the parts of instruction that give them trouble. We might for ex-

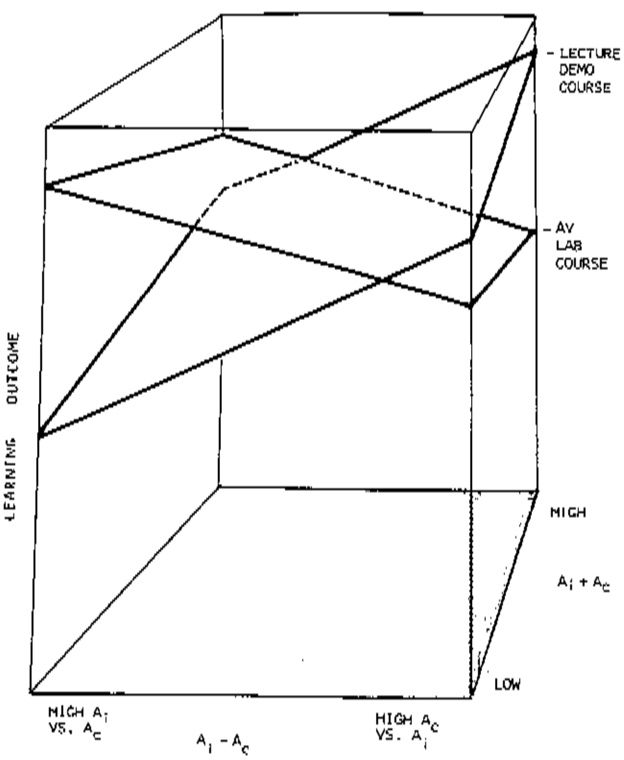

Figure 2. Hypothetical results of a comparison between a conventional treatment and a new audio visual laboratory treatment, showing a bivariate regression plane for each treatment, with A_i+A_c and A_i-A_c as aptitudes.

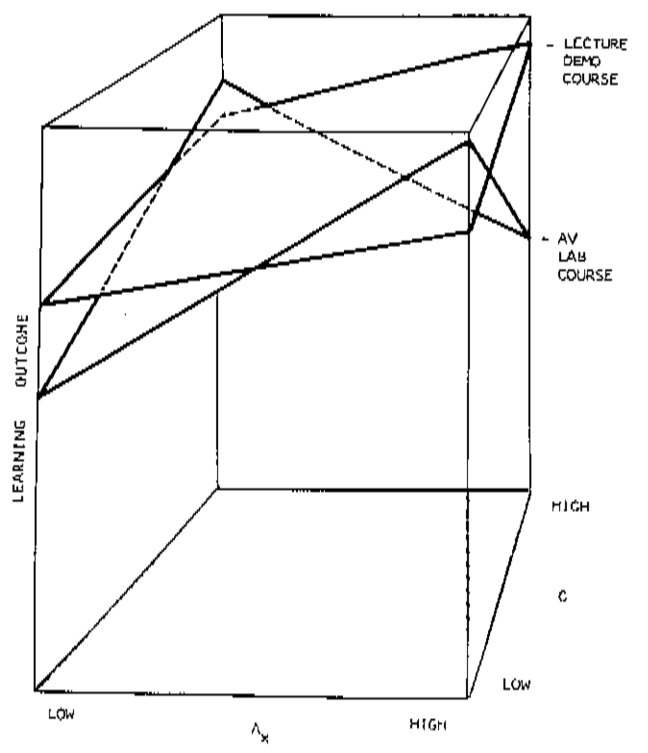

Figure 3. Hypothetical results of a comparison between a conventional treatment and a new audio visual laboratory treatment, showing a bivariate regression plane for each treatment, with G and A_x as aptitudes.

ample ask students with these particular aptitude profiles what aspects on instruction bothered them or were helpful. Or we might observe them at work, or conduct item analyses of criterion tests separately in each aptitude group, to identify weak features of the course. Then we can tinker with these aspects of instruction during the revision process. It might turn out that conforming students need a more detailed procedural outline to follow in the AV lab, that able but anxious students need more clearly specified objectives for their individual work, and that less able, nonanxious students need to be checked frequently by a lab assistant to motivate progress. Making such revisions might erase the ATI effects, or perhaps further revisions will be suggested by ATI in further tryouts. Bunderson (1969) suggested this approach, and has used ATI this way in revising computer-assisted instructional programs. But aptitude-focussed task analysis of this sort has not yet seen wide use. This then completes the third step—diagnosis of individual difference effects and focussed revision of instruction with these effects as guide.

To summarize, one can use ATI to develop macroadaptations of instruction, assigning different kinds of students to different treatments aimed at the same outcome goal. Treatments are then designed on broadly different models to fit different classes of students optimally. Or, one can use aptitude information to make microadaptations by tinkering with aspects of one treatment during revision, so that it becomes individualized more on a day-to-day or even minute-to-minute level, as is possible in computerized instruction. Or one can do both; microadaptation can proceed within broadly differentiated streams at the macro level. In any event, what I believe one must do is to collect and use aptitude information in all instructional evaluations. This is required because the evaluation question is always—did the instruction work well for the students, that is, for each student, not just for the few who stand in the vicinity of the group average. And an instructional treatment that is best on the average may still serve some students poorly. One can choose to ignore student individual differences, but they will be there influencing instructional effects whether they are measured and used or not. Despite the fact that education is ultimately an aptitude development program, individual differences in aptitudes will never go away.

References

Bunderson, C. V. Ability by treatment interactions in designing instruction for hierarchical learning task. Paper presented to the annual meeting of the American Educational Research Association, 1969.

Cattell, R. B. *Abilities: Their structure, growth, and action.* Boston: Houghton Mifflin, 1971.

Cronbach, L. J., & Snow, R. E. *Aptitudes and instructional methods: A handbook for research on interactions.* New York: Irvington, 1977.

Horn, J. D. Human abilities: A review of research and theory in the early 1970s. *Annual Review of Psychology,* 1976, 27, 437-485.

Peterson, P. L. Interactive effects of student anxiety, achievement orientation, and teacher behavior on student achievement and attitude. Unpublished doctoral dissertation, Stanford University, 1976.

Porteus, A. Teacher-centered vs. student-centered instruction: Interactions with cognitive and motivational aptitudes. Unpublished doctoral dissertation, Stanford University, 1976.

Rimland, B. Applying psychobiology. *Naval Research Reviews,* 1977, January, 9-16.

Snow, R. E. Individual differences and instructional theory. Paper presented at the annual meeting of the American Educational Research Association, New York, April 1977. (a)

Snow, R. E. Research on aptitudes: A progress report. In L. S. Shulman (Ed.), *Review of research in education,* Vol. 4. Itasca, IL: Peacock, 1977. (b)

Williams, R. J. *Biochemical individuality.* New York: Wiley, 1956.

Williams, R. J. *You are extraordinary.* New York: Random House, 1967.