Improving science and mathematics education for minorities and women

Contextual factors in education

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Laboratory of
Comparative Human Cognition

prepared for Committee on Research in Mathematics, Science, and Technology Education

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Foreword

The Committee on Research in Mathematics, Science, and Technology Education was established in the Commission on Behavioral and Social Sciences and Education of the National Research Council in 1984 in response to a request from the U.S. Department of Education. Its initial tasks, for that department and the National Science Foundation, were to develop a set of research priorities and to consider the role of multidisciplinary research for science, mathematics, and technology education. That work resulted in two reports, *Mathematics, Science, and Technology Education: A Research Agenda* (National Academy Press, 1985) and *Interdisciplinary Research in Science, Mathematics, and Technology Education* (National Academy Press, 1987).

While preparing the first report, the committee became interested in exploring in more depth two issues: how children learn reasoning and other complex thinking skills, and how the school environment can be manipulated to maximize opportunities for children to succeed in learning science and mathematics. Work on the first issue was undertaken by Professor Lauren Resnick at the Learning Research and Development Center of the University of Pittsburgh and resulted in the paper *Education and Learning to Think* (National Academy Press, 1987). Work on the second issue was carried out by Michael Cole, Peg Griffin, and their colleagues at the Laboratory of Comparative Human Cognition at the University of California at San Diego. Carnegie Corporation of New York is generously supporting wide distribution of both volumes.

The Wisconsin Center for Education Research is delighted to join the National Research Council in publishing the second paper. The Center is committed to three principles that permeate this paper: that the educational opportunities for women and minorities in the United States must be improved, that the knowledge base to make important improvements is being developed, and that major, perhaps radical, approaches that build on the knowledge base may be necessary. In support of these principles, Michael Cole and

Peg Griffin, in concert with over 30 other researchers from across the nation, have pulled together an extraordinary and challenging range of ideas, findings, and speculations—in a very engaging paper.

This paper comes at an opportune time. The nation's educational systems have survived a recent major burst of reform. By many accounts the reforms have been successful: the quality of teacher training is undergoing intense scrutiny; greater numbers of talented college students are entering the teaching force; more students are taking high school courses that will enable them to qualify for college admission; and, especially in the South, education has become a top priority of state governments. By other accounts, however, the reforms have ignored the most pressing problems of American education: relatively few of the state reforms addressed the most needy in the nation's schools—the poor, those whose English is limited, and very low achievers. The percentage of children in poverty has markedly increased since the early 1980s; the dropout rate in many places has increased; and the range of college attendance among blacks has declined. For many students, the opportunities are fewer now than they were before the reforms.

Cole, Griffin, and their colleagues address the issue of creating constructive educational environments for women and minorities, especially in the content areas of mathematics and science. They review the results of recent interesting and successful interventions; they poke holes in some of the superficial policy proposals—such as "increased time on task"; and they explore the possibilities for using new technologies to enhance opportunities. The paper may be usefully read by a public interested in educational issues, by teachers and administrators who wish to improve their school systems, and by social and behavioral scientists who are engaged in developing new knowledge. We are pleased to be involved in the publication of this paper.

Marshall Smith
Former Director

Carl Kaestle
Director

Wisconsin Center for Education Research

Acknowledgments

This report is the result of a group effort over an extended time period. Although we are listed as Editors of the resulting monograph, along with the Laboratory of Comparative Human Cognition, we acted far more as collators of the members' contributions.

We urge readers to turn to the Appendix, which contains a brief description of the process of compiling the report and the names of the contributors who are the real authors.

We acknowledge the support of several people and institutions in completing this work. First and foremost, we are deeply indebted to Peggy Bengel and Karen Fiegener, who gave unstintingly of their time to coordinate all of the contributors and the resulting texts.

The W. T. Grant Foundation, through the Committee on Research on Mathematics, Science, and Technology Education, and the Carnegie Corporation of New York provided financial resources support for this work. We also express our appreciation to Senta Raizen, the study director of the committee, for her assistance throughout the work and publication of this paper.

Michael Cole and Peg Griffin

1: Introduction

The purpose of this review is to arrive at a research agenda addressed to ways in which increased knowledge of contextual factors in education can enhance the basic academic skills and participation in technological literacy by far more of our population. Along with the parent NRC Committee that generated this report (the Committee on Research in Mathematics, Science, and Technology—James March, Chair), we have worried about the vast educational potential waiting to be tapped among a variety of groups that are underrepresented in the technological activities of our society, especially women and ethnic minorities. We have focused on how to use new technologies as a vehicle for general educational improvement, in addition to considering their use as a goal of a specific part of the technical curriculum.

Underlying Concerns

Underlying our specific focus on underrepresented population groups was the shared perception of committee members that the problem of underrepresentation in higher levels of the educational system by certain populations has reached disastrous proportions in this country. In southern California, for example, more than half the Hispanic-American children who enter the school system drop out before they complete high school; less than 10 percent of Hispanic-Americans from southern California enter the University of California. Yet, in many areas of southern California, Hispanic-Americans are an absolute majority of the citizens whose educational needs serve as the *raison d'être* for the public support of a university. Analogous problems exist in other parts of the country and for other populations.

This situation is so obviously dangerous from a political and economic point of view that it deserves the serious concern of policymakers and the academic community, as well as the military and the business community. We assume the

problem of widespread undereducation to be a common concern underpinning this report.

