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ABSTRACT

Research recommendations concerning learning and development that are appropriate for research and development centers supported by the National Institute of Education (NIE) are offered to the director of NIE. Mission statements are presented on the following areas: literacy (reading, writing, and English skill development); learning and understanding mathematics and science; educational technology; the learning process; and home and community influences on learning. Each mission statement considers the following concerns: the national need, current status of research, need for a center, and priority research topics. The mission statement on the learning process suggests that studies of school learning are needed in a national center where learning, teaching, and schooling are combined, not fragmented. Research topics that are identified for this center include: learning mechanisms, general learning skills, and cognitive analyses of teaching and knowledge transmission. The mission statement concerning educational technology suggests that there is a need for basic research on the social, cognitive, and educational implications of new technology, including computer-based instruction. Finally, it is noted that the proposed center on home and community influences on learning would emphasize individual and group (cultural, economic) diversity and specific handicapping conditions. (SW)

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CENTER STUDY GROUP ON LEARNING & DEVELOPMENT

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Executive Secretary

UNITED STATES DEPARTMENT OF EDUCATION
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STUDY GROUP

ON

LEARNING & DEVELOPMENT

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Rodney R. Cocking
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Transmittal Letter: Learning and Development Study Group

Guiding Assumptions

The learning and development study group supports NIE's initiative in rethinking the role of the national Centers for educational research. Our support, and our choice of missions, depends upon what we understand about the form that the centers will take.

Our central assumption is that the Centers will foster excellence in research. They will conduct, coordinate, and disseminate state of the art research on tractable problems of enduring scientific and educational importance. Although problems endure, progress in the field dictates changes over time in theories and methods. To remain institutions of excellence, the Centers must be responsive to such changes.

Excellence can be achieved and maintained only if the following conditions are met. The major initiative for the Centers must come from the scientific community. It is essential that leading researchers in the field play an active and critical role in the selection process and, equally important, in the continual monitoring of progress.

To clarify our assumptions about the role of Centers we contrast them with that of the laboratories. Problems of pressing practical need must be addressed promptly and cannot always wait upon the readiness of the scientific community to answer them thoroughly. Nonetheless, policy decisions should be informed by the best available scientific knowledge. The mission of the laboratories is to be responsive to the urgent problems of their regions. In order to perform this role effectively, they need ready access to state of the art educational research relevant to their current needs. The centers serve an essential function in NIE's mission by ensuring that first rate research is given the long term, stable support required for progress to be made in the areas of fundamental scientific and educational importance. Whereas the agenda for the laboratories is determined by the needs of the day, the agenda for the centers is determined by scientific priority.

Centers operate in a wider scientific context. Indeed, they can only perform their function when the conditions that foster scientific creativity obtain. Scientific breakthroughs are at least as likely to emerge from individual initiative as from collaborative Center efforts. One role of a center would be to integrate the important ideas and results wherever they are generated; this is a crucial function because no center could encompass all the leading researchers in the fields we have suggested for priority missions.

The Selection and Organization of Missions

We are transmitting five statements comprising eight separate missions. These eight mission statements are of two types. Five cover the academic skills areas: reading, writing, English language, mathematics and science. These missions are combined into two large statements, namely literacy (reading, writing and English) and mathematics and science. The remaining three are more general in nature; they have to do with educational technology, general learning skills, and home and community influences on learning.

We include mission statements for the areas of reading and educational technology although these are already served by centers. The group considered these areas to be of such priority that they wished to endorse their continued funding.

Although each of the individual research areas is sufficiently important and the research needs extensive enough to justify separate centers, several have been combined here on the basis of the interrelatedness of the research issues and concerns. We would expect, for example, that a research effort focused on either reading or writing would require consideration of the English language skills prerequisite to the development of basic literacy. However, there was some concern that the expertise required to mount a research effort addressing all three areas is not likely to be found in any one location. Hence, the missions were written as individual statements but can be combined or separated depending upon the availability of funds and the field's response to the competitions.

We emhasize that these five statements are the top priorities of this group. We did not rank them further because in the process of deciding on which particular missions to submit, we eliminated areas of research that were not our top priorities, those that we believed would be covered by other Study Groups, those that lent themselves to incorporation in some or all of the other missions, and those that could be supported by individual grants.

Areas that were among those that were seriously considered but omitted from our priority list because they were not felt to be as important as the ones we selected included art and music, social studies, and foreign language eduation. Topics that were dismissed because they fell into the domains of other study groups were vocational education, teacher characteristics/effectiveness, and discipline. Others were eliminated as separate missions because they crosscut all of the selected areas and, hence, could be incorporated within the priority missions. These included teacher education, measurement and evaluation, learning problems, motivation, and attitudes in learning.

A final area that was considered but not presented as a separate mission was bilingual education. This was not granted individual mission status because of the prior decision to focus the missions on specific subject domains (such as math and science) and general learning and development, rather than on the educational needs of particular groups (e.g., learning disabled students, gifted students). Since the educational needs of bilingual children crosscut all of the subject domains, issues related to this group of students are treated in each of the missions, and especially under the literacy area.

Commonalities across Missions

The panel is recommending five broad mission statements with high priority for the understanding of learning and development: Educational Technology, Home-Community Influences, Learning Processes, Literacy, and Mathematics-Science. There are several considerations of a general nature that apply to all of the mission statements. These considerations include matters of timeliness and relevance, potential for application to current educational problems, the nature and quality of the research, the populations and settings to be considered, and the organizational structure of the

efforts.

Preference should be given to research with a high probability of yielding gains for scientific knowledge and educational practice. It should also contribute to the attainment of national goals (e.g., social and civic concerns, economic and industrial priorities) and recognize demographic trends and technological developments. In any of the work proposed, attention should be given to the implications for developing the capabilities of educational professionals and others involved in the learning and development processes, and to potentialities for the application of any research measurements developed to later practice.

