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ABSTRACT

This information bulletin examines research and practice issues considered critical in resolving the crisis in science education. Analyses are presented of (1) the current reform movement in science education, (2) the changing culture of science, (3) science education research, (4) the rise of the cognitive sciences, (5) science teachers and research, and (6) the issues of science education research. Hurd suggested that a new vision of science education must be developed, implemented, and validated in ways that will be in harmony with the current status of society. A listing of the major issues in science education and explanations of their impact are also included. (ML)

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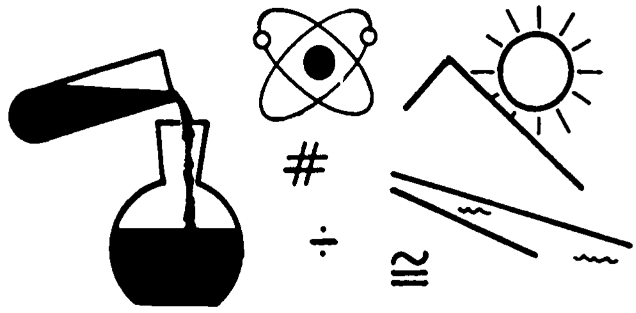

Information Bulletin

No. 1, 1986

Issues in Linking Research to Science Teaching

EDITOR'S NOTES

This information bulletin contains the text of the NARST/NSTA lecture presented as a part of the 34th national convention of the National Science Teachers Association, San Francisco, CA, March 27, 1986. The preparation of the lecture was supported by the Ford Foundation and the ERIC Clearinghouse for Science, Mathematics and Environmental Education. The ideas expressed in the lecture are those of the author and do not necessarily reflect those of the supporting agencies.

The author of this lecture is Paul DeHart Hurd. Dr. Hurd is a professor emeritus of Stanford University. Although he carries the emeritus title, Dr. Hurd is still very active in science education. He is currently a Fellow of the Stanford Northeast Asia-United States Forum on International Policy, a member of the National Committee on United States China Relations, and a consultant to the Board of Directors of the Biological Sciences Curriculum Study.

One of Dr. Hurd's current research interests relates to the topic of the influence of social factors and changing paradigms in science and technology on science education in the United States. He is much interested in policy analysis and research and, for many years, has been synthesizing conditions, philosophy, and research and then identifying possible, and probable, implications for society and science education. Dr. Hurd's work in this area has been used by many people, in science education and in governmental decision-making.

Over the past two decades a massive transition has taken place in the character of our society. Science and technology have been at the root of many of these changes. As a result our nation has been brought to a period of history unlike any other. This break with tradition has been described as a "cultural mutation" (Kenneth Boulding); a "watershed" (Jonas Salk), a "discontinuity" (Peter Drucker), the birth of a "post-industrial society" (Daniel Bell), a new "information age" (John Naisbitt), a "third wave" (Alvin Toffler), and a time "between two ages" (Zbigniew Brzezinski). A central theme expressed by these and other writers is that we will not resolve today's social and institutional stresses in traditional ways.

Beginning as a trickle in the 1970s and reaching flood stage in the 1980s are reports critical of schooling in the United States. Their primary criticism is that schooling is not responding to shifts in our culture and to the needs of young people. A majority of these studies stress the importance of science and technology for understanding the modern world, and at the same time criticize the present curriculum as being historically bound and ill suited for today's world. The criticism extends to the subject matter of the curriculum, context of the courses, learning goals, and modes of instruction.

I have been asked to explore ways in which research in science education can serve teachers better and improve student learning. To do this I think we should first examine the various forces and factors underlying the criticisms of science education that are expressed in national reports. Then we need to look at the culture of modern science and technology to identify any changes in these systems and their implications for a general education in the sciences. To complete our explorations we must look at the status and criticisms of research in science education in relation to the over-all reform movement. The theme that ties these explorations together is this: What are the issues in research and practice that need to be dealt with in order to lift science education out of the crisis it is perceived to be in?

The current reform movement in science education

Before we try to deal with the issues that besiege and malign science education we should examine the forces that are encouraging us to respond to new circumstances. A place to start is with the one hundred or so national reports calling for educational reform in the United States. Most of these documents have come from a wide variety of citizens who participated on national panels, committees, and commissions, or attended government hearings. A smaller number of these documents have come from educators, such as Boyer, Sizer, Goodlad, Lipsitz, Lightfoot and others who reported their observations of school structures and practices. I shall not comment on the character and validity of these reports, but rather consider the thematic changes and issues they project for a reconceptualization of science education.

