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ABSTRACT

The National Institute for Science Education's (NISE) focused mission is to improve mathematics and science education from kindergarten through college. This document reports on NISE's research programs, dissemination programs, and organizational process programs. Contents include: (1) "Systemic Reform: Policy and Evaluation" (William H. Clune and Norman L. Webb); (2) "College Level One" (Arthur B. Ellis); (3) "Professional Development" (Susan Loucks-Horsley); (4) "Secondary Teacher Education Project: Toward a Distributed Professional Community Model" (Sharon J. Derry); (5) "Interacting with Professional Audiences" (Senta A. Raizen); (6) "Communicating with Mass Audiences: The Why Files Research" (William Eveland and Sharon Dunwoody); (7) "Cognitive Studies of Interdisciplinary Collaboration" (Sharon J. Derry); (8) "Information Resource Coordination" (Barret S. Caldwell); and (9) "Formative Evaluation" (Susan B. Millar). Appendices list NISE staff and collaborators; conferences, forums, and workshops; and publications. (YDS)

National Institute for Science Education

University of Wisconsin-Madison • National Center for Improving Science Education

December 22, 2000

Final Project Report to NSF

Andrew C. Porter, Director
Barrett Caldwell and Robert Mathieu, Associate Directors

Funded by the
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National Institute for Science Education
University of Wisconsin–Madison

December 22, 2000

In memory of Susan Loucks-Horsley

During the last five years, Susan Loucks-Horsley did much of her work as part of the National Institute for Science Education. Susan was not only principal investigator of NISE's professional development program, but a member of the leadership of NISE, joining with other team leaders to guide the Institute through its program of work.

From the beginning of NISE, Susan Loucks-Horsley had a profound effect on our entire community. Committing to produce a book by the end of the first year of NSF funding seemed an ambitious—if not unattainable—goal. Susan and her coworkers did produce the book. It was a huge success and continues to have a profound effect on the thinking of people across the country as they design, deliver, and do research on professional development for teachers of science and mathematics. The book was NISE's first "home run." Susan's having set and met such a goal inspired all of us in NISE to demand that level of accomplishment from ourselves.

Susan was an outstanding scholar and researcher, of course, but she was also a person committed to making a difference through her scholarship. An expert professional developer, she was a master of communication skills and, more generally, interpersonal interactions.

Although we will miss her professionalism, we will miss Susan as a friend even more. She was a wonderful, warm, and giving person. Susan made all of us better, both personally and professionally.

—Colleagues from the National Institute for Science Education

Contents

Overview

Mission

The people and the work of the NISE share a strong and focused mission. We are committed to the improvement of mathematics and science education. Our scope includes practice from kindergarten through college, with attention to key transition points along the way. All of our work is directed toward the improvement of student learning; increased student learning is the ultimate test against which we judge our success. We recognize that mathematics and science education has disproportionately failed children from low-income and minority families and that this result must be changed for moral as well as economic reasons. We see education as in the midst of a technological revolution with great potential, but, as yet, little impact on practice. Our work seeks to capitalize on technological advances to create new forms of educational opportunity in mathematics and science for students of all backgrounds and varying interests. The NISE has ambitious goals. We tackle what we believe to be the toughest and most pressing problems. Nevertheless, we are committed to a high rate of productivity and an efficient and effective coupling of our work to the improvement of practice in real settings.

When the Education and Human Resources Directorate of the National Science Foundation created the NISE in July 1995, it charged its first research center to "address the totality of the education enterprise, to assess its effectiveness and examine what new activities need to be established, what activities are no longer needed, and what new approaches will enhance science education." Obviously, the NISE shares this broad and ambitious mission with a great number of other efforts supported by NSF and other federal agencies, as well as by foundations, professional organizations, and universities across the country.