Research excellence must be the major criterion for judging the activities conducted under these missions. Beyond that, the activities should be planned to take advantage of the unique opportunities inherent in the types of organizations envisaged; that is, opportunities that many short-term grants to individual investigators do not allow. These include an interdisciplinary perspective, possibilities for longitudinal research, and the opportunity to address problems of greater complexity. Another research concern that pervades work under all of the missions is the necessity for sound measurement and evaluation.

Recognition of the diverse nature of our society should be reflected in the activities planned under all the missions. Diversity can be defined in ethnic, language, socioeconomic, age, ability and regional terms. Similarly, considerations should be given to the many different settings in which learning and development can take place, e.g., such out-of-school contexts as the home, business and industry, and the community.

Finally, we address the organization and structure of the endeavors undertaken under the five main missions. Some might find it difficult to conceptualize the effort as occurring in a structure other than a center in a single geographical location with an interdisciplinary staff and full support facilities. However, in this age of rapid communication and transportation, such a facility is probably not necessary. It may not even be desirable (in terms of dealing with the diverse populations and settings described above) or possible (in terms of assembling the necessary expertise in one permanent location). Therefore, a consortium model will probably be more effective in many situations. In any case, there is a need for flexibility in approaches to organization and staffing. It should be up to those proposing work under the various missions to outline the structure that best fits the mission requirements.

Selection and Review of Centers

The group was particularly concerned that steps would be taken to insure effective selection of Centers and review of their work.

Selection should be guided by several criteria, including the following: (1) Since the chief goal is to produce high quality research on the relevant issues, competition for Centers should be open to all legitimate research institutions; (2) The requests for proposals should be written in such a way as to promote scientific creativity, flexibility, and initiative. The topics to be investigated and the organizational arrangements to be employed should not be specified in such detail that investigators would be discouraged from

proposing fruitful research approaches and creative administrative arrangements (e.g., consortia or cooperative arrangements between two or more institutions); (3) Winners of the competition should be selected by outside peer reviewers.

Once centers have been selected, they should be assured of a reasonable period of time in which to make reasonable progress toward their goals. This, however, should not vitiate the need for periodic review by NIE staff and outside peer reviewers. The importance to this process of the continuity as well as the competence of the NIE monitors cannot be overestimated. The reviews should focus primarily on the quality of the research efforts.

The selected Centers should not be viewed as permanent institutions. As scientific progress is made, and national priorities change, allowances should be made for the termination of some centers and the initiation of others.

Balancing Centers with Individual Research

Finally, an overriding fear of the study group was that we might be contributing to the demise of individual research efforts. The erosion of NIE's general budget, together with the fixed status of the amount targeted for Laboratories and Centers, means that less and less support is available for research activities initiated by individuals or small groups. Although strongly supporting the Center concept, the group was emphatic in its endorsement of a healthy budget for individual grants competitions. If this is not protected, a state of affairs will exist where the only model for educational research will be that of the Centers. Not only would this stifle individual initiative, it would concentrate the lion's share of resources in a few mega-centers or major Universities, and effectively disenfranchise a vibrant and significant part of the scientific community.

MISSION STATEMENT FOR LITERACY

The National Commission on Excellence in Education (NCEE) reports that 13% of 17 year olds and 20% of adults in America are "functionally illiterate" on the "simplest tasks of everyday reading, writing, and comprehension". Although no group is immune, linguistic and ethnic minority students are particularly susceptible and are thus over-represented among those who leave school without having attained the level of basic literacy skills required for survival in an increasingly competitive economic world. Functional illiteracy may run as high as 40% among minority youth.

The NCEE strongly recommends that all high school graduates should be equipped to: "(a) comprehend, interpret, evaluate and use what they read; (b) write well-organized effective papers; (c) listen effectively and discuss ideas intelligently; and (d) know our literary heritage and how it enhances imagination and ethical understanding and how it relates to the customs, ideas, and values of today's life and culture". In order to help students acquire these competencies, we need a deeper understanding of the reading, writing and oral language skill needed to support academic learning, together with the factors that contribute to literacy failures.

The problem demands a sustained long-term effort on several fronts. The research need is extensive enough to support three separate centers, or the missions could be combined in one or two large center with a level of support commensurate with the complexity and urgency of the problem. The particular combinations should be determined by the field's initiative in responding to the competition. Following are three separate statements on reading, writing, and English language skills that cover the topics.

MISSION STATEMENT FOR READING

The National Need

Universal literacy has been a major aim of American society for more than a century, but 20% of American adults cannot read or understand simple texts. Business and military leaders complain that they must spend millions of dollars on remedial reading programs; for example, the Department of the Navy claims that one quarter of its recruits cannot read at the minimum level needed to understand written safety instructions.

The well advertised decline in standardized reading test scores after the middle grades indicates that high-level comprehension skills are particularly problematic. The National Commission on Excellence in Education (NCEE) reports that nearly 40% of 17-year-olds "cannot draw inferences from written material"; the task of comprehending, analyzing and drawing conclusions from texts is beyond many of our high school graduates.

Reflecting the decline in reading comprehension skills is a concomittant decline in the difficulty level of the material that students are required to read. A recent study by Educational Products Information Exchange claimed that the majority of students are able to master 80% of the content of some subject-matter texts before opening the book; "many books do not challenge the students to whom they are assigned."

The problem is exacerbated by the growing need for technological literacy. The National Commission on Excellence in Education expressed fears of "raising a new generation of Americans that are scientifically and technologically illiterate." School graduates who are borderline illiterates will be further handicapped in an increasingly complex society. Reading will be more important, not less, in the computer age, demanding as it will high levels of natural language proficiency. Reading has never been more important for individual fulfillment and the social, economic, and practical well-being of our society.