The recommendation made most frequently in the national reports is that considerations of technology as a sociotechnical system be incorporated into the goals and curriculum of school science. Several reasons for this proposed change are: 1) it represents more accurately how modern science and research are carried on; 2) it bridges the gap that now exists between science, society, and human affairs; 3) it brings science closer to the lives of students for their understanding of our science/technology driven economy; and 4) it provides a mechanism for developing the intellectual strategies and knowledge essential for effective participation in the technoscientific culture that is modern America.

Possibly the most overlooked reasons for the reform of science education are the factors related to the scientific enterprise itself. Since the advent of "big science" in the 1940s there has been a significant shift in the structure and ethos of science. Science has become a part of our social system in which research is as much a response to social need as it is to theory. Advances in science are increasingly dependent upon technological innovations. The electron microscope opened the door for the development of molecular biology, the cyclotron and linear accelator made atomic physics a reality, and the laser provides a new dimension to modern chemistry. Before this year ends, information fed to earth by Voyager 2, and observations obtained from the new space telescope and the four spacecrafts monitoring comet Halley will generate the next steps forward in astronomical research. The recent invention of the acoustic and the x-ray tunneling microscopes make it possible to study cells at the atomic level. Each of these instrumental advances makes it possible for scientists to ask new and more penetrating questions of nature that were previously unanswerable because of the lack of appropriate technology. In all fields of research the computer plays an important role by organizing information and enhancing observations.

Technology as a part of the science curriculum increases opportunities for developing higher cognitive skills that are important in everyday life and essential for advancement in nearly all vocations today. Some of these skills are decision making by individuals and in group situations, using rational procedures to resolve human and social problems, making informed judgments and optimizing choices. Each of these processes in turn is influenced by the quality of the information one has acquired, whether it consists of isolated and inert facts or has a conceptual base. Herein lies one of the more important issues of the reform movement— how to make knowledge more active and productive in the lives of students.

Another theme running through the national reports is the optimal utilization of knowledge. Economists for a decade or so have been writing about knowledge as a basic resource in the gross national product of the United States. It is frequently pointed out that the world has already entered an "information age." The capacity to generate and utilize scientific and technological knowledge is one measure of a country's competitive position in today's global economy. This is the reason nearly every developed nation in the world is currently reformulating its science curricula. The competitive position of the individual in the U.S. workforce, as we have moved from a "blue collar" to a "white collar" labor market, rests heavily upon his or her ability to remember and make use of what has been learned. Our emphasis in teaching has always been on acquiring information rather than giving equal attention to ways in which knowledge can be of service to individuals. At long last, students may be getting an answer to their persistent question: "What good is all this I'm learning going to be to me?"

When knowledge derived from science and technology is used in the context of social and personal affairs, it brings assets and liabilities and adds a value component to science teaching. What the impact is to be is largely determined by the choices we make for its use. These choices in turn rest upon convictions we hold about values, ethics, or sometimes morals. Events surrounding nuclear achievements, space exploration, robotics, genetic engineering, transplanting of human organs and in vitro fertilization are examples. Whatever decisions are made, they will one way or another contribute to shaping the future of human societies and how as individuals we live and work.

The changing culture of science

A gap has developed between the image of modern science and the way it is represented in school curricula. The traditional school subjects of biology, chemistry, physics and earth science no longer exist as distinct research disciplines. These traditional disciplines have been fractured into nearly 70,000 research fields that distinguish what an individual scientist is and does, and the journals in which he publishes. In addition to being fractured, traditional sciences have also been hybridized, giving rise to new disciplines such as biochemistry, molecular biology, biophysics, geobiochemistry, and hundreds more. No longer can scientists or teachers encompass the field in which they were trained.

The central issues for the reform of the school science curriculum are: 1) What is to be selected from the total of all that is known in science and technology for a 10-or 11-year core curriculum in science? 2) Should the search for new subject matter be in terms of integrative concepts or a sampling of information from a number of distinct fields of research? and 3) How do we assure that a modern science curriculum has both scientific and cultural validity?

