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ABSTRACT

This document explores the mission, goals, and underlying philosophy of the National Center for Science Teaching and Learning (NCSTL). The reform of the U.S. educational system, especially in the area of science education, will require a thorough examination of noncurricular, external factors affecting science education. In order to bring about reform a discourse must be created among the divergent "cultures" of science education, science, and public policy. A brief description of five focus areas chosen for study is provided. The first of the five focus areas considers the influences of social and cultural factors on the nature, teaching, and learning of science. The second deals with public expectations and societal incentives and how they influence the teaching and learning of science. A third focus area looks at the effects of school organization, policy, and economic/political forces on science teaching and learning. The fourth considers how developing technologies will alter tomorrow's education and the psychological and social imp t of technology. The fifth focus area deals with educational in ration. A discussion of the underlying assumptions and predisposi ns affecting the NCSTL's research agenda is also included. (KR)

The Research Agenda of the National Center for Science Teaching and Learning: External Influences on Science Education

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In this exploration of the mission, goals, and underlying philosophy of the National Center for Science Teaching and Learning, the authors explain that reform of the American educational system, especially in the area of science education, will require a thorough examination of non-curricular, external factors affecting science education. In order to bring about reform, the authors argue, one must create a discourse among the divergent "cultures" of science education, science, and public policy

It is the worst of times, it is the best of times for science education. The flight of students from the sciences may now be accelerating: For example, the number of college degrees in the sciences over the past decade have declined both absolutely and relatively (National Science Foundation, 1990), and all efforts to increase the participation of women and other underrepresented groups appear to have had minimal if any effect. As a result individuals educated in other countries make up an ever-increasing fraction of our graduate students, post-doctoral scholars, and working scientists. Moreover, the American public's grasp of scientific concepts and facts, even defined at the most minimal of literacy levels, is appallingly inadequate (Miller, 1989). But this very crisis has helped thrust science education into the limelight, with cries of disaster resulting in exhortations from the highest places, major reform initiatives, and increased funding for research, development and application. It is in these times that the National Center for Science Teaching and Learning, a research endeavor, has been established at The Ohio State University with funding from the Office of Educational Research and Improvement, and it is these times which have influenced the Center's research focus and philosophy.

When we first considered the contributions a new research center might make today, three major national efforts, Project 2061, Science Technology and Society (STS), and Scope, Sequence, and Coordination (SS&C), as well as numerous other projects in teacher education and curricular reform, already existed. It was clear that forming another group to work in these areas would not be innovative and might well be redundant. Moreover, we felt then and are still convinced now that the reform of science education in this country will require more

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than the improvement of content and pedagogy. There is no question that curricular content, teacher education, and classroom materials are all central to any reform in science education. But there are additional factors which, though we might classify them as external to the classroom, nonetheless have a pervasive influence on the educational process in general and on science education in particular.

Because of their importance, we decided to focus on a research agenda designed to develop a knowledge base of these external influences. This knowledge base should assist in the development of new understandings not just for science teachers but also for new audiences, including policy makers, the business community, school administrators, engineers, and basic science researchers. What follows is first a brief description of the problems we have chosen for study. We have arbitrarily divided these into five Focus Areas, the format of the first part of this article. Secondly we have sketched out the intellectual predispositions that guide our work.

The Five Focus Areas

The first of the five Focus Areas considers the influences of *social and cultural factors* on the nature, teaching, and learning of science. There are numerous suggestions that social factors based on race, gender, and ethnic background may either promote or interfere with science education. A conclusion that Oakes (1990) derives on the basis of an extensive literature survey is an example:

> The importance of societal factors on the attainments of women and minorities cannot be overlooked. Undoubtedly, they play a significant role in race and gender differences in achievement and decisions to pursue science.But she also notes that while there is an extensive literature, "less work has explored the mechanisms through which societal factors may actually have these effects.

Thus, it is our goal not only to further document the educational implications of these societal factors, but also to uncover the undoubtedly subtle mechanisms that limit broad participation in the sciences. Second, we know that *public expectations and societal incentives* must influence the teaching and learning of science. For example, Bishop (1989) has posited that:

> The fundamental causes of student and parental apathy toward science, mathematics, and technology education are the absence of reliable indicators of science and mathematics learning in high school and the consequent lack of rewards for learning science and mathematics.