The diffuse nature of factors included under the rubric of context required us to create an investigatory framework that could confront the diversity of the problems with an adequate diversity of solutions. Our group was highly interdisciplinary, including specialists in psychology, sociology, linguistics, anthropology, and education. We took it as our task to come up with recommendations based, insofar as possible, on methods and canons of evaluation acceptable across a variety of disciplines so that we would be confident of their scientific foundation. At the same time, the interdisciplinary nature of the problems insured that methodological and measurement issues would loom large as a problematic element in our review of the field.

It is the Committee's view that the obvious difficulties of the current educational situation represent a period of great promise as well as a period of threat for American education. In particular, it appears that existing research has identified a set of social systems properties which, when implemented, sharply improve the educational achievement of a great many children who otherwise would drop out below the needed level of technological literacy. The problem is that educational programs successful in the "hothouse" of social science interventions do not have staying power when the hothouse supports are withdrawn.

It seems clear, from a variety of public opinion polls and analyses of educational activities in different sectors of society, that the American public is not going to provide expanded budgets to existing educational institutions for extending the school day, extending the school year, reducing the adult-child ratio, or other personnel expenditures that might promote the generalization of the intervention experiments. Yet there is great pressure for increased educational performance. That contradictory set of social constraints can be reconciled with increased achievement only if a significant reorganization of existing educational resources is somehow carried out. There need to be serious proposals for redirecting existing expenditures. It is precisely at this point that we see the special opportunities associated with new information technologies, including interactive computer communication and interactive video pedagogies. New media of

communication offer one potential for institutional realignments that might yield solutions to current problems.

Unfortunately, existing evidence strongly suggests that, in addition to its promise, a new technology of communication is causing a new epidemic of imbalanced knowledge acquisition, instead of a rise of educational excellence across the board. Therefore, special attention has to be paid to the growing disparity between potential for reorganizing diverse people in educationally productive ways on the one hand and the consequences of the current way that new technologies are introduced into the schools on the other.

We will return at the end of this report to summarize recommendations for research and policy that appear to be implied by our review of the facts. As will be demonstrated repeatedly, *excellence can be organized*. The challenge is to distill the lessons learned from locally successful systems and to determine under what conditions they can be generalized.

There has been a great deal of work demonstrating that American schools may be organized for social purposes other than academic excellence—schools are also sorting devices and credentialing bureaus that select among the members of the population in the service of social institutions such as industry (Mehan, 1983; Snow, 1982; Spring, 1976). While we would not deny the validity or importance of research on these other social functions of education, our attention here is to schools as transformation institutions that arrange for the development of the knowledge and skills with which students enter. The tension between the selection and transformation functions of schooling is not unique to the U.S. and will continue to be a matter of international concern, which, although somewhat independent of the issues raised here, may be informed by this discussion.

Similarly, we appreciate that economic and political pressures should loom larger than is reflected in the body of this report. Schools with large populations of minority students are usually located in communities with small tax bases or in large urban areas with declining fiscal resources (Sheingold, Martin, & Endreweit, 1985). The resulting fiscal limitations make it difficult for these schools to keep pace with educational innovations, not only in terms of equipment and supplies but also in terms of attracting new staff

and providing the training necessary to keep existing staff abreast of the latest developments in educational research and technology. Outside sources of support for educational programs in schools attended by minorities are often earmarked for educationally disadvantaged children. While this support may provide resources needed to give minority children access to newer educational technologies, it often comes attached to two sorts of restrictions that minimize the extent to which the technologies can be effectively employed.

First, restrictions are introduced in relation to the kind of educational program that the new technology fits into; computer use in Chapter I programs, for instance, is largely limited to the kinds of drill-and-practice instruction that characterized the educational program before the advent of the new technology (Center for the Social Organization of Schools, 1983-84). Second, there are restrictions that minimize the use of the new technology to enhance the education of children who are doing well—at or above grade level. These restrictions limit the diffusion of new technology in urban and rural schools with large minority populations and simultaneously decrease the possibility of inventing educational activities that go beyond what is already known, i.e., the drill-and-practice activities.

Not only economic pressures but political ones are operating in the same settings. Administrators and teachers in districts with large minority populations are often under considerable pressure to reduce dropout rates and increase achievement test scores. This pressure comes from employers and policymakers concerned about the trainability and productivity of workers with basic skills deficiencies (Carnegie Corporation, 1984-85; Hunter & Harman, 1979) as well as from parents worried about children's prospects for employment and higher education. Communities can hardly fail to respond to the bleak educational statistics: the dropout rate for Hispanics and blacks is about double that of whites; although minorities comprise 25 percent of the school population, they represent 40 percent of the students suspended or expelled; and the average performance of blacks and Hispanics on the Scholastic Achievement Test is over 50 points lower than the means for Anglo students (Carnegie Corporation, 1984-85). Thus, it is not surprising that educators of minority students are pressured to "do the basics" better and

leave innovative educational practices to others. However, a continued imbalance in the educational mandates that guide the education of minorities and of white middle-class children deepens the problem: as schools serving minority children focus their resources on increasing the use of well-known methods for drilling the basics, they decrease the opportunities for those children to participate in the higher level activities that are needed to excel in mathematics and science.