Current Status of Research

Research into various aspects of reading comprehension has been funded by NIE for several years and with notable success. Specifically, great strides have been made in our understanding on four main fronts: (1) We understand a great deal more about how to <u>design texts</u> so that they are readable and interesting. Tests are comprehensible if they are well written; but we now understand that they are well written to the extent that they follow a familiar structure, and the syntax, vocabulary, clarity of presentation, style and coherence reach acceptable levels, all of which we can measure. (2) Firmly established is the importance of the compatibility of reader knowledge and <u>text content</u>; comprehension is clearly influenced by the extent of overlap between a reader's prior knowledge and the content of texts; (3) Variations in <u>reading tasks</u> greatly influence ease of understanding;

efficient readers adapt their expenditure of effort and ingenuity economically in tune with texts of varying complexity, such as reading for relaxation, reading to learn, and reading to understand a government document; (4) Considerable advances have been made in our understanding of reading strategies; mature readers possess a complex repertoire of reading and study strategies for enhancing their understanding, and for detecting and overcoming comprehension failures.
We know a great deal about how these learning activities develop and how they can be enhanced by instruction.

Need for a Center

Reading is a complex process and research must concentrate on linguistic, psychological, sociological and educational aspects of the topic. Although significant headway has been made, we need concerted, interdisciplinary efforts to attack the problem of achieving universal literacy. Stable long-term instructional support would promote the type of research only possible in a center; for example, longitudinal studies of developmental trajectives in the acquisition of reading competencies, case studies of children learning to read under a variety of home, community and school support systems, studies of gifted and learning disabled students, etc. A centralized Reading Center would serve as a national resource where researchers from many disciplines could pool their knowledge and contribute to the development and dissemination of theoretical and practical advances in knowledge.

Priority Research Topics

These should include research on the basic linguistic and cognitive processes involved in reading at all levels such as : (1) decoding fluency; (2) the growth of knowledge of word meanings; (3) the relation between oral and written language; (4) the development and instruction of reading and study strategies; (5) the development of students' own understanding and control of these methods of learning from texts; (6) the influence of enriched background knowledge on reading comprehension; (7) the ability to consider the writer's point of view; and (8) the understanding of text genre.

The relation of reading to other areas of competence needs to be addressed, notably the relation of listening and reading comprehension, the relation of learning to read and learning to write, and the influence of enhanced reading comprehension on other literacies such as the scientific and the technological. Finally, the social organization of reading groups, classrooms, and schools that enhance effective instruction of reading needs careful attention.

MISSION STATEMENT FOR WRITING

National Need

The writing skills of recent generations of American students have been judged and found wanting by the National Commission on Excellence in Education, who report that only 20% of American 17-year-olds can write a persuasive essay, and by the popular press; Newsweek's December, 1975, article titled "Why Johnny Can't Write" paints a dismal picture of the writing competence of American high school and college students. Additionally, parents are concerned about the lack of writing facility on the part of their children, and employers complain about the same lack of writing skills in job situations. This general outcry has led to a national trend toward the acceptance of writing as an academic subject in its own right. Reflecting this trend, a recent Carnegie Foundations study concluded that writing is the most important and most neglected skill in school and should be taught in every class.

Although separate instruction in writing at the college level has existed for some time, only recently has writing emerged as serious consideration in other educational sectors. Within the past ten years, writing courses have become part of one- and two-year technical education programs, but still, comparatively little attention has been paid to systematic instruction in writing in schools. The major impediment to improving the teaching of writing in schools lies not in the motivation of educators or the concerns of the community but in our lack of fundamental knowledge about the writing process. This includes the processes students use in learning to write, the materials and techniques needed by teachers in the instruction of writing, and the appropriate procedures and methodology for the assessment of student writing.

Current Status of Research

Interest in the writing process is also fairly new within the research community, but the area is one of considerable current activity. Recent research has concentrated on common student writing problems revealed at all stages of the composition process: planning (drafting), organizing, editing, development of content and argument, and revision.

Encouraging results in improving writing strategies have been obtained through the provision of external cues and supports; consultations between teachers and students during writing; strategy modeling; and, for older students, direct explanation. Intrinsic to this research are the examination of the child's initial understanding of written symbols and developmental trends in the attainment of writing competence. Also receiving considerable attention is the development of the composing process itself and such issues as the student's own misunderstanding of the writing process, methods of fostering independent editing, and the possible role of interactive computer programs in promoting more effective writing.

Many educational jurisdictions in the U.S. have called for systematic evaluation of writing, but writing evaluation has long been recognized as a thorny problem characterized by uncertainties both in the manner of obtaining products for evaluation and the methods of scoring. Thus, writing evaluation has become a major subject of research.

The National Council of Teachers of English reported recently that aspirants who wish to teach high school English can progress through school and college without taking a single English composition course. Not surprising, many school teachers are ill-prepared to teach writing. How to improve teachers' ability to be effective writing instructors is a major research question.

The Need for a Center

Current research programs are promising but limited and fragmentary, and there is a need for a major centralized effort on the cognitive processes underlying writing, the teaching of composition, and methods of assessing excellence in writing. The need for stable long-term funding that would permit extensive commitments to the collection of longitudinal data on achievement outcomes, basic studies of writing in a variety of contexts, and interdisciplinary collaboration. The need for a center on the study of writing is urgent and compelling.

Priority Research Topics

These would include basic research on the cognitive processes involved in writing, including the acquisition of composition and editing skills, the effect of various instructional and learning environments, the importance of student experiences and practice in writing, and the effect of improved writing on general learning skills. It has been argued that "learning to write is learning to think" if so, writing can represents a fruitful forum through which students can be taught to organize their ideas, develop arguments, and display their knowledge to advantage.

In addition to the basic knowledge that has direct implications for the instructional process, an array of pedagogical needs must be examined. At the heart of these pedagogical issues is the widely recognized deficiency in the training of teachers in the instruction of writing. Incorporated in teacher training programs should be methods of helping teachers facilitate the acquisition of writing skills such as mechanics, word usage, sentence formation, handwriting, composition, and computerized text editing.

The field is faced with the task of assessing writing when little is know about how to do it. However, there is an immediate need to investigate differences in the quality of student writing as a function of length and content of the stimulus materials provided to students to elicit their writing; response formats (letters, composition, notes, reports, etc.); modes of discourse required of the student; and audiences to be addressed. Other important assessment issues include

the validity, reliability, and consistency of measurement of student performance; procedures for scoring and scorer training; and a methodology for establishing appropriate achievement standards.