Another dimension for the reformulation of science education is the effort to orient instructional goals and subject matter toward the future. This does not imply a direct effort to teach a future. Rather it means we select concepts from the sciences and from technology that are potentially useful for resolving persistent human problems in our society which require a knowledge of science or technology for a rational course of action. The list is long and includes such issues as optimal health and longevity, energy resources, environmental pollution, food production, knowledge production, advancing our humanity, and many more. In all of these problems students are recognizably a part of the problem as well as involved in framing solutions, which in turn will form the world of their future.

An intent of the reform movement is to move the learning of science from a passive to an active phase. The ultimate purpose is to make it less possible to distinguish between school learning and life experience. This is the reason there is an appeal for a real-life problem oriented curriculum, where students will have an opportunity to use what they have learned in science for problem solving, making decisions, and planning actions.

Ranking high on the agenda in the science reform movement is the need to teach students how to learn. There is little knowledge so basic and so stagnant that it will not change in meaning during one's life time. Never has the flow of new knowledge in the sciences and technology been so great as it is now, and there is little likelihood we will enter a "dark age" in the next couple of centuries. Continuous learning has become a fact of life for everyone who is not to be disengaged from our culture as a scientific and technological illiterate. Whatever is taught in school must establish a base for learning more without formal instruction. To do this the process of teaching must provide a dimension in which students have an opportunity to learn on their own.

Criticisms of science education research

I have emphasized the general nature of the educational reform movement and the shifting of social forces in the United States because they harbor and define the science education research agenda for at least the rest of this century. Unless the research in science education is in someway related to the problems of teaching, learning, and curriculum criteria inherent in the reform movement, there is no way to justify its worthiness and no base for absorbing its findings. Though the elements of the reform movement are not yet fully sorted out, they nevertheless provide a first step toward building a conceptual coherence between research, practice, philosophical analysis and educational policy.

The reform movement has brought forth much criticism of educational research — not all of which is deserved. To stem this tide, researchers must first recognize that a change in the conceptual framework for science education serves to make obsolete a considerable fraction of previous research and at the same time strengthens the legitimacy of other studies.

It is well that we briefly examine what critics are saying about research in science education. Studies generally are viewed as too narrow in concept and flawed in method to deal realistically with the complexities of human behavior. The physical science model, so widely used in educational research, with its emphasis on the experimental control of variables and statistical analysis has limited value for investigating issues raised by the reform movement. The whole idea of trying to pinpoint answers to questions that are raised in advance of a study produces results of little consequence. Better would be a model derived from ecology which recognizes complexities and assumes broad patterns of interactive behavior such as would be characteristic of a teacher and students in learning situations. Critics also propose that educational researchers end their ongoing debate about "quantitative" and "qualitative" interpretations of data. They argue that the debate is no more productive than those on the nature-nurture issue.

At a time when teachers are under pressure to be more effective in raising student achievement, they report little guidance of practical value from the research on instruction and learning. Whatever value it may have is lost in an amorphous mass of piecemeal studies, uncoordinated and without generality. The lack of appropriate research for improving instruction, curriculum, and learning leaves the reform movement badly undernourished.

Politicians and the general public express a disappointment with educational research for its failure to enhance learning. They point out that, when supporting research in medicine, they look forward to better health, and, in agriculture, to better crops. Why then, they ask, is it not reasonable to expect better learning from educational research?

Other critics think that research in science education suffers because of its isolation from the social, behavioral, and policy sciences. As long as researchers isolate themselves from the rest of the world the results of their research leave everything the way it has always been. Critics further contend that this research has become divorced from its historical roots and is detached from the conceptual issues that form the mainstream of the current reform movement. It is the conceptual framework that determines how we view the results of research and when the framework is reformulated, the past research findings gain or lose significance. To date, the existing research in science education has not been assembled, synthesized, and interpreted in ways which could influence either the direction of the reform or future research.

The rise of the cognitive sciences

The science education reform of the 1960s differs significantly from that of the 1980s. The 1960s reform was guided by curriculum concerns and science courses were redesigned to esent more adequately the knowledge "structure of particular disciplines." The goal was to represent science as it was known to research scientists. The 1980s reform is driven by a concern for the learner and how what is learned may contribute to effective citizenship. The focus is on the optimal use of knowledge for making reasoned judgments and fostering further learning.