Our report does not have the scope to analyze the economic and political pressures and recommend solutions to the apparent binds, but we believe that our discussion can contribute to such analyses and action as we indicate the points of change within schools that can be productive. According to the extensive and sophisticated study of technology and society undertaken by the Conservation of Human Resources project at Columbia University (e.g., Noyelle, 1985), new technologies and new economies call for more emphasis on effective off-the-job training for many sectors of industry. Hence, it is important to identify points of change within schools.

With these comments in mind, we turn to a systematic survey of the issues involved in addressing the role of context factors in educational achievement.

An Embedded Context Framework

Our deliberations began with an attempt to define the basic terms we had been given to work with. It was not an easy job.

As a starting point we discussed what was meant by the distinction between cognitive and contextual factors influencing education. Starting first with the presumably better-understood side of the cognitive-contextual dichotomy, we defined cognitive factors influencing education to be the specification of the mental work that occurs when a child is doing a particular curriculum task. The implicit start of cognition, in this framework, is the posing of the task by the teacher. The end is the response produced and usually interpreted as the production of a single pupil. Cognition refers to the information processing that occurs between presentation of the problem and the response.

Cognitive factors may be subdivided in a variety of ways, depending on one's particular theory. And, cognitive factors may be attributed to an individual or to social "collusion" in a variety of ways, depending on another set of particular theories.

As a way of specifying a systematic constraint on our review of contextual influences on educational processes so that they could be more than everything that is not related to the task itself, we adopted the embedded contexts representation of our topic depicted in Figure 1.

According to this view, it is possible to identify a unit of analysis called a cognitive task. Cognitive tasks can be created experimentally, or they may arise when a student is confronted with a part of the curriculum and begins to spend time on the task (Bloom, 1976). The quantity and quality of the time on task can be used as a mediating variable of common interest to those studying both cognitive and contextual factors in education. The cognitive and contextual approaches differ in emphasis: The cognitive approach manipulates factors within the task; the contextual approach deals with the constitutional relations between the task and broader levels of context.

Although we have found a commonsense notion of context useful, it is important to emphasize that a noncritical acceptance of the commonsense division between task and context is an oversimplification that itself needs to be examined critically. For theoretical reasons as well as many problems of concrete research, it is inappropriate to equate *context* with *environment* (literally, "that which surrounds"). Two hints of the more specialized understanding of context with which we have grappled can be seen in our use of the phrase *constitutional relations* in the previous paragraph and our depiction of the task itself as one of the levels of context.

Even a simplified view of context such as "that which surrounds" is complicated. Context refers to the events preceding, occurring with, and following the cognitive task; context so conceived includes all the factors that might influence the quality of time spent on the task, ranging from

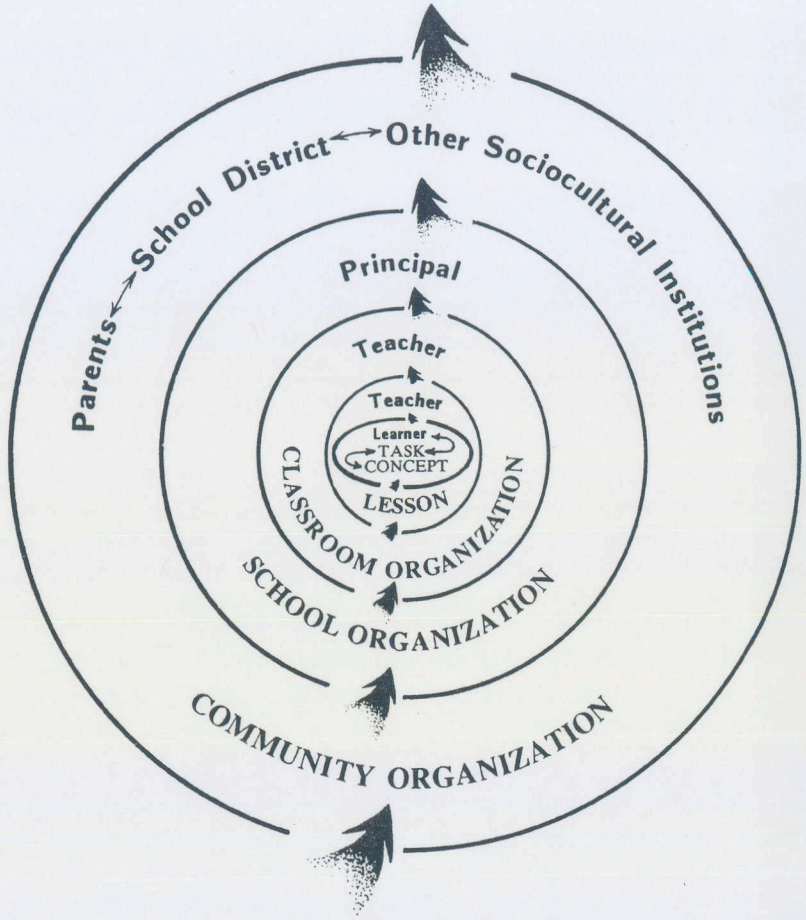

Figure 1. Embedded Contexts.

the arrangement of a lesson in the curriculum, to the relation of the classroom to the school as a whole, and to the relation of the school to the community of which it is a part. From the original Latin term *contextere*, "to weave together," we obtain a close approximation of context as we conceive of it.

Within each level of this scheme it is also necessary to look at behavior in as many settings as possible to understand the range of variability that characterizes current educationally relevant cultural practices. The complexities of

incorporating a rich interpretation of context underlie a great many methodological disputes in discussions of contextual factors in education.