While the NISE was funded by NSF through a cooperative agreement, NISE was charged with identifying the substantive directions for its work. One of the major contributions of the NISE proved to be its ability to identify the most important and timely areas for science, mathematics, engineering, and technology (SMET) education R&D. The NISE architects recognized that in the EHR portfolio essentially no investment was being made to analyze and pull together large bodies of work in ways that would reveal emerging consensus. NISE not only completed much needed analysis of ripe bodies of research, but interpreted that work in ways that lead to productive development efforts serving the needs of practitioners (e.g., teachers, education administrators, professional organizations, federal agencies). Thus, from the very beginning, the NISE focused much of its resources on conducting analytic syntheses and meta-analyses of bodies of education R&D judged to be important and pressing and with sufficient work to make analysis and interpretation useful.

Initially, professional development of K-12 teachers was identified as an important and ripe target. Susan Loucks-Horsley's team and the resulting book, *Designing Professional Development for Teachers of Science and Mathematics*, as well as their highly successful dissemination efforts, proved that the choice was good. NISE's work led to a major reconceptualization of professional development and identified a new research agenda that has been taking K-12 professional development an important step forward.

In 1995, EHR's largest investment was in systemic reform, with programs for statewide, urban, and rural initiatives. The initial theory for systemic reform was more a hypothesis than an

established theory (Smith & O'Day, 1991). The NISE architects recognized the need to document and analyze the practices and effects in this mushrooming and rapidly evolving line of reform. Again, the decision proved to be wise. Bill Clune's team extrapolated, from the wealth of data about practices and from the Smith and O'Day hypotheses, an empirically based theory that has the highly desirable property that it can be empirically tested. At the same time, NISE discovered that systemic reform presents new challenges for evaluation, challenges not adequately met by current evaluation procedures. After five years, Norman Webb's team has produced a promising book that documents the challenges of systemic evaluation and proposes new methodologies.

NISE recognized the need for research-based tools to support the reform of first-year SMET courses in undergraduate education. These courses are the entry points for students who will pursue majors in SMET. They are the entry points for prospective K-12 SMET teachers. They are also often the last SMET experiences for college students, too many of whom become turned off to science and mathematics through bad experiences in their college coursework, and too many of whom are minorities and women. Again, NISE made a good decision. After five years, Art Ellis's team has created a family of faculty professional development Web sites to support much needed undergraduate SMET reform. The development of each Web site began with a research synthesis, followed by a year-long institute, staffed by experts from across the country who identified promising practices and made them available to their colleagues through Web-based tools. Early response to the family of Web sites has been enthusiastic.

Not all of NISE's work has entailed big-picture, analytic synthesis of an existing body of work. We have also pursued narrower targets of opportunity for first-line empirical research. Two examples illustrate the point: The World Wide Web has revolutionized communication. The effectiveness of NISE has in large measure profited from Web-based communication, as illustrated by the Web sites to support reform in undergraduate SMET education and by the NISE's own highly developed and carefully maintained Web site (*http://www.nise.org*). What NISE recognized was that (a) the Web might be a powerful tool for addressing science literacy and (b) creating a Web site in support of science literacy would also offer an excellent base for research on how Web-based learning occurs and how Web sites might be redesigned to better support learning. The result is the highly acclaimed *The Why Files*, created by Susan Trebach and Terry Devitt, which offers the science behind the news. Using the Web site as a launch pad, Sharon Dunwoody and William Eveland carved out a path-breaking program of research on Web-based learning.

Because NISE's mission requires an ongoing assessment of the most important SMET education R&D targets, it was only natural for NISE to assess continually the productivity of its own efforts. Early work on interdisciplinary problem solving, conducted by Sharon Derry, using NISE interdisciplinary teams as the focus of her study, was completed in Year 3. Early investments in formative evaluations by Susan Millar proved so useful in the beginning years that this effort could be scaled back.

Freed up resources were redirected toward initiation of a new line of work on a Web-based approach to undergraduate teacher education in mathematics and science. Sharon Derry leads the effort. Many have recognized the inadequacies of current undergraduate teacher education programs to produce the kinds of teachers needed in K-12 schools; how to overcome the weaknesses in undergraduate teacher education has been less

evident. Once again, NISE is utilizing the power of the Web to provide a whole new approach to undergraduate teacher education, one that might ultimately solve the highly problematic disconnect between undergraduate teacher education and the continuing professional development that teachers receive once leaving college and taking a teaching position.