Possible Efforts Needed

One task of the center should be to establish a consortium of individuals with basic and applied writing research expertise to evaluate the work of the center and to recommend research priorities on a continuing basis. This type of input is necessary for the center to be responsive to the needs of the field. The establishment of a centralized effort would facilitate the extensive, interdisciplinary, long-term effort needed if a major contribution to knowledge in the area is to occur.

Well-developed oral language skills are a prerequisite to literacy. Some of these skills are learned in the home prior to school; some must be learned in school. Ordinarily there is a continuity between the development which takes place in the home, and that which takes place in school. It is assumed that written texts themselves constitute an important source of input for the learning of mature forms of the language, and that in dealing with texts, students develop skills in the use of that language for sustained reasoning and the careful exchange of information. Issues raised by these assumptions include the following: whether some texts work better than others in promoting vocabulary and structural development; whether instructional activities such as those in which students are made explicitly aware of the differences between oral and written language forms enhance the development of academic language skills; whether the development of academic language skills is improved by grammatical instruction in which the format, vocabulary, rhetorical structure of English are made explicit, and whether the acquisition of reading skills is enhanced by practice in writing.

The academic learning problems experienced by students from minority groups, especially Blacks, Hispanics and Native Americans are particularly acute. Some of these students come from non-English speaking homes, and therefore have less than a full mastery over English; others speak dialects of English which differ substantially from the standard variety used by teachers and in textbooks. It is generally assumed that prior knowledge of the school language is a prerequisite to learning to read in it, and to making sense of classroom instruction. The problem of learning the forms of the language needed for literacy is a much greater one for linguistically different students than it is for those who already speak the language or dialect of school.

Some issues related to the problems these students face include establishing the level of proficiency in the school language required for literacy development, and for comprehending the subject matter which is taught in that language (both in textbooks and in classroom instruction); discovering what is involved in becoming proficient enough in that language to be able to learn through it; determining how much and what kind of instructional supports students need in order to acquire those skills; determining how long it takes for students at different ages; and from various linguistic backgrounds to acquire the language skills needed for school; and determining what kind of instructional support students must have in order to deal with school while they are learning English. Some other topics that must be investigated include discovering what aspects of linguistic and literacy skills the student's native language or dialect transfer to the school language; determining what aspects of dialect differences affect literacy development and academic development generally, and whether some types of dialects (e.g., social class or ethnic-substrate dialects) interfere more with educational development than do others (e.g., regional dialects). Issues asking whether it can be acquired through literacy

development, or whether it has to be mastered in an oral form before students can successfully learn to read in it; and to what extent written texts can provide the basis on which students learn standard English as a second language or dialect.

The learning of the school language as a second one is an enormous job, but it is not ordinarily an insurmountable one for most linguistically different students. Eventually most of them learn English well enough to handle its use in school. But there are other problems these students face in becoming literate, and in dealing with school in general, that are more difficult to overcome, the more so because they are largely unrecognized and not at all understood.

Some crucial problems have to do with critical mismatches between the learning styles and values that their cultures provide these children, and the teaching approaches and teacher expectations that they encounter in the classroom. What is needed is research that attempts to establish what learning strategies, experiences, training, and patterns of expectations these underachieving students bring to school.

MISSION STATEMENT: MATH AND SCIENCE - OVERVIEW

Our country's position as a world leader in basic science, medical science, and technology is crucially important to our economic and political interests, and is a source of great national pride. However, the quality of science and mathematics education in the United States seems to have fallen dramatically in the past 20 years. Recent research has shown that American children perform poorly on mathematics achievement tests as compared with peers in other advanced societies such as Japan. American children often exhibit an extreme aversion to science and mathematics, and stop studying these subjects as soon as they are allowed to. Science and math teachers at all levels are in short supply; many elementary school teachers have little training in science and mathematics; not enough new teachers are being trained; and many qualified teachers are leaving the profession. The last major curriculum reforms were instituted in the 1960's, but these often did not fulfill their promise because many teachers were not trained well enough to carry them out and because aspects of these curricula are widely held to have been misguided. This state of affairs obtains at a time when our increasingly technological society demands ever higher levels of competence in mathematics and science. Furthermore, illiteracy in science and mathematics deprives ordinary citizens of full participation in American culture, just as surely as does ignorance of history or literature. Clearly, major efforts must be made to improve the teaching and learning of these disciplines. To this end we require intensive research on student's learning and understanding of science and mathematics. Recent developments in psychological research and theory now make it possible to make progress in this area and to produce practical improvements in curricula, teaching and testing.

How many centers?

Mathematics and science are closely related. Major developments in science often depend upon, and motivate, mathematical developments. For example, Newton's achievements in physics required the invention of the calculus. Nonetheless, each field has its own structure, its own research problems and traditions, and its own interdisciplinary requirements. Accordingly, in what follows the two are treated separately. Different proposals for centers might divide the broad area in a variety of ways, some respecting and some cross-cutting the major division between mathematics learning and science learning. Two or more smaller centers might be preferable to one very large one.

Current state of research.

Over the past 15 years, there have been major new developments in research on mathematical thinking and learning, many supported by NIE. Mathematics educators and psychologists have provided research and theory which sheds light on the growth of mathematical thinking from the preschool years through adulthood. This body of research provides insight into such matters as the informal mathematical knowledge possessed by preschool children, the nature of school children's understanding of basic arithmatic concepts, and the comprehension of higher mathematics. The new research combines analysis of the mathematical domain with the direct study of mathematical knowledge in children and adults. As a result, the new work bears direct relevance to mathematics education in the schools at all levels, and if expanded upon can produce significant improvements in mathematics education.

The need for a Center.