Important Complements: The Example of Family Stress

One consequence of our organizational framework is that certain bodies of literature fall outside the scope of the work. Our approach to contextual factors provides a strategic avenue of access into the aspects of the problem that are contemporaneous with school performance, achievement or failure, and the aspects that are accessible to manipulation under the rubric of educational policy and practice. There is, however, a complementary body of literature, and perhaps a complementary report needed, with foci such as mental and physical health and affective factors, as well as issues of nutrition and social development. We think that these issues are complementary because, while they point to problematic aspects in the life of the children who are our main concern here, and while they point to problems that can clearly interfere with the achievement of academic excellence, they are less directly related to schools as currently constituted in our society than the research under review. There is clearly overlap and need for an eventual reconciliation of this subdivision between context factors closely related to the school and other context factors relevant to education. To exemplify this arena of overlap, we consider the case of stress and family circumstances.

Later we point to the importance of community and family involvement in effective educational programs; as we do so, we must consider the difficulties within families. An important limitation on the family's ability to serve as a resource for children is the degree to which parents are under stress for reasons having nothing to do with the immediate task of bringing up their children and seeing that they get a good education.

An experiment by Zussman (1978) demonstrated the influence of even minor stress on parenting styles which in turn have been related to educational achievement (see Maccoby, 1984, for a review). Zussman invited parents with two children, a preschooler and a toddler, to come to an observation room where there were both play materials and

opportunities to get into mischief. Some parents were simply allowed to watch and help their children. Others were given a paper-and-pencil problem to solve while keeping an eye on their two children. Under these very mild conditions of stress, the preoccupied parents played less with their children, ignored attention-getting initiatives they might otherwise have responded to, and used more peremptory "short tempered" control strategies. The parental pattern that emerged under stress bears a striking resemblance to the pattern of child rearing that has been associated with a child's subsequent reduced scholastic achievement.

This same pattern appears in real life conditions when interviews and observations are combined to trace the relationship between stress and parenting styles. Forgatch and Wieder (summarized in Patterson, 1982) obtained daily reports from mothers about such stressful events in their lives as unexpectedly large bills, the illness of a family member, and quarrels with their husbands. The investigators also made periodic visits to the home to observe patterns of interaction between mothers and their children. They found that maternal irritability usually increased when things outside their specific relationship with their children were going badly. When they were irritable because of this stress, mothers were more likely to hit or scold their children and more likely to refuse to comply with their children's requests.

The kind of everyday circumstances that provide the background stress of child-rearing for many parents living in the United States today is illustrated by interviews with working-class mothers who have a three-year-old child to raise in addition to a full-time job:

> We don't have any kind of life. When you work, you're constantly racing around back and forth. There's never any relaxation. Work, come home and work, go to bed, etc., over and over. No respite. It's not my idea of living. . . . There's no way you can cram seven days of housework into less than 2 days (weekend). . . . Seems like I'm always running around on my lunch hour. There's so little time. (Bronfenbrenner, Alvarez, & Henderson, 1984, p. 1367)

It is not very surprising that the frequency of such stressful events is greater among poor families than the well-to-do ones (Brown, Ni Bhrolchami, & Harris, 1975) and is increased by father absence, early parenthood, and a variety of other forces that render family interactions uncertain. As a result, it is to be expected that studies in the United States and Britain (Bernstein, 1971; Kohn, 1977) would report that lower socioeconomic households have a high frequency of the child-rearing patterns associated with parental stress and reduced school success.

We must be very cautious about our judgments of the parenting practices of America's working-class and poor populations. Kohn stated the problem quite clearly:

> Since social scientists understand (and largely share) middle-class values, we find middle-class parental behavior [which emphasizes independence and self-direction] self-evidently reasonable. But because many of us have not had an adequate grasp of working-class values, it has been less apparent that working-class parental behavior is also reasonable. . . . Working-class parents are as concerned as are middle-class parents about their children's future. (Kohn, 1977, p. 197)

A crucial fact about socialization is that parents raise their children to confront the world as they understand it on the basis of their own experiences. There is a perplexing consequence of this convergence for societies like ours. Kohn (1977, p. 200) again pinpointed the issue: "The family, then, functions as a mechanism for perpetuating inequality." Some change in the pattern of the family's coordination with other social institutions (like schools, churches, unions, workplaces) is an approach that may break this perpetuity.

The educational dilemmas posed by the close links between problematic aspects of adult life in the community and the quantity and quality of the resources available for children are not unique to the United States; they reoccur in all industrialized countries. Pressures and inequities that

make family life difficult certainly do not make the job of education any easier; however, such conditions should be taken neither as determinants excusing failures that are accomplished in the schools nor as a rationale for failing to find ways to obtain family and community input to educational programs, especially when coordination with family and community can be shown to be advantageous for school achievement.

While our organizational framework forces—or allows—us to give short shrift to the contextual factors like stress that are less institutionally linked to schools, we wish to underscore their interrelatedness with the issues we address and the general problem we are concerned with. As will be recognizable below, some effects of recontextualizing tasks, classroom organization, curricula, and schools are associated with changes in factors like self-esteem and higher expectations about achievement. However, the designs, methods, and measurement techniques—the technology of research—in the studies that can fall under our recontextualization rubric differ greatly from those that would be found acceptable by other scholars concerned with issues like stress, self-esteem, attributions, and expectations. An early recommendation, in fact, would be to provide for a critical review of the relationships between the two sorts of contextual factors in education. We suspect that there is room for productive interaction that could result in better theories and better research on both sides of this divide—and that could increase the utility of the research for educational practice.