Figure 1 provides a schematic of NISE's research program in the year 2000. While the mission of the Institute is broad, the Institute's program is focused and coherent. Focus is necessary because resources are limited, and fundamental progress requires depth of effort. Coherence is important so that each separate line of work holds the potential for not only achieving its goals, but informing the work of other lines of work.

The three lines of work (see Figure 1) are tied together through a number of linkages to form a coherent focus for the Institute. Teacher education is arguably the single most important and most complicated piece of successful systemic reform. At the same time, college-level SMET education sets standards that drive the K-12 SMET education system. These higher education standards are key to any successful approach to K-12 systemic change. College-level SMET education also plays an essential role in defining the nature and quality of preservice teacher education. While preservice teacher education and professional development are not tightly coupled, either in concept or in practice, both would surely profit from such a linkage, which the Institute is seeking to make. A deep commitment to making the work accessible to the Institute's target audiences permeates all activity.

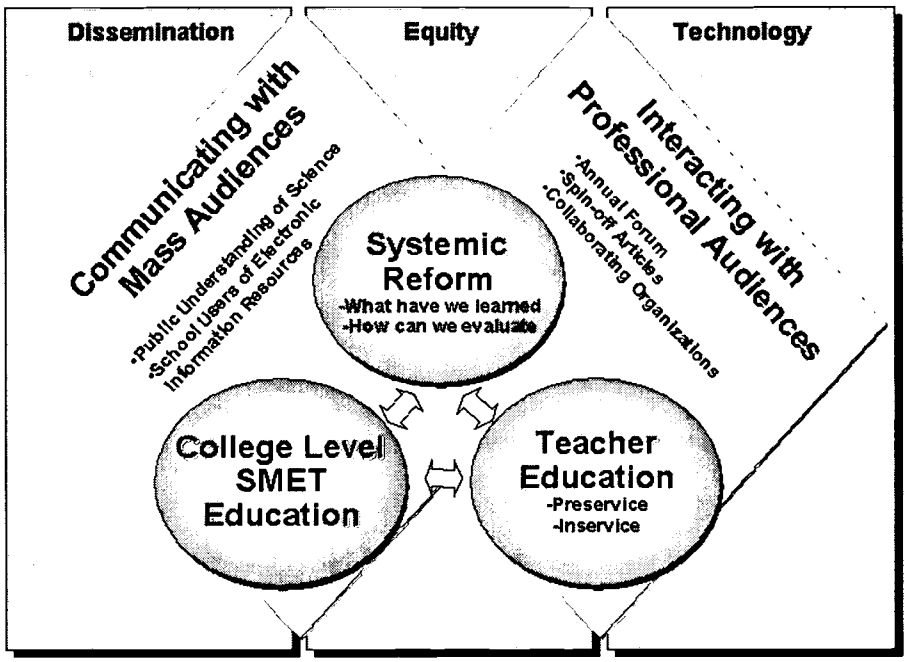
Three themes cross cut all of the work of the Institute. One is a deep concern for understanding how equity in SMET education can be achieved. Another is the role of technology in improving the quality of SMET education and providing strategies for implementing successful innovations on a national scale. The third cross-cutting theme is a commitment to dissemination. All lines of the Institute's work—professional development and preservice teacher education, college-level SMET education, systemic reform—share a focus on problems of equity, profit from innovative uses of technology, and are committed to high-quality dissemination.

Accomplishments

NISE research on professional development in science and mathematics is a good example of the strength and influence of our work. Susan Loucks-Horsley's 1994 book, *Designing Professional Development for Teachers of Science and Mathematics*, written with Peter Hewson, Nancy Love, and Kathy Stiles, is a top seller for Corwin Press. It has been put out twice in short form by the Eisenhower National Clearinghouse: once with a focus on science and once with a focus on mathematics. Tens of thousands of copies of each short form have been distributed to members of the field. The NISE Brief that presents the framework for professional development has been widely copied for use with practitioners in workshops and courses around the country. The work guides the current national evaluation of the Eisenhower Program. Clearly, the field needed this synthesis and reconceptualization of professional development in mathematics and science and gave it an enthusiastic reception.