While the recent research provides a useful foundation, much more needs to be accomplished in the way of research and theory. In particular, an interdisciplinary effort needs to be mounted, bringing together cognitive developmental psychologists, mathematics educators, and mathematicians. Psychologists can provide theoretical and research sophistication concerning thinking and learning; mathematicians can provide useful analyses of the foundations of their discipline; and mathematics educators can provide a perspective based on practical educational concerns and experience. Moreover, planning must be undertaken to focus research on key areas of concern. Such coordinated efforts should avoid fragmentation of research.

Many research problems need to be addressed.

Areas in which recent research strides have been made include children's understanding of arithmetic, higher thinking processes in mathematics, acquisition of mathematical skills, and group differences in mathematics abilities. These studies should provide a good base for the Center's research into such issues like the following:

> It is well known that children develop mathematical skills and concepts before entrance to school. Future research needs to examine this informal mathematics in greater depth, and needs to determine how children's informal mathematics develops in relation to minority status, race, and social class. Investigations should also be undertaken on the possible effects of educational experiences in the preschool years on informal mathematical concepts, and on the relation between these concepts and later formal instruction.
>
> Recent work has begun to clarify the nature of learning problems in elementary school arithmetics, showing for example that children's computational errors usually result from systematic (but incorrect)

rules that have an orderly learning history. This work paves the way for future investigations into the misunderstandings and learning difficulties of low achievers, the "learning disabled", and retarded individuals, and may well result in effective remedial procedures.

Mathematics achievement differs among various cultural and racial groups, and between men and women. Yet recent cross-cultural research suggests that even members of illiterate societies possess many basic mathematical concepts and skills, and that the same is true of minority group members in our own society. Abstract thinking is not limited to the advantaged. The recent research provides a framework for examining more closely the existing achievement differences in our own society. What are the roles of intellectual, motivational, and other factors in determining these group differences in achievement?

Students are required not only to calculate, but to understand basic principles and to learn such subject matter as algebra, geometry, and the calculus. In recent years, research has begun to address issues like these, and progress has been made in understanding children's grasp of such essential notions as base ten and place value, and of the thinking processes involved in such activities as algebra. Basic misconceptions about central mathematical concepts such as probability and mathematical functions have been diagnosed even among mathematics majors at the college level. Clearly, the investigation of the learning and understanding of mathematical topics more advanced than simple arithmetic is a high priority.

While many children within any given social or cultural group experience learning problems, current diagnostic procedures are primitive and ineffective. We know how to test achievement but not how to uncover the intellectual factors responsible for it. Recent research and theory may provide practical solutions to this problem. The recent cognitive research provides insight into the kinds of thinking that are important for mathematics achievement and that interfere with it. This new understanding of mathematical thinking may even suggest new diagnostic procedures employing both standardized and alternative testing approaches. Research into these matters needs to be conducted in close consultation with the classroom teachers, school psychologist, and other personnel who will ultimately use the diagnostic procedures.

CONCLUSIONS

The resources may exist for setting up a Center at one institution, or at several physically adjacent institutions. However, researchers may also wish to consider the establishment of a consortium, involving relevant investigators in different areas of the country.

Research on mathematics learning and thinking should result in many practical benefits. The research will have implications for the development of improved mathematics curricula, materials, and learning environments. The research will result in improved testing and assessment

procedures. The research can also lead to a useful restructuring of teacher education in mathematics. Furthermore, contact with the practical problems of mathematics education may lead to significant theoretical advances in cognitive developmental psychology.

CENTER FOR THE LEARNING AND UNDERSTANDING OF SCIENCE

Current state of research

Two developments since the last major push at improving science education make the formation of a center on this topic particularly likely to yield dramatic and important results. One of these developments was initiated from within the science education community itself, the other comes from within academic psychology, linguistics and computer science. First, for the past decade science educators have been documenting intuitive theories students have constructed before formal training in certain domains of science. In many ways these intuitive misconceptions that are theories potentate learning, but sometimes they embody highly entrenced misconceptions that are highly resistant to tuition. For example, it can easily be shown that even students who have studied Newtonian mechanics for one or two years at good universities do not understand Newtonian concepts such as force and velocity. One way of thinking about this state of affairs is that students bring complex alternative theories of some domains of science to the learning situation, and the process of learning involves theory change of the sort seen in the history of science. The second development is within the new field of cognitive science. New techniques for representing knowledge and for studying the processes of learning and problem solving make it possible to study in detail how the learner's current knowledge affects his grasp of material being presented to him.

These two developments complement each other. Cognitive scientists have been studying the nature of human knowledge for some time. A recurrent theme emerging from this research is the important role of cognitive structures in the process of learning and problem solving. The work from the field of science education, while confirming the general point of view of the field, pushes it beyond where it had been. One may even predict that psychology's understanding of human knowledge will be deepened and changed as the interdependence, in the context of scientific reasoning, between theories, concepts, learning, and problem solving is fully understood. Conversely, the developments within cognitive science make possible as never before our understanding of the acquisition of scientific literacy and proficiency.

The need for a Center.

Before the work alluded to above yields significant educational dividends, an interdisciplinary effort must be mounted that includes representatives from most, if not all, of the following fields:

1) Cognitive scientists. These would include people trained in information processing analyses of cognitive processes, computer simulations, cognitive development, the mechanisms of learning and conceptual charge, the analysis of misconceptions.
2) Expert teachers, experimental curriculum designers, and evaluators. For the research to pay off in the classroom, ideas of how to induce conceptual change must be formulated, tested, and evaluated, in <u>diverse</u> school settings.

3) Experts in the content areas of the sciences. Sophisticated analyses of the domain of knowledge is a prerequisite for an analysis of experts' and novices' conceptualizations of a domain.
4) Historians or philosophers of science. Currently, some of the deepest understanding of the problem of conceptual change in scientific domains comes from these fields.

Clearly, an interdisciplinary effort of this sort requires time, both to assemble the team and to find fruitful areas of collaborative research. The execution and evaluation of teaching methods is a time-consuming process. The scope of research envisioned justifies a center.

