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HELPING STUDENTS LEARN ONLY WHAT THEY DON'T ALREADY KNOW

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Well-known, well-validated principles of individual-difference psychology and education should lead to major changes in classroom instruction. Students need to be helped to learn what they do not already know, instead of being marched through course materials in lockstep, largely regardless of what they knew at the start of the course. The lockstep method especially hurts the intellectually talented, who tend to be far ahead of grade level. This finding led the Study of Mathematically Precocious Youth (SMPY) at Johns Hopkins University to devise a Diagnostic Testing followed by Prescribed Instruction (DT-PI) procedure. It has been tested often and successfully, especially for instruction in middle and high school mathematics, but the procedure is applicable to other subjects. Nevertheless, the DT-PI model is viewed by SMPY as merely a stopgap on the road to radical reorganization of instruction in schools.

Many teachers seem to assume that their beginning students know nothing about the subject. This is a fail-safe strategy. By not having to realize the vast individual differences in knowledge background students bring to the course, the teacher avoids feeling responsible for differentiating instruction accordingly. An anecdote may help emphasize this point. In one of my Study of Mathematically Precocious Youth's (SMPY's) annual January talent searches, a 12-year-old 7th grader in a public school scored 760 on the mathematical part of the College Board's Scholastic Aptitude Test (SAT-M). The average male college-bound 12th grader that year scored 500, with a standard deviation of 115. The 7th grader's mathematical reasoning ability placed him in the top 1% in 10,000 of his age group. After he learned his score, this 7th grader went to the teacher of beginning algebra in his middle school and asked to be admitted to that class. The teacher refused for what he considered two good reasons: His course was for able 8th graders, and he thought no one could enter it in midyear and catch up. Despondent, the boy telephoned me. I told him I would call his teacher and suggest that he administer to the boy the Cooperative Mathematics Test, Algebra I—a difficult 40-item, 40-min multiple-choice test covering the first year of high school algebra on which a score of 32 correct is excellent for anyone who has completed a school year of that subject. The boy made no errors. His score of 40 would be rare for anyone. Then, the teacher foolishly remarked, "Well, you really are ready to enter my class." The boy replied, "Of course not. Obviously, I already know beginning algebra." He then enrolled part time in a university mathematics class. As a high

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school senior, he was one of the six members of the USA's International Mathematical Olympiad (IMO) team and won a silver medal in the worldwide competition.

What would probably have happened if we had not "discovered" him? The next school year, as an 8th grader, he would have "studied" Algebra I, been bored and inattentive, and because of damaged motivation ended the year scoring, say, 38 on the test. The teacher would have taken credit for the high score, not realizing that he had hurt the boy's achievement. It seems unlikely that this youth would have ever qualified for the IMO team.

Of course, he was most unusual. The principle holds, however. SMPY found that half of all 7th graders who score 500–800 on SAT-M (about 14% of the talent-search participants score that well) know more algebra, as measured by the standardized algebra test, before they study the subject in school than do half of the students after completing a school year of it. The need for pretesting is not confined to mathematics. An 8-year-old boy scored 54 on the College Board's Test of Standard Written English (TSWE), whereas the average college-bound 12th grade male scored 39, with a standard deviation of 11. How much increase in writing ability might this 8-year-old get from the standard 3rd grade curriculum? Also, pretesting is applicable to other subjects such as high school biology, chemistry, and physics (Stanley & Stanley, 1986).

Such observations led us in SMPY to devise what we termed the Diagnostic Testing, followed by Prescribed Instruction (DT-PI; Benbow, 1986, 1992; Benbow & Lubinski, 1996; Benbow & Stanley, 1996; Lupkowski & Assouline, 1992; Stanley, 1978, 1979, 1991; Stanley & Benbow, 1986) model for instruction in our fast-paced courses for intellectually talented boys and girls. The DT-PI model operates on the following principle: Determine what the student does not know (diagnosis) and help him or her learn just that, without needless repetition.[1] This is simple in principle but difficult to achieve in practice because it runs counter to the "begin on page 1" mindset of many teachers. The DT-PI model conforms to well-validated ideas about individual differences, so it can be effective and timesaving. Here is an example of how it works for mathematics:

1. Choose students who are excellent in mathematics (e.g., who have scored high on a standardized math test, perhaps part of the achievement-test battery administered in school the prior year).
2. Administer Educational Testing Service's Sequential Tests of Educational Progress (STEP) Mathematical Concepts, Level 4, Form A (for Grades 4–6), under standard conditions, including the time limit. Ask the student to put a dot to the left of the item number if he or she is not fairly sure about the answer.
3. Score the test. If the examinee did as well as the average student two grades higher, then they may continue.
4. Have the student retry, with plenty of time, those items missed and show

[1]This prescribing is precise and rational, rather than authoritarian. It is analogous to the medication and treatment a competent pediatrician prescribes for a specific patient, after examining that patient carefully, instead of writing a modal prescription for all ill children of the same age.

the work so that it can be checked. Also, the examiner should ask the student to show the work for the dotted items.