Soon there will be an NISE book that does for evaluation of systemic reform what Susan Loucks-Horsley's book has done for professional development. The book by Norman Webb and others not only synthesizes the field, it pushes the field forward by reconceptualizing alignment, by making clear that the methodologies of program evaluation are not

Figure 1. Institute Research Program



adequate for coping with the complexities of systemic reform, and by offering alternatives. Also within the year, NISE's book on a theory of systemic reform by William Clune and others will be completed. The real power of Clune's theory lies with his ingenious operationalization of the variables. Empirical tests of validity can be conducted, and he has conducted the first. For systemic reform to remain useful, clarity and empirical tests are essential.

NISE's College Level One team, under Arthur Ellis's leadership, is among the few groups in the country conducting serious research on how to improve the quality of learning, teaching, and assessment in undergraduate SMET education. Our early work on small-group cooperative learning began with a meta-analysis to see whether a research base existed for this often-promoted pedagogical strategy. We identified a large positive effect that has caught the attention of college teachers of science and higher education administrators across the country. Since then, we have extended the work to address classroom assessments, resulting in an exciting new Web site where SMET faculty can access powerful alternative assessment strategies for use in their instruction (*www.wcer.wisc.edu/nise/CL1*). Current work is analyzing the impact of technology on student learning in undergraduate SMET education. Our research on undergraduate education and the resulting Web-based tools have been key to NISE's successful involvement of scientists.

As the above examples demonstrate, NISE is committed to research that steps back from the field and takes a big-picture view, pulling together what is known in new ways, sometimes leading to reconceptualizations, and always pointing to promising directions for practice and for future research.

The NISE is equally committed to making its work influential. An unusually large percentage of resources is invested in connecting NISE's work with its target audiences. One especially effective mechanism is the NISE forums. Under Senta Raizen and Ted Britton's leadership, the NISE offered its first annual forum in its initial year of funding. The format was to select a rapidly developing area of NISE work, convene 300 or so leading practitioners and researchers in that area, and engage them in dialogue that results in a written statement capturing the current wisdom of the field. These invitational forums proved so successful that others, including NSF, increasingly looked to NISE to conduct forums on topics they identified or to advise them on how to run similar events of their own. The forum strategy is now widely available through a Corwin Press book, *Designing Successful Meetings and Conferences in Education: Planning, Implementing, and Evaluating* (2000).

NISE has proven effective in producing highly visible and influential work. In five short years, NISE (a) built working partnerships with states, districts, scientific and education organizations, federal agencies, and foundations; (b) completed eight books; (c) published over 100 journal articles, research monographs, and briefs (including two articles in the most recent issue of the premier research journal in education, the *Review of Educational Research*, and a special issue of *Teachers College Record*); (d) produced eleven Web sites including the award-winning *The Why Files* (see *http://whyfiles.news.wisc.edu/*), which gives the science behind the news, now institutionalized in the UW–Madison Graduate School budget; and (e) conducted five innovative and highly successful forums (and two additional national meetings at the request of NSF).

Strategies

What accounts for NISE's tremendous success, despite enormous challenges? During the course of five years of work, the following strategies have proven especially successful for the NISE.

Getting the Best People

Typically, education research centers place unnecessary boundaries around where they look for scholars to involve in the work. An early decision to commit NISE to interdisciplinary work has paid enormous dividends. NISE researchers come from the sciences, including mathematics; the social sciences; and education. Of the 95 individuals associated with the NISE leadership, 42 percent came from education, 33 percent from SMET fields, and 15 percent from social sciences.

