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AUTHOR Helms, David: Graeber, Anna
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ABSTRACT

Observations are offered on some of the problems that seem to relate to children's acquisition of basic skills and learning of mathematics. Some research and development options are suggested. Discussion of the problems is divided into the two areas "Instructional Program" and "Management of the Instructional Program." The first of these is further subdivided into "Basic Mathematical Skills and Learnings" and "Strategy and Materials of the Instructional Program and Problems that May Raise Barriers to Learning." (MK)

PROBLEMS RELATED TO CHILDREN'S ACQUISITION OF BASIC SKILLS AND LEARNING OF MATHEMATICS

by
David Helms
and
Anna Graeber

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RESEARCH FOR BETTER SCHOOLS, Inc.
1700 MARKET STREET
PHILADELPHIA, PENNSYLVANIA 19103

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I. INTRODUCTION

We appreciate this opportunity to offer a few observations on some of the problems that seem to relate to children's acquisition of basic skills and learning of mathematics - and to suggest some R & D options. To the extent that our observations correspond to similar findings of others, they may suggest dimensions along which the quest for ways and means of enhancing mathematics learning might be pursued to some benefit. To the extent that the circumstances that gave rise to these observations are open to alternative interpretations, perhaps, they should be foci for disciplined study.

We do not assert that the problems upon which our observations are fixed constitute an all-inclusive set. Neither would we argue that they are the most likely causes of barriers to learning. We do contend that they will require attention in any instructional treatment that is intended to enhance students' acquisition of basic skills and learning of mathematics. The problems we perceive to be related to children's learning of mathematics are discussed under the "Instructional Program" and "Management of the Instructional Program."

II. Instructional Program

A. Basic Mathematical Skills and Learnings

In our work at RBS, as developers, implementors and evaluators of instructional programs in mathematics, we have been more concerned with problems of instructing than with problems associated with the choice of appropriate mathematics content.

Nevertheless, it has been our intention to provide "good mathematics" that is eminently instructable and learnable by learners in grades K - 8. Frankly, we have attempted to insure the quality of the mathematics content mostly by selecting it from areas of consensus among major national programs.

The careful analyses employed for the identification of consensus and our subsequent experiences developing and implementing programs based upon this content prompt us to wonder about several aspects of the "modern math" as they might relate to problems of teaching and learning. Mathematics that is appropriate for inclusion in the school curriculum it seems to us, is a function of: (1) content that can be offered to learners at their respective stage of development, (2) relevant learner need for and interest in mathematics, and (3) the time likely to be available for mathematics instruction.

The argument that "...any subject can be taught effectively in some intellectually honest form to any child at any stage of development" (Bruner, 1965) is well known. The condition upon which that statement is predicated is less popularly observed. "The task of teaching a subject to a child at any particular age is one of representing the structure of that subject in terms of the child's way of viewing things." (The underlining is our own.)

We suggest that one explanation for the failure of new math to help the majority of the national student body to improve performance through better understanding (Gray, 1974) may be the use of mathematical heuristics that do not reflect "the child's way of viewing things." It is our observation that the mathematical heuristics employed to elucidate structure and operations frequently have had a contrary effect upon many students. Perhaps, set notions; associative, commutative and distributive symbolic manipulations; and computations in unfamiliar non-decimal number bases have been extended and emphasized beyond the use intended for them. Still, we wonder about the value of heuristics that require more sophisticated behavior of the student than the learning they were intended to elicit.

At any rate, we propose that the effectiveness of the mathematical heuristics of the new math be studied in terms of the degree to which they promote understanding.

Arguments made for the retention of certain mathematical heuristics (those not justified in terms of their superior enhancement of understanding) on grounds that the mathematics is worthy in its own right, or, that it provides valuable precursor experience that will benefit learners in some way at a later date are arguments of need. Such claims should be evaluated in the context of competing need claims which suggest other kinds of studies.

We are struck by the reasonableness of Gray's assertion that two principal concerns guiding overall determination of content needed at every stage of student development should be: (1) mathematics necessary for a minimal level of quantitative competence that contemporary culture and its immediate future prospects demand and (2) mathematics necessary for some intellectual grasp of the mathematical sciences and their applications to our complex world. We would add a third major concern, mathematics relevant to the experience of the learner. All learners are not so turned-on by the beauty of mathematics as we would hope. Mathematics that is patently relevant to their interests and needs in daily living is more likely to be motivating. To the extent that more esoteric mathematics can be made relevant to learner interests and needs, motivation for study of such mathematics may be aroused.

Apparently motivated by the startling announcement made in 1965 that anything can be taught to learners at any stage of development, many textbook publishers and teachers have responded as if whatever can be learned ought to be taught as early as possible. Economists know full well that the needs and wants of humans are endless, but the means of their satisfaction is limited and they have devoted themselves to the problem of maximizing utility through optimal allocation of available resources. If there were no other limitations, the pressures exerted upon learners by the amount of learning expected in the time available for instruction in mathematics should cause us to weigh carefully <u>what mathematics learning is of most worth and when</u>.