Over the past several decades and more or less independent of the science education reform movement, a scattering of researchers known as cognitive scientists have emerged. These scientists represent a new point-of-view in thinking about research on teaching and learning. Researchers in cognitive science assume that students are in control of learning and that research should be concerned with how students acquire information, in what form it exists, and how they interpret knowledge and use it to analyze problems. Cognitive scientists view the curriculum and textbooks functionally. They also recognize a relationship between the quality of learning and the performance of the teacher. Therefore, their research models extend beyond the traditional boundaries of learner, curriculum, and teacher, viewing these variables as part of an integrated system.

Cognitive scientists believe that research on learning has in the past been too narrow to generate robust findings with predictive value. They prefer educational studies concerned with the mutual influences of goals, policy, instruction, learning, and the culture of schools. To encompass these dimensions entails an interdisciplinary perspective drawing upon the research from the social sciences, cultural anthropology, linguistics and the diverse fields of psychology. Furthermore, since science and technology represent special ways of knowing, researchers in science education should not ignore the image and ethos of modern science and technology as portrayed by scholars in the sociology, philosophy, and history of science and technology. Cognitive researchers believe that it is possible to develop practical strategies for teachers to use for achieving a higher order of learning, developing skills to improve retention, and enhancing understanding. Their hope is to close the gap between theory and practice in science education. Their research plan is an engineering model in which learning and instructional problems can be laid out in ways that are amenable to solution. The cognitive scientists have yet to develop an overarching learning theory. They currently work in terms of models and metaphors.

Although the present science reform movement and the cognitive sciences began to take shape in the late 1960s, the two developments were not at first directly related. The concern that brought them together was the tendency of educational researchers to separate in their investigations the instructional practices, expectations for learning, and use of knowledge. Critics of educational studies were of the opinion that an adequate paradigm for exploring the interactions of instruction, knowledge, and learning did not exist. They felt that science education research needed a "macro" perspective and a paradigm that could link the social, psychological, and science components of learning and to do so in terms of the individual. Cognitive scientists see the need for methods of research uniquely different from the kinds of studies that have dominated the research in science education for the past fifty years. A first step is seen as a fusion of the empirical with the normative and the quantitative with the qualitative in terms of practical problems as they relate to long-range educational policies.

The science teachers and research

There is little reason to do research in science education unless there is a pay-off in the classroom. But this rarely happens. Teachers view most research findings as impractical, difficult to interpret and rarely possible to implement.

The cognitive scientists believe it is imperative that teachers be made partners in research. They are equally adamant that the interpretation of research data and its cognitive worth has roots in the experience and practice of good teachers. As partners, teachers provide insight, feedback, and experience needed to validate the cognitive worth of research findings. Unless research on instruction, curriculum, and learning is tested in practical endeavors its findings are cut off from verification and the study at best can only be regarded as an interesting exercise. Teachers should have opportunities to propose problems for research as well as participate in the conduct of studies. Pre- and in-service teacher programs ought to stress how teachers can make the best use of research finding. In general, this means developing an awareness that research provides new options for improving teaching and learning.

Teaching in the United States is not now regarded as a profession. There is little hope it will ever become one until we develop a commitment to research and find ways for using its results to advance our professional responsibilities. Once we effect a system that will bridge research and practice, our professional status will be close at hand.

Confronting the issues in science education research

My purpose to this point has been to show that science education is in the process of a reform. Old beliefs and practices in teaching and research are being challenged anew. The sources of these challenges are found in the changing character of our society, in the current images of science and technology, in new perspectives for science education, and in contemporary developments in the cognitive sciences. It has been my intent to argue that there is little to be gained by attempts to relate traditional research findings to questionable practices in instruction, curriculum, and learning. In this next section of the essay I will define the major issues more specifically.

1. Although there have been numerous restatements of science education goals in recent years, there has yet to emerge a coherent theory or conceptual framework for science education for which there is a consensus. Lacking this statement we have no over-arching perspective that indicates the kinds of variables that should make a difference in research and identifies reasons why they are significant.