NISE's aggressive commitment to the strategy of interdisciplinary work can be seen in the following examples. When we created *The Why Files*, we went to the director of the University's Office of News and Public Affairs, Susan Trebach, to lead that effort. When we saw the need for research on how individuals learn via the Web, we went to Sharon Dunwoody, professor of journalism. When we needed policy research on systemic reform, we went to William Clune, professor of law. When we sought to launch efforts to reform undergraduate SMET education, we went to Arthur Ellis, professor of chemistry. When we sought formative evaluation, we went to anthropologist Susan Millar.

Neither has NISE limited itself geographically to the boundaries of the University of Wisconsin-Madison. When we launched our program of research on professional development, we went to Susan Loucks-Horsley, who was splitting her time between WestEd in Tucson, Arizona, and the National Research Council in Washington, DC. For leadership of our efforts in communication and dissemination, we went to Senta Raizen, forming a partnership with her National Center for Improving Science Education in Washington, DC.

At the suggestion of EHR/NSF, we vigorously initiated a robust program of research fellows. Over the course of five years, 43 fellows joined NISE teams through varying arrangements and for varying periods of time. The fellows mechanism allowed the NISE to recruit the most capable scholars and practitioners in the areas on which NISE was focusing its efforts. Junior and senior scholars, practitioners, and members of the private sector have enhanced the quality of discourse and maximized the impact of NISE work. At the same time, NISE has provided opportunity and visibility to promising young scholars.

Leadership

Leadership is a key ingredient to the success of any organization, and NISE is no exception. Codirectors and associate directors have been used to provide complementary perspectives at the top leadership level. From day one, there has been parity between scientists and educators in NISE leadership. Initially, Denice Denton, an engineer, and Andy Porter, an education psychologist, were codirectors. In the fifth year, Porter, as director, was joined by associate directors Robert Mathieu, an astronomer, and Barrett Caldwell, an engineer. In the intervening years, Terrence Millar, a mathematician, served as codirector. The stability provided by Porter and project manager Paula White, and the new perspectives and new ideas contributed through changes from Denton to Millar to Mathieu and Caldwell, served to keep the NISE on course, with continuing renewal of ideas.

The most powerful leadership for the NISE comes from the Team Leaders Team. NISE early on was organized into research teams, one for each area of work. Each team is led by a senior scholar who makes NISE work a top priority. These leaders convene as the Team Leaders Team on a monthly basis. All evaluations of past progress and analyses to determine new directions are conducted by the Team Leaders Team. Rich substantive discussions of each team's work at the team leaders' table provide opportunities to learn from each other and to think about the work at the Institute level.

Self-Evaluation

NISE made a major investment in formative evaluation, led by Susan Millar, an anthropologist. The work of Millar and her team proved extremely valuable to the strength and well being of the Institute in its early years. In the first year, the formative evaluation identified some teams that were not functioning as well as expected, due to team leaders not having sufficient time assigned to the activity. At the beginning of year 2, time assignments were increased, and in one case a team leader was replaced. The result was dramatic improvements in productivity. Early problems in patterns of communication were detected and addressed.

The NISE used two advisory boards as mechanisms for critical review, sometimes leading to redirection of efforts. A 17-person National Advisory Board consisted of a rich and balanced mix of scientists, education researchers, education practitioners, and representatives from business, industry, government, and foundations (see listing of membership in Appendix A). The National Advisory Board met each fall in years 2-5; each meeting focused on assessment of a specific aspect of NISE work.

National Advisory Board meetings are expensive, with members coming from across the nation. NISE created an advisory team, essentially a local advisory board, comprised primarily of individuals in the Madison area, most of whom were professors at the University of Wisconsin-Madison. This group proved to be especially useful in reviewing the quality and quantity of each team's productivity and in reviewing the Institute's draft plans for new areas of work to pursue. The local advisory board, which met quarterly, required no travel costs, and all members volunteered their time.

EHR/NSF made a third-year review part of the initial cooperative agreement. This, too, proved to be a valuable tool for criticism and reflection. In preparation for NSF's third-year review, NISE used both its national and local advisory boards to review the productivity of each team and to help the NISE develop plans for where the work should go in the final two years. The investment in formative evaluation was decreased; the work on interdisciplinary problem solving was completed; and work on undergraduate teacher education was begun. The third-year review also led to combining the systemic policy and systemic evaluation teams into one integrated effort. For its part, the NSF completed both a site visit and a reverse site visit for the third-year review.