Potential topics

The heart of this research area is the analysis of particular domains of science. The curricular reforms of the 1960s were based on expert analyses of the sciences being learned. What has been learned since then is how to model expert practitioners' cognitive processes--mental models of the phenomena in the fields, problem solving methods, and so on. Also learned since then is how to analyze beginners' knowledge of the field in the same way. The heart of the problem is the characterization of conceptual change, and all of the tools of cognitive science, of history and philosophy of science, must be brought to bear on this problem.

In addition to the description of how novices differ from experts (i.e., what conceptual change must be accomplished in learning a new field), the mechanisms of learning must be studied. Ideas about mechanisms must be tested in the context of teaching. Prototype curricular modules must be developed and critically evaluated.

The above two topics must be represented in any center on science education. The below listed topics are all important, and some combination of a significant subset of them is highly desirable.

Younger children.

Most of the work on the change from novice to expert has concerned high school and college students. There are important developmental questions that need to be addressed with respect to elementary-aged children. Do young children mentally represent theory-like structures? What conceptual reorganizations occur in the years before high school? What forms should elementary school science instruction and curricula take?

Age related constraints.

Are young children unable to understand key ideas in science? Many have claimed that the young child's cognitive system places constraints on the scientific concepts that can be learned. Although this is an old topic, it is still a focus of controversy, and its resolution has important consequences for science education.

Domains of study

The most studied domain to date is a subfield of physics--mechanics. How general are the conclusions from this research? Do subjects bring intuitive theories to bear on the study of biology, social sciences, chemistry, other domains of physics? A concentrated study of science learning should probably analyze at least two domains of science, carefully chosen to contrast in significant ways.

Consequences for instruction.

What implications do the new research areas have for teacher training? Should teachers be taught about conceptual change in order to be better able to effect it? Should teachers be trained to diagnose their students' prexisting conceptions of the domain they are learning? Pilot programs of teacher training should be constructed, and critically evaluated.

The nature of science.

Besides the content areas of science, how can students be taught about the nature of science. Science must be demystified. We all frequently engage in scientific reasoning, in building causal accounts of the phenomena we encounter. Even the most advanced theories are certainly incomplete, if not actually wrong in crucial details. Should children be taught about science? If so, at what age? Can such teaching affect the child's motivation to continue studies in scientific fields? What are the cognitive and motivational consequences of introductions to science and scientific reasoning at various ages?

Mission Statement

The Learning Process

The National Need

Quality education is a fundamental national priority - so fundamental that it deserves to receive the highest quality scientific support. The continued development and refinement of a basic science of learning and instruction is central to this scientific endeavor. Two reports on the status of American education (from the Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy and the National Commission on Excellence in Education) have recommended that fundamental research into the learning process should be a top priority. The imperatives for "educational reform" and for "excellence in education" are hollow, indeed, unless they include research into the learning process.

The Current Status of Research

Learning has always been an issue of fundamental importance to psychologists and educators. In the past decade or so, a new science of learning has emerged from the integration of research on human development, cognitive science, and human and artificial intelligence. The advances in these fields have made possible both the study of skilled and complex human performance and the analysis of instructional processes. Reading, writing, and mathematics ability, aptitudes for learning, and skills of thinking and problem solving are being studied with powerful new techniques.

The new science of learning is a branch of cognitive science. At its core are detailed theories of the structure of memory, of how knowledge is represented in the mind, and about the processes that take place during learning and problem solving. The last major curricular reforms, in the 1960s, were based on earlier psychologies of learning (behaviorist). Armed with new insights, the time is ripe for a major interdisciplinary effort, a collaboration between educators and cognitive scientists of many sorts, to attack the problem of learning and the instructional process.

The Need for a Center

The learning processes that are important for education can best be studied in research settings where theories of learning and human cognition are tested along with theories of instruction and the design and evaluation of educational environments. In this way, studies of learning as it takes place in schools are shaped by scientific developments, as well as by knowledge relevant to educational needs. Although such a research agenda is certainly feasible, it requires an interdisciplinary effort organized and maintained with great finesse.

There is a clear and present need for at least one national center where learning, teaching and schooling are combined, not fragmented. Similarly, if other mission statements promote the development of center and consortia that focus on a single (i.e., mathematics) or at best a limited combination of subject matters (i.e., mathematics and science) then

this development needs to be balanced by the existence of a national center where research into learning is conducted in a variety of academic domains.

The provision of stable, long-term financial support to such a center would enable it to become a national (even international) resource where scholars interested in education and the learning process could pool resources, become acquainted with state of the art research, and contribute to the dissemination of theoretical and practical advances in knowledge. Such a centralized effort would also permit the stable interaction of first rate groups of researchers and school specialists who could work collaboratively, and stimulate each other to take a broad view of the learning process without diluting the strength of the theories and methods of their own disciplines.

Priority Research Topics

Learning Mechanisms.. The current cognitive theories of learning have taught us that it is necessary to study general problems of learning in the context of rich domains of knowledge. These could include basic areas such as mathematics and writing, or other content-rich domains such as music, social studies, a foreign language, and so on. It follows that a national center for the study of learning must include experts in the cognitive analysis of knowledge of the domains chosen for study. The priority research topic of the learning center would be to foster understanding of the mechanisms of learning. How does learning occur? What changes as new knowledge is imparted? And what are the processes involved in such change?

General Learning Skills. Another major focus of a learning center should be general issues of learning that might get lost in centers that concentrate on particular types of knowledge. There are at least two classes of such general issues. The first concerns the mechanisms of learning that apply to all domains of knowledge. General considerations of induction, hypothesis-testing models of learning, the role of conflict in promoting learning, and so on, fall in the first class of issues. The second concerns such questions as whether there are general problem solving skills or study strategies that promote learning in many disparate academic domains. This is a controversial issue, and has not been definitively settled. Clearly important to education, this question would fall under the mandate of a national center for learning. Absolutely central to claims for such general skills is the problem of evaluation. An important corollary of there being general learning skills is that individual differences in learning ability and aptitudes might be analyzed in terms of them. Again, this important topic should have a central place on the research agenda of a learning center.