   Standards for the legitimacy of research lie in its relevance to a conceptual base and to the real world of learners. Until the reluctance to consider normative, historical and policy research in science education is overcome, there is no way to bridge research and practice. Also there is no guide for establishing a coherent, systematic strategy for the improvement of research in science education.
2. The largest fraction of the research in science education is a first, and usually the last, effort of a novice. The complexity of modern cognitive research is such that we need committed researchers with deep scholarship and experience to generate the new methodologies required for dealing with cognitive problems. We should consider the development of research teams and centers of specialization to work on specific problems. Whatever the organization, the staff should include teachers and specialists from cognate fields of scholarship.
3. To improve inquiry and synthesize findings we must develop a taxonomy of research terms and more precise descriptions of methodologies. Lacking these attributes we are not able to guide the improvement of methodological design and effectively communicate findings. We have already experienced the limitations placed on meta-analysis resulting from the lack of a common language and poorly defined methodologies.
4. We especially need a system for the transfer and implementation of research in the classroom.
5. We need a yearbook written for teachers that is in ordinary language that will enable them to interpret, use, and compare research findings. The volume should also illustrate ways in which teachers can directly participate in new research. Researchers in reporting their findings in journals should be required to include an interpretive summary that identifies their specific significance in real-life terms for teaching, learning, or curriculum.
6. To achieve the goals called for in the national studies will require that educational research be more problem oriented and in terms of real-life rather than contrived conditions. Undoubtedly this will make educational research more complex and difficult since real-world problems of teaching and learning tend to be multicausal, multifaceted, and nonreplicable. New methodologies of research must be designed or borrowed from cognate disciplines. The new researcher in science education must understand both quantitative and qualitative approaches to data interpretation and recognize that applied research has predictive value that extends beyond statistical analysis.
7. There is value in coding research studies as to whether findings have been tested in teaching situations; have value for normative or policy setting criteria; or are simply informative such as survey findings. The whole purpose of classification is to create an awareness on the part of researchers regarding the practical value of their efforts and its limitations. The hope is that research can become a more potent factor in educational improvement.
8. In 1983-84 more than 700 pieces of state legislation were passed to presumably benefit education in the United States. In nearly all instances the mandates were not supported by valid or relevant research. As a result, many of the actions have proved to be counter-productive, some harmful and a few beneficial. Our failure to respond to these mandates on the basis of research findings means we are forfeiting our professional responsibilities and placing them in the hands of legislative agencies.
9. To advance education research we must have specialists trained in two or three fields who devote most of their time to the task. Ways are needed to cluster research studies in terms of critical themes that can provide an inner logic and a sense of unity to our efforts. It would be helpful if we had more team and inter-institutional cooperative effort in carrying on research.
10. If I were to choose the one area of science education in the most need of serious research it would be **curriculum**, an issue the majority of the national reports on science failed to consider. Cognitive scientists are interested in how knowledge is acquired but they do not directly consider the curriculum or its context. Science educators have been restating the goals of science teaching but have neglected to identify the supporting subject matter changes and the curriculum organization essential for achieving the reformulated goals. The public has been active in blaming teachers for the decline in student interest and achievement in the sciences over the past decade, but has failed to recognize that problems lie in a curriculum which students find lacks meaning and relevance, and has little value in life. Science textbooks, the curriculum for most teachers, have become little more than elaborate, colorful, dictionaries. Standard achievement tests stress vocabulary more than they assess the student's level of understanding, reasoning ability, and capacity to relate science to life and society. Currently the most crucial and most neglected issue in science education is a well structured curriculum that recognizes the new instructional goals, that is provocative for

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Patricia E. Blosser
Bulletin Editor

the student, and which can be taught operationally. The researcher has the intriguing task of carrying on studies that consider jointly cognition, instruction, and curriculum so that the quality of learning and achievement can be raised to new heights.

A final note

My focus in this paper has been to indicate that the sphere of activity for science teachers and researchers has changed in significant ways. The roots of these changes lie in social and economic shifts, the new image of science and technology, public concerns about the conceptual base for a general education in science, new perceptions of methodology in educational research, and changing concepts of what it means to learn and know. Each of these transitions mutually influences all others. We are at a period in history that is unique and the pressures on science education suggest that a new vision must be developed, implemented, and validated in ways that are in harmony with the way things are. To effect these changes rests upon developing a mutual respect and cooperation among scientists and educators, researchers and practitioners, and the public for the realities of schooling.