Additional Funding

EHR/NSF set the budget for NISE at $2 million per year for each of five years. The plan for level funding proved to be a mixed blessing. Any productive institute needs progressively more financial support as it becomes established and matures. Level funding, in that sense, inhibits effective progress. Recognizing that level funding would soon become a problem, NISE leadership put in place three strategies.

First, NISE attempted to manage its NSF funding, spending less in the early years so that, through

carryover, more funds would be available in the later years. This was an error in judgment as NSF did not permit carryover from year 4 to year 5 of the Institute. NISE's second strategy was more successful, moving activities off its budget and onto the budgets of other organizations where ongoing activity could be sustained. One successful implementation of this strategy was *The Why Files*. In year 3, the Graduate School at the UW–Madison took over the effort; the Graduate School will continue *The Why Files* for the indefinite future. Another successful implementation of this strategy concerns the Web sites to support reform of undergraduate SMET education. In particular, the Web site supporting the improvement of classroom assessment has been spun off with continued NSF support to the University of New Mexico, under the leadership of NISE Fellow Michael Zeilik.

Yet a third strategy NISE used to deal with level funding was to secure additional support from other sources. For example, in year 5, in addition to the $2 million from EHR/NSF, NISE received $2 million from a variety of other sources. Not only has this strategy been especially effective in solving the level-funding problem, but it positioned the NISE for continuing beyond its fifth year, even though EHR/NSF decided not to extend institute-level funding through the mechanism of a recompetition.

As an institute, NISE has evolved a unique and productive approach to pursuing work. We collaborate in interdisciplinary teams with a rich mix of scientists, education researchers, and educational practitioners. We employ a vigorous fellows program to bring a diverse group of both junior and senior scholars, from across the nation and around the world, to join our interdisciplinary teams and to give our work a national base. We see the interplay among research, development, and practice as multidirectional and interactive; each is dependent upon insights and knowledge from the other two. Our commitment to improving student learning in real settings has brought us to a strategy of producing useful and effective tools to place in the hands of practitioners; the World Wide Web has been an especially effective medium in that regard. We make a large and intense investment in dissemination, using multiple and complementary strategies. Our innovative approaches to dissemination include Web-based tools, special relationships with collaborating professional organizations, and our unique annual forums, together with more traditional approaches of books, journal articles, research monographs, occasional papers, and workshop series. We produce timely, widely circulated briefs on pressing topics.

Making the Institute work requires a powerful and robust infrastructure. Over the course of the last five years, our management structure has developed into an efficient and effective force for keeping work on time and of the highest quality—and for producing a multitude of products. We have evolved into a productive and unique community of scholars, with ongoing cross-fertilization among teams and with our target audiences. This community of scholarship serves as a hotbed for identifying new initiatives and ideas. The Institute seeks to continually reinvent itself by (a) spinning off successful developed products so that they can take on a life of their own through other support, (b) bringing to a close lines of work that have fulfilled their intentions, and (c) initiating new lines that hold greatest promise for accomplishing our mission.

Challenges

The NISE overcame a number of serious challenges during its initial five years. Being the first center-level activity of the EHR and funded through a cooperative agreement,

NISE had to negotiate with EHR the procedures for working together. Initially, all of the EHR divisions contributed to NISE funding. Understandably, each wanted to have a say in what work the NISE would undertake. Coming to agreement about what work would be done in a timely fashion proved to be challenging. Even after EHR funding was consolidated in the Research, Evaluation, and Communication Division (REC), frequent changes in leadership at REC made building a functional relationship difficult.