We must be able to identify and describe specifically those expectations and incentives and how they might act both positively or negatively. We must then learn how to redirect negative to positive. One potentially negative expectation we shall explore is the curious absence of a strong high school science experience from almost all college entrance requirements. An incentive we are exploring is whether a professional partnership between university science faculty and middle school teachers will promote classroom science enthusiasm in both teacher and student. A third Focus Area looks at the effects of *school organization, policy, and economic/political forces* on science teaching and learning. We know that these forces often operate independently of any effort to reform science education, but they also profoundly affect science teaching and learning. For years for example, policymakers have mandated standardized achievement tests which either ignore the scientific disciplines or assess low-level scientific knowledge and skills. To the extent that tests drive the curriculum – and there is convincing evidence that they do (e.g., Evertson, 1990) – there are unfortunate consequences for science education. We must describe precisely how policy initiatives and organizational practices influence, either for better or worse, the educational experience of teachers and students. We must learn how to harness those forces that act in the interest of good science education, and how to live with and perhaps even avert those that will be harmful.

Fourth, we have already seen, and expect to see in an ever greater rush, the introduction of *new technologies* into the classroom. These technologies, now largely driven by semiconductor developments, will undoubtedly alter the ways in which we teach and learn. While the details are still vague, there is already sufficient reason to believe that these alterations will lead to a new school environment. Therefore, simply to consider the advantages an individual technological advance brings to today's classroom is insufficient: we must consider these current and emerging educational technologies all together and must under stand the qualitative changes they will bring. We must understand how they will, and perhaps more importantly, how they should, alter tomorrow's education.

We must also consider the psychological and social impact of technology. There is, for example, the perplexing problem described almost a quarter of a century ago in an article by Mazlish (1967). He began with Freud's suggestion that our cultural ego was subjected to rude shocks, "...administered by Copernicus (or Galileo), Darwin, and Freud," who respectively eliminated the conceptual discontinuities of our cultural heritage: that earth is unique within the universe, that humans are uniquely different than animals, and that in humans the "primitive, infantile, and archaic", is distinct from "the civilized and evolved." Clearly, the elimination of these intellectual barriers caused painful readjustments unfinished to this day. With great prescience, Mazlish proposed that we were even then going through a period in which a fourth discontinuity – that between us and the tools and machines we construct – was being abolished.

> ... we are now coming to realize that man and the machines he creates are continuous and the same conceptual schemes, for example, that explain the workings of his brain also explain the workings of a "thinking machine." Man's pride and his refusal to acknowledge this continuity, is the substratum upon which the distrust of technology and an industrialized society has been reared.

Twenty four years later advances in computer technology have reinforced Mazlish's insight. If we are to consider classroom use of the computer, arguably the most important of the new technologies then we must consider also the distrust and fear that the breakdown of this last discontinuity will attach to computer use. Teacher education must deal with such distrust lest it be transmitted, even inadvertently, to students.

The fifth and final Focus Area deals with *educational integration*. It is perhaps already a truism that knowledge both shapes and is shaped by our culture; that the chosen goals and the intellectual inclinations forming an approach to a problem, the attitudes shaping the acceptance of new ideas and other thematic factors are crucial components in the scientific endeavor. Yet we continue to teach the various sciences as fragmented disciplines, isolated from one another and from the surrounding culture. No doubt there are benefits gained from isolating smaller and more intellectually digestible units of knowledge, but science must also be understood as the sum of its various parts and the product of its cultural environment. We must therefore investigate how best to integrate science with itself and with the various other disciplines in our schools. We must also learn to understand when attempts at integration are natural and reinforcing, and when they are unnatural and even perhaps detrimental to understanding.

These are the interests of the National Center for Science Teaching and Learning, and the emphases that will shape our research and our goals. It is our belief that the recognition of these interests and problems as a group is at least as significant to science education as is the recognition of problems in content and pedagogy. Moreover, it is our contention that research into the external factors can form the core of a vital and exciting research agenda.

It is our intention that this research agenda produce a knowledge base which will affect the teaching of teachers. For example, we are looking for information that should help sensitize teachers to the importance of culture in both teaching and learning. But in addition, we expect to alert teachers to specific ways of using the culture a child brings to the classroom as an asset. We anticipate similar benefits with respect to the variable of gender. Research conducted in the Center should also help teachers understand how to integrate science with other curriculum areas and when such integration is desirable. Curriculum integration has been an educational ideal since the progressive era, and continues to be a central tenet of contemporary curriculum reform efforts such as Project 2061 and STS. Nonetheless, virtually no empirical research has been conducted to indicate how teachers can meaningfully integrate content in their classrooms.