Characteristics of Successful Programs

An important study conducted by the Office of Opportunities in Science (American Association for the Advancement of Science, 1984) provides hope at the outset that with serious efforts the educational problems of underrepresented groups *can* be overcome. This report summarizes data from 168 special programs and identifies the characteristics that produce successful mathematics and science education for underrepresented populations. Because of its strong affirmative nature, the basic conclusion of this report is worth highlighting:

> The evidence gathered to date indicates that if minorities and women are provided early, excellent and sustained instruction in these academic areas . . . then their achievement levels parallel those of white males. (AAAS, 1984, p. iv).

The report listed 16 characteristics of the successful programs:

1— Strong academic component in mathematics, science, and communications, focused on enrichment rather than remediation.
2— Academic subjects taught by teachers who are highly competent in the subject matter and believe that students can learn the materials.
3— Heavy emphasis on the applications of science and mathematics and careers in these fields.
4— Integrative approach to teaching that incorporates all subject areas, hands-on opportunities, and computers.
5— Multiyear involvement with students.
6— Strong director; committed and stable staff who share program goals.
7— Stable long-term funding base with multiple funding sources.
8— Recruitment of participants from all relevant target populations.
9— University, industry, school, etc. cooperative program.
10— Opportunities for in-school and out-of-school learning experiences.
11— Parental involvement and development of base of community support.
12— Specific attention to removing educational inequalities related to gender and race.
13— Involvement of professionals and staff who look like the target population.
14— Development of peer support systems (involvement of a critical mass of any particular kind of student).
15— Evaluation, long-term follow-up, and careful data collection.

16— "Mainstreaming"—integration of program elements supportive of women and minorities into the institutional programs.

These characteristics are, for the most part, self-explanatory, but some comments may be helpful regarding interaction of components and their relationship to classroom-level and school-level factors. With respect to classroom-level findings, the report supports the notion of peer-grouped curriculum with a good deal of hands-on work and a constant interplay between theoretical and practical activity. It also supports the conclusions of Berliner (1984) and many others that students should experience, and teachers should expect, high levels of successful performance.

At the level of schools, these programs have all the characteristics of a subculture. There are shared values and activities; there are multiple years of participation that ensure that there will be multiple generations of participants interacting at any one time. There is interaction not only between teachers and students but among students, as an essential facilitating factor. Point 13 is worth emphasizing; involvement of adult role models who are from the same population group as the students requires the participation of minorities and women in a supervisory role.

The programs are not isolated from the rest of the students' lives. On the one hand, there is the clear goal of mainstreaming at the end of the program. On the other hand there is community support and participation from parents at the start of the program and during its course. These features can be summed up by the idea that successful programs allow for vertical integration of the educational experience beginning at the start of schooling and continuing into the college years.

A major point stressed in the report is that the different categories of underrepresented populations should not be lumped together with respect to the particular program elements that should be emphasized. One template of a program cannot be found that can be superimposed in various places to produce effective learning. Local invention is needed not only in the planning but in the ongoing implementation:

> The variability among racial/ethnic groups and within a particular group is likely to be very great. Successful intervention programs learned early to smooth out the differences and at the same time to be sensitive to them. (AAAS, 1984)

The specification of group differences is too lengthy for inclusion here but well worth reading for anyone engaged in this line of endeavor. The 16 general characteristics listed above allow for some information exchange to guide local invention, but their appearance in an effective program is concretely related to the local language and cultural circumstances.

At the time the AAAS report was prepared, computer use was a rising point of interest. Note that communications is listed as an essential content area in the curriculum. These two aspects of the program are interconnected: computing is not just a topic in itself but a toolchest full of resources for all kinds of academic endeavors, and the report recommends a computer/communication component for such programs. The issues raised by the AAAS study will reverberate throughout this report; we will return to consider its implications in summarizing one of our recommendations for further research.

Organization of the Review

As an expository device, we will organize our review from the inside out, e.g., from the task to its context. We begin, in section 2, with a very brief discussion of limitations associated with time-on-task approaches to assessing how effectively the teaching/learning process is organized, relying on a simplified conception of context. We move in the following sections to a discussion of the levels of context depicted in Figure 1: recontextualizing individual tasks; recontextualizing the social organization of the instructional process, emphasizing the special case of linguistic and social variations and social organization; recontextualizations afforded by the advent of computers in education; the school as a distinctive cultural organization; and, finally, links between schools and various nonschool settings.

2 • Spending Time on Learning

Following the common-sense principle that learning takes time, much recent research on improving education has focused on "time on task," the time that students spend engaged in—attending to and participating in—academic work (Bloom, 1976). More refined concepts such as "active learning time" or "engaged learning time" have been constructed to measure effective learning time (Carroll, 1963; Harnischfeger & Wiley, 1981). Within the system of assumptions that permits a dichotomy between the task and its context, this approach treats contextual factors as independent variables that influence effective learning time (the mediating variable) and improved achievement (the dependent variable). A very solid body of research demonstrates that, when students spend time on tasks with high levels of success, their performance improves with increased time devoted to learning (Fisher, Berliner, Filby, Marliave, Cohen, & Deshaw, 1980). This evidence has made research on ways to increase the amount of time students spend on task an important topic for educational researchers.