Insufficient attention to the constraint of time, we observe, has some students feeling bombarded by successive waves of radically new ideas and too little time to gain even a modest grasp of some of them. We are told that feelings of "pressure" frequently motivate some students to declare for themselves unofficial holidays from school.

Given that some people are prone to prescribe what learning is of most worth solely on the merits of the mathematics and the capability of the students at specified stages of their development, it should be noted that sufficient time allowances need to be made for both developmental activities <u>and</u> practice if the learners are to acquire the predicted learning. A number of studies point to improved student achievement when between 50 and 75 percent of the class time is devoted to development activities. (Reidesel and Burns, 1973). Yet, if too little time was spent on development activities in previous years, it is our observation that too little time has been spent upon practice in the recent past. The result of the latter has been that learners spend discouraging hours on problems they could quickly solve if they had a ready grasp of the arithmetic facts.

At the risk of overloading an already difficult content determination, our experiences, nevertheless, tell us that not only does the kind of mathematics that can be offered differ according to the developmental stages of the learners, but learners also differ in terms of their positions within the developmental stages and in terms of the relative amounts of developmental activities and practice they require. This suggests that the study of what content should be offered, when, and for how long should, additionally, consider how the determination might be adaptive for variations in competency and need among individuals.

It is proposed here that the determination of what mathematics is most worth learning is a task that will require careful and systematic study from the perspectives of several interest groups. In this respect, Wiloughby's comments in the Proceedings of the Conference on the Future of Mathematics Education (1975) deserve attention.

> The process of setting goals...probably should be overseen by a distinguished commission of citizens, some of whom are mathematics educators (including classroom teachers), mathematicians, natural and social scientists, humanists, consumer advocates, and other representatives of the society at large.

To impose the decisions implicated by the questions we have raised upon already overburdened teachers, as seems to be the inclination of today's educational leadership, is grossly unfair. Gagne (1970) has noted other important and time consuming tasks that are dependent upon teachers for their adequate treatment.

> Predesign of instructional conditions greatly reduces the necessity for the teacher to use valuable time in extemporaneous design, and thus makes possible for a proper emphasis to be restored to the teacher functions of managing instruction, motivating, generalizing, and assessing.
>
> The...point should not be taken lightly, since these other functions deserve a great deal of emphasis in education, and are likely to suffer neglect by teachers who are overburdened with the very difficult task of extemporaneous design of instructional conditions.

That the studies proposed here are the proper concern of research and development is confirmed for us by the prospect that such studies will need to be continuing efforts. A reading of the history of mathematics education in the United States indicates the continued growth of the discipline of mathematics and the technological advances of society are reflected in school mathematics content. The most constant aspect of change in school mathematics - the inclusion of more content - presses upon us today. We are being told that we need to teach metrics, we need to teach problem solving, we need to do more with applications of mathematics, we need to attend to consumer mathematics, we need to teach students how to use calculators and how to estimate? The temptation to once again "add on" to the content is strong. The question of what mathematics learning is of most worth, when, under what conditions of time and for whom obviously requires continuing resolution.

The studious determination of what mathematics is of most worth under the priorities and circumstances of the time likely will be considered the basic mathematics skills and learnings of that period.

B. Strategy and Materials of the Instructional Program and Problems that May Raise Barriers to Learning

Whatever the mathematics program, we are convinced that instruction can only be effective to the extent that the teacher is successful in achieving appropriate matches between learners and their instruction. Glaser (1967) notes several minimal tasks of instruction that must be systematically attended to if "good fit" matches are to be consistently arranged for learners. They are: (1) specification of expected learning, (2) pre-instructional assessment of learner competency and need, (3) provision of appropriate learning experiences, (4) post-instructional evaluation of learning.

The difficulty for teachers in arranging appropriate matches lies in the differences that distinguish learners. Logically, critical differences among learners imply that the instructional tasks be attended to for the learners, individually. Failure to do so, we observe, tends to cause problems that inhibit learning of mathematics.

Persistent mismatches between students and their mathematics instruction lead to cumulative boredom or defeat and eventually to disruptive classroom behavior and/or absence from school. In every case, the learner's self-concept as a mathematics student is likely to be less appropriate than it could be, and, in every case, learning by the student likely will be less effective than it might be.

On the other hand, it is our experience that frequent achievement by students of demonstrable success in mathematics, positively reinforced, is a most powerful motivator of mathematics learning. Continuous progress seems to occur, according to our observations, when the student possesses the necessary prerequisite competencies; when the transitional instruction provided the student is appropriate for the mathematics to be learned <u>and</u> the individual needs of the student; when specific feedback and reinforcement are accessible to the student on his/her need; when the criteria for success are objective and clearly understood; and when the time for testing the student's acquisition of the learning is his/her determination.