Cognitive Analyses of Teaching and Knowledge Transmission. Effective teaching is said to require that the teacher diagnose the learner's current state of knowledge. Is this necessary? Or feasible? How can a teacher of 30 students tailor teaching in this way? Key research topics of a learning center should include: The cognitive analyses of teaching and knowledge transmission, social influences on learning in the classroom, management and planning of instruction, and the adaptation of instruction to meet individual needs, including those of the gifted, the disadvantaged, the language deficient, and the minority child.

Developmental Differences. In order to study learning and instruction, fundamental questions concerning intellectual development must be addressed. Does the young child differ from the adult in ways that have important consequences for the process of learning? This is an age-old question that is far from resolved. Research on this topic would fall under the mandate of a national center for learning. The instructional consequences of any important developmental differences should be studied.

Dissemination. Basic research in learning and schooling should be supplemented in a national center by the careful dissemination of research findings to help in the development of instructional methods and materials, including computerized curricula, methods of measuring achievement and evaluating performance, and effective design of classroom and instructional environments.

Conclusions

The agenda for such a center would be ambitious, and the amount of support should be equally ambitious. But only through sustained, long term, programmatic, interdisciplinary efforts to consider learning in context can we hope to make major contributions both to the basic science of learning and the practice of educating for excellence. Research from centers or consortia with more limited focus (e.g., reading or mathematics) could feed into this center, and vice-versa, in fruitful collaborative efforts. At issue is to help individual learners perform "at the boundary of individual ability in ways that can test and push back personal limits" (the National Commission on Excellence in Education).

Mission Statement

Educational Technology

Although many agree that much of the educational, and by extension, economic future of the United States is tied to computer sciences and related technologies, little is known about how this transition will take place or what effect it will have on either our students or our educational institutions. Moreover, the readiness of the nation's schools to apply the new technology is at present stalled by a shortage of reliable information and a lack of coherent resources. Not only is there a shortage of information on how to apply available technology to education, but there is also a shortage of qualified teachers and researchers able to study the multifaceted problems created by advancements in the field.

Of even greater importance, given the interest in applying technology to educadtion, is the fact that we do not know whether or not these devices actually facilitate achievement. In other words, there is a need to establish the educational utility and/or effects of the wholesale use of microcomputers. This need is at least partially met by the establishment of a center whose mission would be to provide research, development and service on a national scale. The center would mobilize the efforts of professionals from different disciplines working in a coordinated fashion. Results from this work would be of both immediate and long term value to the educational coimmunity.

WHY A CENTER?

The diverse nature of the tasks to be accomplished requires the participation of individuals with different skills and backgrounds. For example, cognitive psychologists are needed to examine the types of learning or restructuring which are amenable to instruction via the computer. Computer programmers are needed to develop the software prototypes to be used. Educators are needed to establish the content of instruction. Finally, anthropologists and sociologists are needed to examine the socio-cultural and organizational factors associated with the use of technology. Clearly, multi-disciplinary teams are essential. Potentially, at least, such teams already exist at a number of major universities in various departments.

While a centralized location is desirable for the sake of administrative convenience, it is important to note that not all research or developments in this area need take place at a single location. The breadth of the field is simply too great to concentrate all of the effort at one location. In addition to its centralized function, a center must be allowed, if not encouraged, to work cooperatively with individuals at other institutions who are experts in their respective fields.

PROBLEM

Recent developments, particularly in the microcomputer industry, have underscored the importance of technology for education. The work force

needed in the technologically based society of the future will be radically different from that of past traditional industry. In recognition of this fact, and in an effort to stem the "tide of creeping mediocrity" in education, the United States Commission on Excellence has gone so far as to recommend that one half year of study in computer science be required for all high school students. In the same vein, a recent survey on computer use in the schools found that 51% of the school districts surveyed ranked computer literacy, along with basic skills, as a primary instructional goal. Not only is there great interest in developing computer literacy skills, but there is a great deal of hope that innovations in technology can be applied to the educational process itself.

RESEARCH

The need for basic research on the social, cognitive and educational implications of the new technology are profound. Not only is there a need to study the effectiveness of different computer-based approaches, but there is also a need to study the processes associated with their use. In general terms, there are two basic questions to be addressed which are of fundamental importance. First, what are the social, psychological and educational implications and/or effects of microcomputers in the schools? Second, to what extent are these effects (or lack of effects) consistent across academic subject matter domains and student populations?

Research is needed to determine whether or not computer-based instruction facilitates the acquisition of basic skills and of more general problem solving skills. Where there is some evidence that working with computers aids in the development of math computational skills, there is very little empirical evidence showing that the experience actually produces long term conceptual gains.

Historically, computer-based instruction has tended to focus on "drill and practice," with little attention to the development of more complex concepts. Recent developments make it possible to conduct research on the effectiveness of computer-based approaches to other more conceptually-based content areas. The purpose here should not be to evaluate particular software packages but to examine the impact of microcomputer approaches in general. For example, we need to know whether teaching students to use word processing programs facilitates the development of literacy skills in the broader sense or whether the effects are restricted to typing skills.

An area in need of major study concerns the general questions of individual and group differences. Are computer based instructional paradigms applicable across different age groups? The study of the understanding of programming functions across ages is certainly needed before requiring programming throughout the grades.

There is some indication that positive effects associated with micro-based instruction are primarily motivational in nature. In this sense, it is reasonable to ask if the use of the microcomputer affects traditionally found sex and ability group motivational differences in the study of math and the sciences.

There is a great need to examine the relative effectiveness of different computer-based approaches with different ethnolinguistic and

social class populations. Studies of this type would, no doubt, have to concern themselves with issues of language characteristics and cultural differences, both in the design and use of research prototypes. Given the enormous populations shifts that the U.S.A. is experiencing, such questions become critically important.

The existence of special populations gives rise to additional questions regarding the use of technology in the school. For example, the current push toward mainstreaming makes it important to study special problems faced by handicapped students.