While acknowledging the importance of research on time on task as one means of understanding the educational process, the simplifications involved in the operationalization of *effective* time on task have led, in practice, to some problems of their own. Since it is very difficult to know what is going on in children's heads, even under the most carefully designed experimental circumstances, time on task gets coded operationally, in terms of what the children are *not* doing; they are not whispering, not looking around, not sleeping, not away from their desks, or some other not. Time on the task is the residual of these other behaviors. The suggestions for classroom practice that are generated by this criterion also have a negative tint to them; they emphasize management tactics that keep the children from appearing to be off-task.

In reviewing the time-on-task and classroom organization literature, four areas of concern kept reappearing in

our discussions. When time on task is inverted (viewed as a residual, equivalent to "not off-task"), the research depends on, and subtly validates, certain pedagogical assumptions, and it leaves some important matters uninvestigated and unresolved.

First, standardized time-on-task analyses seem to deal almost exclusively with (and to work most effectively for) teacher-led lessons and seat work. This connection seems altogether natural; if there is no adult discussion leader and the children are busy talking together as a part of their lesson, it is much more difficult for teacher or researcher to judge what is on-task and what is off-task behavior.

Simply on the basis of frequency of occurrence, it is not unreasonable that time-on-task studies should have focused on teacher-led lessons. Descriptive studies suggest that teacher-led whole groups predominate in American classrooms (Dunkin & Biddle, 1974; Goodlad, 1984). Teacher-led small groups are common but tend to occur primarily in early grades, and particularly in reading instruction (Cazden, 1986). Peer groups are infrequent in today's schools, but are more common in social studies and science than in other subject areas (Stodolsky, 1984). Sirotnik (1981) has reported findings from observations in 129 elementary school classrooms selected to represent varying community types nationally; he found only 2 percent of students engaged in cooperative groups.

These less frequent situations are difficult to code or engineer for common measures of on-task behavior. But these are the sorts of situations that we have found among the promising alternative modes of instruction, especially in science, mathematics, and technology education.

Second, discussions of the time-on-task literature often appear to assume that the number of students engaged in a lesson is equivalent to the number of students in the classroom. When the teacher deals directly with a subset of the class, good or bad time on task for that subset of the children cannot stand as a full measure for all the children in the classroom. How does the quantity of students directly involved with the teacher relate to the quality of instructional interaction for all the children in the class? In most of the effective learning time literature, an increase in quality of performance is produced by a combination of tighter

control and fuller feedback. Thus, this literature promotes reduced teacher-student ratios (perhaps arranged by rotating children through teacher-led small group lessons) but fails to investigate any qualitative reorganization of instruction for the rest of the children in the class. In such an approach, the most effective management of time for students who are not working with the teacher becomes an issue. This assumption that reduction of size will bring no qualitative change in interaction is not a necessary conclusion, nor is it consistent with the facts.

An alternative is to reorganize the relationship of the students to the instructional materials and the teacher at the same time in a variety of alternatively structured groups. In this arrangement, the teacher becomes an advisor and facilitator rather than task presenter and central control mechanism.

There are many problems associated with a shift to decentralized classroom management, not the least of which is evaluation. But we should not compound the problems we set out to solve by using research designs and evaluation methods that subtly limit the range of solutions that can be considered.

Third, whatever options for reorganization are adopted, any attempt to measure, analyze, or engineer effective learning time needs to recognize the question of group heterogeneity. It should not be assumed that the effect of the degree of heterogeneity within an instructional group is independent of group size or of the organization of interaction within groups. It is quite possible that principles of small-group instruction and heterogeneity interact. Moreover, these two factors may well interact with curriculum content. Clearly, until these interactions are sorted out, prescriptions based on the time-on-task literature should not be taken too strongly.

Fourth, it should not be assumed (as much of the learning-time literature does implicitly) that the definition of *task* remains invariant across methods of organizing instruction in classrooms. We have reservations about the ability of a researcher, even a teacher, to recognize discrete tasks and their boundaries (and, hence, off-task behavior) in the ordinary life of the classroom (Griffin, Cole, & Newman, 1982), and these reservations increase as we consider the

plausibility of locating "same" tasks in different social organizations (Newman, Griffin, & Cole, 1984). Yet, any notions that a task allows more effective learning time in one instructional arrangement (e.g., teacher-led small groups) than in another (e.g., children without adults in small groups) assume that the same task *can* be compared across settings. Other literature that recommends the superiority of reduced size instructional groupings, in fact, makes an opposite assumption: Tasks will not remain the same when the social situation of instruction changes; a reduction in the size of instructional groups can create a qualitative (not just quantitative) difference in the context, thereby creating a qualitatively different definition of the task by individual students. When such reorganization is achieved, it can transform the relationship between task success and what are usually called cognitive entry behaviors; a task may be easier or harder than a quite similar task encountered by the same person in another context. This emphasis is especially important for addressing the invention of successful programs for populations currently underrepresented in mathematics, science, and technology. Thus, section 3 explores the issue of modifying the ease of performance by changing task-level context.