For us, the keys to effecting good matches between learners and their mathematics instruction are: (1) appropriately specified and adequately sequenced curricula of generous scope, (2) criterion-referenced assessment instruments correlated with the performance objectives, (3) self-instructional materials, and (4) specific preparation of teachers for the management of adaptive instruction. The first three keys warrant special comment to reflect design progress we have made since the early days of <u>IPI Mathematics</u>. The fourth item will be attended to in the next section.

Our recent work has confirmed our suspicion and fond hope that specifying and sequencing mathematics performance objectives <u>does not</u> necessitate trivial objectives, forfeiture of exploratory and inductive experiences for learners, deprivation of student content choices, isolated study, or exclusion of enactive learning. It taught us that accommodation of these attributes does require greater imagination, more creativity and sharper designer skills than we had supposed necessary.

That the kind of instructional program we describe may be positively related to significant improvements in student learning of mathematics is suggested by the findings of Holzman and Boes (1973) in a study they conducted for the United States Office of Education. According to these researchers, eight common characteristics of successful compensatory education programs included: (1) clear objectives stated in measurable terms and supported by instructional techniques and materials closely related to the objectives; (2) attention to individual needs including careful diagnosis and individualized instructional plans; (3) structured program approach which stresses sequential order and activities and frequent, immediate feedback. The criteria for identifying a successful program were: (1) student achievement, (2) student attendance, (3) positive self-concept, (4) fulfillment of physical needs.

III. Management of the Instructional Program

Barriers to learning mathematics are not likely to be reduced by programs alone, at least, not by programs with which we are familiar. Programs provide means, procedures and accommodating materials to facilitate the teacher's attention to the tasks of instruction for, or with, the students. How well the tasks are attended likely determines the probability of success for students and their attitude toward learning. The ideal combination would seem to be well motivated students with a well-designed, well-managed mathematics program.

In our work with teachers, helping them to shift from standardized attention to the tasks of instruction for the class, as a whole, to adaptive attention for individuals, it is our observation that many opportunities exist for pre-service and in-service improvement of the teacher's program management skills. Needless boredom and frustration of students could be avoided if more teachers had a better grasp of mathematics content and necessary diagnostic skills.

For many teachers, knowledge of mathematics is too meager and diagnostic skills too deficient to recognize the patterning of errors that reveal the nature of student misunderstanding. Too often, lack of versatility in mathematics and one-to-one instruction causes teachers to miss opportunities to provide just the right enactive or iconic experience that might pierce the barrier to a student's comprehension. Many options revealed in teacher-student exchanges urge the use of adroit questioning to move the student to higher order reasoning but are missed for want of both mathematics and tutorial skill.

Programs do not provide teachers with these skills, only the opportunities for their use. If learning of mathematics by students is to be enhanced, teachers must be helped in developing their own mathematics competence and, particularly, their skills in diagnosing difficulties and prescribing a variety of appropriate alternative learning solutions. Moreover, their preparation to conduct these activities should focus on attention to individual students. Learning and erring are individual behaviors. If, at times, and on the surface, individuals seem to share the same learning or the same erring, it is likely that they do so for reasons that, privately, are unique to each of them.

Just as important as mathematics competency are the skills of program management that encourage students to pursue learning whether independently or in groups. If the teacher concentrates upon attention to the tasks of instruction for students, individually, obviously, students not receiving immediate attention must be engaged in their own self-instruction. Delegating instruction to students requires that they be free to move about and to engage in a variety of experiences alone or in the company of other learners. Successful management of such a program requires a high level of trust on the part of both teacher and students. Generating trust in themselves and among their students is a difficult skill to acquire for many teachers. But, again, it is presumed that teachers bring such skill to the program.

Attention to the tasks of instruction for students, individually, is highly compatible with the notion of small group instruction. There are many reasons for learning in small groups even though emphasis may be on matching individuals with instruction. Several learners sharing the same difficulty, if not for the same reasons, may be more effectively attended to in a group. Safety, practice in communication, cooperative inquiry are all reasons for small group settings. When emphasis is on "best fit" instruction of individuals, formation of small groups will be predicated upon (1) the need for some kind of learning that is best acquired in a group setting and (2) all members having the prerequisite learning necessary for success in the group. Arranging and guiding small group instruction are demanding skills that need special attention in pre-service and in-service preparation.

It is our observation that many teachers do not possess many of the skills necessary for effective program management. Nor do many acquire them as a result of the mathematics program itself. Since the skills, well performed, are probably positively related to children's acquisition of basic skills and learning of mathematics, we recommend that a careful study be made to determine the necessary program management skills, adequacy of pre-service preparation of teachers in these skills, and effective means for their instruction.

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