DEVELOPMENT

In order to address many of these issues, there is a need to develop a core of researchers trained specifically in the issues defining the area, who are able to conduct the critical studies that will be needed. There are already in place a number of graduate study programs in the application of micro-computer technology to the schools; however, these programs are largely experimental and fragmentary. Without a cadre of qualified researchers, it is doubtful that the full potential of the new technology will be examined in educational contexts, thus leaving future applications to chance.

SERVICE

There is an imperative need for the development and evaluation of training in computer literacy which could be implemented at local levels. Several states have established "tech centers" to provide training and, to a lesser extent, information dissemination. Unfortunately, however, these centers are not supported to the extent necessary to enable them to review the full range of hardware and software materials that are commercially available, nor do they have staff who are technically competent to develop and test different approaches. As a result, locally supported centers are foced to operate primarily as demonstration centers within limited geographical regions and cannot provide service at a national level.

There is also a need for information dissemination which goes beyond merely compiling lists of software. The need is to establish a comprehensive computer data base on the educational uses of micro technology which can be accessed by those interested in computer science issues in education. This should include parents as well as educators, since the educational uses of the microcomputer in the home are increasing rapidly and will have an impact on "home based education."

MISSION STATEMENT: HOME AND COMMUNITY INFLUENCES ON LEARNING AND DEVELOPMENT

Much of what our citizens learn, including important skills, knowledge, and attitudes toward learning--which provide the foundation for successful school performance--takes place out of school. For excellence in education to become a reality for all groups in our society, educators, parents, employers, and others concerned with the educational enterprise must develop an adequate understanding of the teaching, learning, and development processes that occur in such out-of-school environments as those provided by the family and the community.

The purposes of this center will be: (1) to conduct a coordinated research program on home and other non-school influences on learning and development; (2) to conduct research on nonacademic characteristics of individuals (e.g., attitudes, values, self-discipline) that influence learning and/or are the outcomes of educational experiences; (3) to collect, synthesize, and analyze past and current research conducted elsewhere on these topics so that the center can serve as a major national resource to the field; and (4) to disseminate research findings, methodological approaches, and critical analyses of research on home, community, and other influences on learning and development to researchers and practitioners. Special emphasis will be given to both individual and group (cultural, economic) diversity and change, and also to specific handicapping conditions.

Problem and Need

Although the schools are blamed for all of the failures of American education, in fact much--some suspect most--of learning and development occurs outside the confines of the schools, under the influence of the home, family, church, business community, peer groups, and mass media. Some of this learning is formally organized (e.g., 4-H Clubs, nursery schools, museums), and some is informal. Furthermore, learning and development are not restricted to the conventional school years, but occur throughout life--deliberately (as in the case of planned career change) or incidentally (through TV). Some of this learning complements the more formal attempts of the schools; some supplements school efforts; and some interferes with, or is antithetical to, the goals the schools claim for themselves.

Attempts to improve education and raise standards of accomplishment will be less than enlightened if these external influences are not taken into account. Yet, in spite of a growing body of research--for example, on the relationship between family and school--there is no systematic and centralized group charged with investigating the quality and quantity of external educational opportunities or the juncture of these opportunities between home and school. Of special interest are the problems that occur when a child from a minority culture is confronted by the demands of a school situation that emphasizes the values of the majority culture.

Every parent possesses a repertoire of strategies for teaching children. There is evidence that different strategies are used by parents of different sociocultural backgrounds. There is also some evidence that the strategies parents use in teaching their children affect the manner in which the children approach learning (learning styles). In addition, there is some evidence that the match between the teaching strategies of the home and those of the school may influence school adjustment and achievement by children. There is a need to identify and examine the effects of various parental teaching strategies in order for classroom teachers to capitalize on the learning that children bring to school.

At the same time that we are concerned with the influences of out-of-school learning, we must also be concerned with the nonacademic learning that takes place both within and outside of school. "Nonacademic" is the term chosen for use here to refer to attitudes, perceptions, values, modes of learning and responding, and styles of interaction with others. These may affect what people learn and how they learn it, as well as the application of learning in their lives and careers. Nonacademic characteristics may also be an outcome of specific educational experiences. Where do students learn their study habits? How are their attitudes toward learning formed? How are the values they attach to self-expression developed?

Such topics as attitudes and values were popular in educational research four or five decades ago. They have tended to fall into disfavor in recent years for several reasons, including the confusion between studying such nonacademic characteristics and prescribing what they should be, failure to distinguish between general traits and those adaptive in particular situations, and the inherent difficulties in measuring such variables. However, it is increasingly recognized that education, directly or indirectly, has a larger mission than teaching people basic verbal and mathematical skills and promoting knowledge in the conventional school subjects (science, literature, social studies, etc.). Further, students' abilities or inclination not only to learn these subjects but also to make a living in the real world may be dependent on these traits.

Center Considerations

These two areas, out-of-school learning and nonacademic development, although different, can profit from: (1) the interdisciplinary perspective that an educational research center/consortium can provide (cross-cultural psychology, sociology, anthropology, developmental and educational psychology, statistics and demography, industrial and organizational expertise), and (2) opportunities for longitudinal studies which are especially important in our ability to understand the kinds of pervasive influences and characteristics described. More directly, researchers with the same kinds of research talents and interests can work in both areas, frequently within the boundaries of a single study. For example: What learning strategies associated with parents' teaching styles are most adaptive for successful learning of traditional school subjects? What habits and values transfer most readily from the school setting to the work setting?

It is important to note that it is unlikely that the research directed toward this mission could be conducted at a single site; rather, a consortium arrangement would seem to provide a more productive organizational approach because of the diversity of populations and settings to be addressed.

The kinds of variables discussed here will certainly figure in research conducted under other NIE center mission statements (e.g., literacy, mathematics, and science). However, of necessity, such variables will be of secondary concern in that research. A separate center is proposed to ensure that systematic and major attention is given to the place of out-of-school learning and influences on learning and to the so-called nonacademic characteristics that students learn and that affect their learning.