3: Recontextualizing Tasks: Reorganizing Cognitive Processes

It is important to demonstrate that changes in contextualization of tasks can be engineered to make a difference in task performance. Before progressing to evidence from existing curricula, we turn briefly to existing lines of research at a level more or less equivalent to a lesson, problem, or task. The experimental work that will be called to mind by these examples is usually referenced in arguments demonstrating that young children are not as cognitively limited as had been claimed on the basis of more normative experimental procedures or in arguments demonstrating that older people are not able to do the advanced cognitive work one might expect, unless the conditions are modified (Cole & Means, 1981; Gelman, 1978). In this review, the cases are intended to demonstrate that contexts for cognitive tasks can be changed and that such changes can produce a change in ease of learning. Having shown evidence for this claim in cognitive research conditions, we will explore its fate when embodied in the curriculum.

Research Evidence

Istomina (1975) compared the performance of preschool children on a test-like version of a free recall task and the same task embedded in a role-playing game of being sent to a make-believe store for a list of items. In both versions, the child wants to do what the experimenter tells him to do—he tries to remember and reproduce the list of words. Activation of the 4- and 5-year-olds' still-crude memorizing operations was greatly facilitated by the play situation. They learned and remembered more in the *same* amount of instructional time.

Young children have long been thought deficient in their ability to keep the location of objects in mind. The basis for this conclusion was decades of research on delayed responses: an object is hidden in one of several boxes, and children are required to search for it several seconds or a few minutes later. DeLoache and Brown (1979) repeated this

experiment with 2- and 3-year-old children in their homes. Instead of a piece of candy, children's favorite toys were hidden under a piece of furniture. Under these conditions, children would remember the location of the hidden object for at least 24 hours, the longest interval tested.

Margaret Donaldson (1978) and her students addressed the presumed inability of small children to take account of another person's visual point of view. In the original research on the problem by Piaget and Inhelder (1975), children were required to identify pictures representing a different view of a model of three mountains. Not until age 10 or 11 does this task become accessible to children.

However, perspective taking ability has been shown to be present for recruitment into problem solving by very young children in the right circumstances. Donaldson arranged for the model to represent toy children hiding from a toy policeman. The model was so arranged that only by taking the 'policeman's point of view could the child-subjects know where the toy children should hide. Four- to five-year-olds succeeded at this problem even when they had to coordinate the points of view of two policemen, whose views of the scene were different from their own. Thus, when the purpose of such perspective taking was made accessible to the youngsters, they managed to succeed at tasks hitherto thought beyond their capacity.

Recontextualizing in a Curriculum

The potential for recontextualizing tasks does not have to be limited to classical problems in the developmental literature or to very young children. Beneficial effects of recontextualizations have been demonstrated to occur with older populations (especially university students) who were trying to achieve solutions to syllogistic reasoning problems (D'Andrade, 1981; Johnson-Laird, Legrenzi, & Sonino Legrenzi, 1972). Rather than review these results, which are widely known and have entered the main body of scholarship involving cognitive factors in education, we will review two projects that could provide for recontextualization of tasks outside of experimental conditions and in the educational domains especially relevant to this report—science and computer technology.

The computer program Dynatrack (diSessa, 1982, 1984) can play a role in arranging for the recontextualization of physics learning by providing for its embedding in a larger activity. In high school or college sciences courses, students are expected to learn that there are physical laws governing the motion of physical bodies. In Dynatrack, the student enters a microworld where some physical laws do not hold. It is a very simple program. The player is represented on the screen by a small object; the goal is to move around a circular track; at first, the player, not applying the proper physical laws, loses control and crashes into the barriers of the track; eventually, the player's actions become coordinated with the particular physics of the Dynatrack world.

Playing Dynatrack by itself is not the recontextualization; rather, including Dynatrack in a curriculum aimed at teaching and learning physical laws is the recontextualization. If experience with Dynatrack is organized so that observations about the experience in the special world can be related to observations about the ordinary world we live in, as well as to the experience of learning physical laws and the computation of their explanation, then experience with Dynatrack can be an activity that provides for the recontextualization of knowledge in a standard physics curriculum.

A great deal of recent work in cognitive science (e.g., Gentner & Stevens, 1983) demonstrates that the mental representation of problems held by experts in a domain like physics appears to be holistic and to involve qualitative reasoning; the final specific computation is simply a verification of the answer. Experts do not start their work on problems with computational procedures, but beginners and low performers do attempt to start with computations. The problem for the educator is to discover how to provide a beginner with something like an expert's viewpoint, a holistic framework where qualitative reasoning can be supported. Dynatrack, and programs like it, can contribute to providing experience with the world of physics that can complement and provide a productive organizational framework for the procedural steps that students are taught in current curricula (Heller & Reif, 1984).

A final example, from Japan, involves a book for the general public. The *LOGO Handbook* (Miyake, Honda, Tanaka, & Nakano, 1984) is intended for adults learning LOGO,

a programming language. The six chapters cover the crucial aspects of the language; the book, and the approach to teaching/learning, mixes LOGO with rich reference to life in Japan.

In the first chapter, a well-known and loved poet's work is analyzed, and learners have their initial LOGO lesson while mimicking a part of the process of juxtaposition that the poet uses to create his art. The learner begins with a full and interesting program, focusing on characteristics especially important about LOGO, i.e., in contrast to first learning "Forward" (as most LOGO curricula encourage), these students learn "First," "Last," "But first," etc., the commands that embody the sophisticated nature of the LOGO language. The book helps to create an activity system that mixes poetry and the programming language, creating an environment for learning very advanced features of the programming language very early in the instructional sequence.