5. Help the youngster learn the points underlying the missed items, rather than pointing to the missed items themselves.[2]
6. Administer the comparable Form B under standard conditions.
7. Score Form B.
8. Repeat Steps 4 and 5.
9. Follow the same procedure for the STEP Computation Test.
10. If the student's progress warrants, move up to STEP Level 3 (for Grades 7–9).
11. Continue through Levels 2 (Grades 10–12) or 1 (Grades 13–14).
12. Go on to McGraw-Hill/California Test Division's Cooperative Mathematics Tests, Algebra I–III.
13. For a few extremely precocious youths, it may be desirable to try other Cooperative Mathematics Tests (Geometry, Trigonometry, Analytic Geometry, and Calculus) in the above ways. Occasionally, we have found young students who have somehow learned as much as 4.5 years of mathematics (through analytic geometry) before studying math formally.

In the 1970s, when SMPY was experimenting constantly with various ways to facilitate the learning of mathematics (e.g., see Benbow & Stanley, 1983), we carried out a "stunt." We taught 75 youths who reasoned exceptionally well mathematically the first year of algebra in 1 day! This was done mainly to train 15 young math mentors on the DT-PI procedure so that they could serve as teaching assistants in our summer courses. Each mentor sat at a table with his or her five mentees, about whom the mentor knew a great deal. As 7th graders, each mentee had scored at least 500 on SAT-M and at least the 50th (but not more than the 75th) percentile of national norms on the Cooperative Mathematics Tests, Algebra I, Form A. Knowing which algebra items each of his or her mentees had answered incorrectly, and which distracters had lured them away from the correct answers, the mentor went to work with pre-prepared practice materials covering every point missed. The mentees worked on these individualized exercises, soliciting from the mentor whatever assistance was needed. Then, when it appeared that the mentee had mastered the points originally missed, he or she took comparable Form B of the algebra test in the standardized way. About two thirds of the mentees reached our preset criterion of success, which we defined as the 85th percentile or higher. More mentees would probably have done so if the university mathematics professor we secured to lecture about algebra had not taken up much of the mentorial time with his (fascinating) talk.

[2]As noted later in this article, a tutorial method may be used that emphasizes self-instruction. Also, the teacher may choose to do group explaining with those students who answered a particular item incorrectly, or with the entire class for those items missed by nearly all of the students. Proceeding from the least known material toward the most known should decrease needless repetition and save instructional time, even if the full DT-PI approach is not used. Of course, the effectiveness of that reverse approach can depend on the sequential or hierarchic structure of the content of the subject studied, as well as the intellectual capabilities of the students.

As noted earlier, this 1-day marathon was sort of a stunt. We did not expect such hastily acquired knowledge to "stick," nor did we expect all 50 students who met our 85th-percentile criterion to be fully ready for Algebra II immediately. We did learn, however, who the best performing mentors were. Some mentors had 100% success with their groups, others had little. During the day, we observed each mentor closely to ascertain his or her interaction with the mentees. Thus, our goal of deciding which of these young mentors might make excellent teaching assistants for our fast-paced mathematics summer courses was met. All of the mentees had been screened for their mathematical reasoning ability and knowledge of algebra, but the "hands-on" performance evaluation (work sample) helped assure that the chosen individuals could adeptly use the DT-PI model.

For diagnosing learning deficits, we had to make do with standardized achievement tests. Because these tests are not constructed for this purpose, they are less than ideal instruments to use in deciding how to proceed from DT to PI. A longer, more focused sampling of knowledge would be desirable to make this determination. Modern computer technology and adaptive testing can make that strategy feasible (see Ashworth, 1997). For example, an examinee might be faced with well-constructed diagnostic five-option, multiple-choice items at the right level of difficulty and be required to try options until the correct answer is chosen. By timing and tracing the progression through the distracters to the correct response, a mentor well versed in the subject matter should, in principle, be able virtually to "read the mind" of the examinee and thereby devise appropriate computerized instructional strategies to erase ignorance. In expert hands, this diagnostic should proceed rapidly. Even without the special items and computer enhancements, one of my associates in the 1970s cleared up, in a few hours, all the confusion about prealgebraic mathematics topics that a very high IQ 9-year-old had; thereafter, the student could proceed successfully in algebra. Where in teacher-education programs are such procedures taught? Where are such procedures practiced, if taught?