REFERENCES

Best, J. H., *Inquiry in Education: A Research Agenda.* Washington, D.C.: The American Educational Research Association, 1983.

Bybee, R. W., J. Carlson and A. J. McCormack, eds., *Redesigning Science and Technology Education.* 1984 Yearbook of the National Science Teachers Association. Washington, D.C.: The National Science Teachers Association, 1984.

Champagne, A. B. and L. E. Klopfer, "A Sixty-year Perspective on Three Issues in Science Education.
I. Whose ideas are relevant.
II. Representation of women.
III. Reflective thinking and problem solving."
Science Education, 6(4):432-452, 1977.

Committee on Research in Mathematics, Science, and Technology Education. *Mathematics, Science, Technology Education: A Research Agenda.* Washington, D.C.: National Academy Press, 1985.

Caroll, J. B., J. S. Coleman, R. Glaser, H. Howe, II, R. A. LeVine, J. Mincer, L. B. Resnick, and L. S. Shulman, *Improving Education: Perspectives on Educational Research.* Pittsburgh: National Academy of Education, 1984.

Cronbach, L. J. and P. Suppes, *Research for Tomorrow's Schools: Disciplined Inquiry for Education.* New York: The Macmillan Co., 1968.

Frey, J. B., K. Blansdorf, G. S. Kapune, and F. Archenhold, *Research in Science Education in Europe.* Amsterdam: Swets Publishing Service, 1977.

Glassman, N. S., Ed, *Review of Educational Research,* 54(4): Entire issue, 1984.

Holdzkom, D. and P. B. Lutz, Eds, *Research Within Reach: Science Education.* Charleston, West Virginia. Appalachia Educational Laboratory, Inc., 1984.

Hurd, P., *Toward a Theory of Research in Science Education.* A report to the National Science Foundation. Washington, D.C.: National Science Foundation, 1978.

Hurd, P. D., "Research in Science Education, Planning for the Future." *Journal of Research in Science Teaching,* 8(3): 243-279, 1971.

Kaplan, G. R., *Items for an Agenda: Educational Research and the Reports on Excellence.* Washington, D.C.: American Educational Research Association, 1985.

Kiesler, S. B., and C. F. Turner, eds., *Fundamental Research and the Process of Education.* Washington, D.C.: National Academy of Sciences, 1977.

Klein, M. S. and F. J. Rutherford, eds., *Science Education in Global Perspective: Lessons from Five Countries.* AAAS Selected Symposium Series. No. 100. Boulder: Westview Press, Inc., 1985.

Lockhead, J. and J. Clement, eds., *Cognitive Process Instruction: Research on Teaching Skills.* Philadelphia: The Franklin Institute Press, 1979.

Mumby, H., G. Opwood, and T. Russell, eds., *Seeing Curriculum in a New Light: Essays from Science Education.* Ontario, Canada: The Ontario Institute for Studies in Education Press, 1980.

Report to the National Council on Educational Research. *Creating and Disseminating Knowledge for Educational Reform.* Los Angeles: Center for Leadership Development, 1984.

Robinson, J. T., ed, *Research in Science Education: New Questions, New Directions.* Columbus: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 1981.

Segal, J. W., S. F. Chipman, and R. Glaser, eds., *Thinking and Learning Skills—*
Vol. I. *Relating Instruction to Research.*
Vol. II. *Research and Open Questions.*
Hillsdale, N.J.: Lawrence Erlbaum, Publishers, 1985.

Shipman, M., ed., *Educational Research: Principles, Policies, and Practices.* Philadelphia: The Falmer Press, 1985.

Shymansky, J. A., ed., *Journal of Research in Science Teaching.* 20(5): Entire issue, 1983.

UNESCO-NIER, *Broadening the Scope for Educational Research.* Tokyo, Japan: National Institute for Educational Research, 1984.

Ward, J. A., and L. J. Reed, eds., *Knowledge Structure and Use: Implications for Synthesis and Interpretation.* Philadelphia: Temple University Press, 1983.

Welch, W. W., "Research in Science Education: Review and Recommendations. *Science Education.* 69(3): 421-428, 1985.

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