Another example of the richly contextualized learning approach is apparent in the treatment of recursion. Here, a narrative about an everyday event is told in two versions, and the learner can create dialogue for a scene in each narrative with a LOGO program. The two LOGO programs that are produced provide a minimally contrasted set, in which tail and center recursion are the elements contrasted. The basic schema for the story is the opening of an after-school school (a *juku*) for learning English; a person is trying to teach but must also answer the phone in case there are new pupils wishing to enroll. In one version of the story, a calm teacher asks a question, gets interrupted by a phone call, gets the answer from a student and evaluates it, and then asks the next student the same question. Tail recursion is used in the program for this version of the narrative. In the other version of the story, a very opposite sort of teacher is the lead character; this teacher asks a question, gets interrupted by a phone call, asks another student the question and so on, until at the end there is a raft of student answers, in the opposite order from which they occurred in the prior story. The program for this version uses center recursion. Again, the focus on a very important feature of the task domain (recursion) is embedded in a context that is rich with cultural understanding and, here, whimsy.

Casting Doubt on the Assumed Contextualization

The sophistication of the cognitive activities promoted by these unusual experimental and instructional procedures cannot be denied; moreover they are precisely the "basic cognitive activities" (holding information in memory, building structured representations for later use, comparing perspectives, learning physics, learning programming) that are relevant to achieving basic technological literacy, the central concern of this review. Evidence indicates that changes in the *context* of the logical task structure change the cognitive task itself, making available otherwise untapped cognitive resources which subjects/students can bring to researchers/educators for purposes of instruction.

Research on the educational status quo may show that some things are very hard to learn (cf. Pea & Kurland, 1984, regarding recursion in LOGO) or that some things take a long time to learn; but, when such research relies on the assumed normative contextualization of the tasks, it may be seriously misrepresenting the problem. The work described above suggests that a fundamental way of changing the requirements for success on a particular task is to *recontextualize* the task as presented to, and understood by, the learner. In all the sample cases, the subject is initially presented with the activity—the whole task—embedded in, contextualized as part of, some larger activity. For the subjects themselves, the recontextualization involves familiar scripts and human intentions. Aspects of the concentric circles in Figure 1 influence how the task is perceived by the learner and/or the motivation with which he/she tackles it.

We do not expect that recontextualization of academic tasks and of assessment will make the problems of education disappear. Rather, we expect that innovation at this level of the context, in concert with innovations in the social organization of lessons and in school-community linkages, will provide educators with more fertile ground for effective educational action. A recontextualized task can give the instructor something more to take advantage of in instructional sequences.

4 • The Classroom • Level

A great deal of research is relevant to ways in which reorganization of classrooms changes the quality of educational performance at the level of the lesson. After reviewing the factors producing increased effective learning time and student achievement, Harnischfeger and Wiley (1981) summarized their conclusions as follows (with numbers added for easier subsequent reference):

> There are only four ways to increase achievement. One (1) is via a reduction in time needed to learn. All of the others depend upon increasing active learning time. These latter three routes consist of:
>
> (2)—increasing the total amount of time which is allocated to learning,
>
> (3)—increasing the portion of that allocated time which is actually allowed for learning, and
>
> (4)—increasing the amount of this allowed time which pupils actively devote to learning.
>
> The last of these routes (4) is solely influenced by a teacher's effectiveness in monitoring and maintaining pupil pursuits via surveillance and teaching interchanges with pupils, which motivate or coerce them to spend more of their time actively learning. Increasing the proportion of allocated time which is actually allowed or used for learning (3), on the other hand, is primarily achievable via managerial improvements, both intra- and inter-task. And direct increases in allocated time (2) are entirely the outcomes of procedural and curricular policies of districts and schools. (Harnischfeger & Wiley, 1981, pp. 30-31)

Of these four factors, the first can be related to the "context rich" instruction/assessment described in section 3 above; the recontextualization strategy might as easily be described as increasing the efficiency of the teaching/learning context as reducing the time needed to learn. The second factor is at the level of the school and beyond and will be addressed in subsequent sections. Recent developments in the implementation of time-on-task research have understandably concentrated on the third factor, managerial improvements, focused on categories such as classroom discipline and decreasing interruptions, because they can be quantified within the standard, context-free framework. (Cf. Purkey & Smith, 1983, for a critical review of the spate of studies on effective schools showing the pervasiveness of managerial improvements in another aspect of educational research.) This section is about the fourth strategy, increasing the amount of active, engaged learning time.

Manipulating Class Size

One of the obvious ways to change the management climate of a classroom is to manipulate class size. *More is learned in smaller classes.* Based on the exhaustive study of data on nearly 900,000 students, Glass and Smith (1978) concluded that student achievement increases as class size decreases, especially when class size goes below 20.

The policy implication would appear clear: decree that all classes will be smaller than 20 students and more effective education will result. Although there may be no objections to such a solution in principle, in practice it means money, a lot of money, and probably more space as well. Since all sectors of society are being asked to spend less public money, not more, giant increments of funds to produce smaller classes are not likely. The challenge for research is to point the way to reorganizing the process of education that remains more or less within spending constraints, as they vary with the political and economic climate. Currently that means coming up with suggestions for change that do not entail greatly enlarged budgets—an almost free lunch.