Finally, we hope to provide a knowledge base that will inform other actors -- policymakers, school administrators, research scientists, engineers, and others -- who influence science instruction. Together with this knowledge base we look also to providing forums and processes in which all the various actors on the science education stage can educate one another. To appreciate these goals, one must also understand the assumptions and predilections which cut across all five focus areas and which undergird virtually all Center activities.

Underlying Assumptions and Predispositions

A research agenda is more than a programmatic arrangement of defined problems. There is also an underlying, although often unspecified, thematic basis that can be described loosely by terms such as point-of-view, perspective, conceptual framework, paradigm, research style, epistemological base, intellectual predisposition, and so on. To be effective an individual or institution often need not define or describe carefully this thematic basis. Such inattention is well illustrated by current physical and biological scientists who in the main ignore and even shun the philosophical and historical discussions that accompanied European scientific research into the beginning of this century. The power and beauty of current science is none the worse for this inattention. However, science education has a distinctive intellectual positioning that requires the conscious explication of *a priori* assumptions. Therefore, let us first consider this intellectual positioning and then move on to the consequences for the National Center for Science Teaching and Learning.

As indicated in its name, science education sits between different *cultures*. First, science education concerns not only the academic disciplines; it is also a public policy field. Second, science education is the concern of both the natural sciences and the social sciences, two sets of quite different academic disciplines. These cultural distinctions between individual academic disciplines and between the academic disciplines and public policy have been clarified by the philosopher Stephen Toulmin (1972).

According to Toulmin, those in an academic discipline can work within an ideal typical world of their own collective creation. Disagreements arising from different conceptual visions of that ideal typical world (that is to say, paradigm disputes) are eventually resolved by deciding which paradigm best serves the discipline's purposes. For example, the field of biological systematics is currently involved in a dispute between those who classify organisms utilizing large scale characteristics and those who rely on details of protein structure and DNA sequence. But when purposes differ, a discipline often divides into subdisciplines. Linguistics, for example, at one point subdivided into psycholinguistics and sociolinguistics. Should the two sides in the dispute over biological systematics find that their purposes do not coincide, then we would expect a subdivision to occur here as well.

In contrast, public policymakers cannot and do not work within an ideal typical world. All participants in the policy making process have limited conceptualizations of the world, to be sure. Disagreements arising from differing conceptualizations, however, cannot be so easily resolved as in the academic disciplines. Policy disputes, for example, can seldom be resolved by appealing to shared purposes, because value disagreements are at the root of many policy disputes. Similarly, the subdivision solution cannot be employed since decisions must be made and actions must be taken.

Toulmin demonstrates the academic discipline/public policy distinction with an example. Even if civil engineers recommend that a dam be built in a particular location, policy makers will not necessarily heed their advice. For the engineers' technical perspective will only be one of a multitude of concerns and perspectives that policymakers need consider and weigh in the course of making their decision.

What does this mean for the National Center for Science Teaching and Learning's research agenda? We hold that science education is ultimately a public policy field as well as an academic discipline. Thus, we must perhaps be much more reflective than those who work in academic disciplines over the assumptions, conceptual frameworks, perspectives and intellectual dispositions which direct our empirical work. In public fields it is often the *a priori* assumptions which are most influential (Donmoyer, 1991; Weiss, 1982).

For example, before an empirical researcher can determine whether teaching method A produces more learning than method B, the researcher will have to define the term learning. The researcher, for instance, might view learning as the acquisition of discrete skills or as the construction of conceptual understanding. Therefore, the outcome expected would likely depend on the conception of learning selected. In essence, the *a priori* assumptions will determine the researcher's findings at least as much as the empirical reality does. Indeed, one might argue that the *a priori* assumptions create the researcher's reality.

In addition, since different intellectual dispositions often take the form of different theoretical languages and discourse styles, an awareness of our orientations and the ways of talking and thinking that they create is essential if we hope to communicate effectively with the wide range of players in the public policy arena. Self consciousness regarding discourse is required for effective communication between academics in different fields, much less between academics and policy makers.