Unfortunately, the current age-in-grade grading and the A-to-F lockstep system that characterizes nearly all schools, with the exception (sometimes) of kindergarten through third grade, militates against use of a DT-PI approach. In industry, this system is called *batch processing*. Educational processing does not, however, enjoy the uniformity of raw materials typical in industry. Great individual differences in the learning rates of students make educational batch processing ineffective. As I urged elsewhere (Stanley, 1980), a radical reorientation that capitalizes on individual differences is sorely needed. Students need to start learning where their current knowledge base exists and proceed from there to some substantial criterion of achievement. Grading by age, and awarding A-to-F marks (or euphemistic versions thereof), interferes severely with starting at the learner's current knowledge base. Any standardized achievement test reveals the wide range of knowledge and skill in any school subject, but school organization usually ignores that fact, except to the extent that skilled, dedicated, overworked teachers can individualize within the classroom. My suggestion for remedying this was as follows:

> While highly successful, SMPY's various procedures occur only because the age-in-grade, Carnegie-unit lockstep of schools, both public and (especially)

> private, makes such heroic measures essential. If schools were organized differently, SMPY would not have been necessary—nor, indeed, would the present special "remedial" provisions for most slow learners. In my opinion, age-grading for instruction in academic school subjects has crept insidiously upon us as we have moved from tutorial instruction and the one-room schoolhouse to the current situation. It needs to be reversed. But, of course, that will not be done easily or quickly.
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> My proposal in the area of mathematics is for a longitudinal teaching team that spans kindergarten through the 12th (or 14th) grade in a school system. Working in a mathematics learning center, the various members of this team would be responsible for meeting all the mathematics needs of all the students in the school system. The buck would stop with them. Every student would be helped to meet clearly stated, substantial criteria of mathematical competence. A few students would accomplish these early, perhaps by age 8; a few others would have to work hard until age 18 in order to attain the minima. Some students would proceed far beyond the minimum essentials; others would stop with them and devote their efforts thereafter to other subject matter.
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> Much of the instruction might still be in groups, but not age-graded ones. Attaining levels of achievement instead of letter grades would be stressed. All members of the longitudinal mathematics team would have to be highly competent, but some would specialize in helping slow learners and others in helping fast-moving ones. (Technologically sophisticated educational diagnosticians would also be essential.)
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> Obviously, this longitudinal-teaching-team model could be applied to other subject-matter areas such as language arts, social studies, science, and foreign languages. There might also be art, music, drama, physical education, and social and emotional development teams. Attention to individualized differences, both within areas and across areas, would be increased vastly.
>
> I should like to see a sizable public school system pioneer this approach for at least 25 years. Because of problems that one can readily anticipate and many that one cannot, almost certainly this would be extremely difficult. I believe strongly, however, that some such plan is our only hope for the educational future of America's youths. All else will be sorry stopgaps. (Stanley, 1980, p. 11)

Of course, longitudinal instructional teams of the kind I propose are an extreme form of "tracking." The slow learners in a given subject would be taught together with the highly individualized DT-PI method aimed to help them learn on their own; so would the average and fast learners. This is the ultimate form of homogeneous grouping because it takes each student from where he or she is in their understanding of the subject toward the performance criterion at whatever pace the individual needs. It is a far cry from segregating the "smart" students from the "dull" ones, without assessing each person's readiness in each subject. The curriculum would be truly differentiated in a way that it is not, when high, average, and low sections of a subject follow the same lesson plans.

Most of the possibly negative effects of tracking by ability (e.g., IQ), rather than by actual knowledge, can be assuaged by avoiding age-grading and stigmatizing children through the use of A-to-F marking and by having the student proceed in each subject from his or her own knowledge base. There will be no "remedial" instruction because the pace will be adjusted to avoid mislearning.

Traditional tracking and homogeneous grouping have their adherents and detractors. Benbow (1998) and Benbow and Stanley (1996) examined the evidence in great detail and concluded that, when properly done, careful attention to individual learning differences helps students at all ability levels. Longitudinal instructional teams using the DT-PI model should be even more effective for nurturing various talents (Gardner, 1997; Stanley, 1997; Van Tassel-Baska, 1997).

My message is that, in the next century, diagnostic testing followed by suitable instruction should be refined so that it can help teachers facilitate learning more in accordance with individual differences in knowledge and learning rate.

Eventually, DT-PI adaptive-testing computer programs for home use by highly able students might emerge and leave schools in the dust as far as those youth are concerned. Where is the educational equivalent of Bill Gates who will pioneer this curriculum revolution? For the present, however, the moral of this article is, "Avoid trying to teach students what they already know."

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