Let us turn next to the apposition of the natural and social sciences. For background we start with brief descriptions of both, descriptions sufficiently stripped of detail to hope for the absence of dispute. The natural sciences deal with two apparently distinct domains. The first is the infinitude of observable facts, data, and observations; the second the infinitude of our internal mental constructions, among which are our understandings of how the world functions. Given these two domains, the sciences set out to find and express explicitly with language the correspondences between these two domains. Phrased differently, the sciences seek those functions that allow for a mapping between the real and the conceptual domains. Before going any further, the reader may have already recognized that this description has important flaws. Consider just one example: the two domains are not truly distinct from one another. For example, our conceptual world alters the real world insofar as our data is generally recognized to be theory laden, and for some even theory driven. But our conceptual world does not just interpret our real world, it also physically alters it. The steam and internal combustion engines are tools constructed from our conceptions of energy and work. No one today can doubt the profound changes these tools have wrought on our physical environment.

The social sciences also deal with two apparently distinct domains: the infinitude of observable facts, data, and observations versus the internal mental construct. And the social sciences also seek mappings. This analogy with the natural sciences can be extended further. No one today, least of all the educator, can doubt the profound changes that our educational vision can have on society.

But though analogies can be drawn, the natural sciences and the social sciences are different sets of disciplines. One deals with the physical material world and the other with the partly ideational world of human society. Thus, each has either explicitly or implicitly carved out a subdomain of the observable, and these subdomains, though they might overlap, are very different. To utilize the language of Toulmin, the *purposes* of the natural sciences differ from those of the social sciences. These differing purposes result in very different conceptions of what research is and of the intellectual tools used in that research.

It is science education's position between these different cultures that presents the National Center so many opportunities and so many dangers. The individual at any border has the opportunity to become bi- or even multilingual. And the apposition between different predispositions and procedures can result in an excitement and tension that may lead to the creative play of new nuances and the discovery of new procedures. As illustrations of this potential we cite just two of many possible examples. The first, from the conjoining of history and science, is Holton's (1988) stirring plea for the introduction of science into the study of history since:

The history of science can show that

might comes from being right, rather than, as in the rest of history, more often than not the converse. Bringing science and history together . . . in scholarly research and in the classroom, for scientists and the nonscientists is one effective way to enlarge the beachhead of reason."

And David Faust (1984) has proposed the important role that psychology can have in understanding scientific knowledge, thereby implicitly affecting science itself:

> . . . there are tenable grounds to assume that science is judgment laden, that scientists are faced with complex and difficult judgment tasks, and that scientists are not perfectly equipped to manage the judgment tasks they face. An emerging awareness of these "realities" of scientific life, and basic developments within the philosophy of science and cognitive psychology, all point towards the same conclusion that the study of scientific judgement and its limitations is essential to an understanding of the processes involved in the acquisition of scientific knowledge.

The extension of Faust's view is a position already held by many educators and scientists. Namely, while the practice of science clearly must influence the teaching of science, the reverse also holds: the teaching of science can and must affect the practice of science.

But locating oneself on the border can also be dangerous. The hybrid is always subject to attentions from the surrounding cultures, attentions that may elicit harmful defensive responses. One defensive response is to step away, to view the border as an impenetrable barrier, and then to face only one community. Thus there has arisen among both scientists and educators the notion that context and content are separable. The two parties appear to have agreed that the educator should know best how to teach the student; the scientist should know best what to teach the student.

This theme of multicultural excitement and tension will influence all the research activities of the National Center for Science Teaching and Learning. This emphasis explains: i) our efforts to define problems that engage scientists and educators together; ii) our interest in "teaching across content," the fifth Focus Area of the Center; iii) our interest in partnership programs with scientists and engineers acting as resource people for teachers; iv) our initiatives to establish a cooperative effort between classroom teachers, scientists, and engineers to develop intelligent computer tutoring systems as tools for the classroom; and v) our attempts to link science educators, policy makers and school administrators. Furthermore, the location of the Center at a large research oriented university will help us enlist educators, scientists and policy makers into our research program.

Conclusion

Simply placing individuals side–by–side yields insufficient benefits. An emphasis on true intellectual interaction must underlie any program. To obtain true interaction among educators, scientists, and policy makers requires discourse to bridge the gaps between their various cultures. These gaps derive from differences of purpose and are further enforced by methodological and conceptual differences. It is only through discourse which exposes the predispositions of the various cultures that meaningful interaction between the individuals from those different milieu becomes possible. For this reason the Center shall involve itself in discussions both of the basic themes that underlie our various research efforts, and of what forms those research efforts should take.

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