Two strengths developed over time in the relationships of NISE to NSF. First, we had the same project officer throughout the five-year period, Larry Suter. A knowledgeable education researcher himself, and an effective, dedicated federal official, Suter sustained a positive, useful relationship with NISE. He understood the importance of NISE work and became an advocate for the Institute at the EHR leadership table. Second, NISE developed excellent working relationships with other divisions within EHR. For example, the College Level One Team, reforming undergraduate SMET education, worked closely and productively with the Division of Undergraduate Education. The Professional Development Team worked closely and productively with the Division of Elementary, Secondary, and Informal Education. Finally, because of the quality of NISE work, because of NISE's increasing visibility in the field, and because of NISE's good relationships with the other divisions within EHR, NISE established a positive relationship with then EHR Director Luther Williams.

The final challenge to NISE was EHR's decision not to recompete the Institute for an additional five years of funding. A center is a difficult and complicated organization to create and bring to productivity. Five years of support is simply too short a period for such a fragile but valuable capacity. An additional five years would definitely have been a wise decision on EHR's part and would have resulted in maximum utilization of the initial five-year investment. Even without NSF institutional support, the NISE has decided to continue as an institute. At this point, it is too early to tell whether we will be successful, although funding for at least one additional year is in hand at this writing.

Systemic Reform: Policy and Evaluation

The objective of the Systemic Reform Team, codirected by William Clune and Norman Webb, is to make a significant contribution to the study of systemic reform, including how knowledge about it can be strengthened in the future. The present combined team was formed by consolidating the efforts of two previously independent research teams, Policy Analysis of Systemic Reform (PASR) and Strategies for Evaluating Systemic Reform (SESR), and has produced a new body of integrated research. Through the work of team members, outside experts, conferences, forums, and fellows, we have generated a knowledge base that has been presented in joint activities and research papers and will soon culminate in production of two books, one on the theory of systemic reform and the other on the challenges to evaluating systemic reform in mathematics and science. We have successfully built on our core NSF work to obtain outside funding for studying systemic reform and building district capacity in the Milwaukee Public Schools (funded by the Joyce Foundation, the Helen Bader Foundation, and the Spencer Foundation) and for studying the impact of the Statewide Systemic Initiatives (funded by the National Science Foundation). These projects complement the research we have done with core NSF support by creating a synergy between confronting and solving very practical challenges while also being reflective and theory-driven in analyzing systemic reform as a strategy for large-scale change.

Policy Analysis of Systemic Reform

I. Policy Team Mission

The Policy Analysis of Systemic Reform component of the Systemic Reform Team seeks to generate useful knowledge about implementing and improving the effectiveness of systemic reform in mathematics and science education. The Policy Team focuses on meta-analyses and syntheses of existing knowledge about systemic reform in SMET education, including research, evaluation, and the wisdom of the practitioner.

II. Accomplishments

Convening of Scholars and Practitioners

The early research conducted by the Policy Team culminated in a "summer seminar" held July 25-26, 1996, in Madison, attended by a broad group of reformers, policy analysts, evaluators, and experts in the content standards and their subject matters. William Clune (1999) wrote a research monograph synthesizing the problems identified as central in the seminar and suggesting how the future research agenda could be shaped to deliver the most useful knowledge about reform. Clune's monograph deals with two general issues: (1) how to think about systemic reform as an effort to produce substantial gains in student achievement; (2) how to design the research to produce knowledge that is useful in improving systemic reform in mathematics and science education. Michael Knapp (1997) wrote a research monograph on the implementation of systemic reform; Michael Kirst and Robin Bird (1997) on the politics of standards; and several authors (policy analysts, mathematicians and scientists) wrote papers on the national standards themselves

(Clune, Haimo, Roitman, Romberg, Wright, & Wright, 1997). The set of papers on the national standards resulted in a special issue of *Teachers College Record* (1998, Fall). Senta Raizen (1997) prepared an NISE Occasional Paper on standards for science education that provides the current rationale and historical background for science standards, discusses the various meanings and interpretations associated with the standards, and addresses the current status of science curriculum frameworks including commonalities and variations among them. In addition, the NISE Occasional Paper prepared by Michael Kirst, Robin Bird, and Senta Raizen (1997) uses historical and recent concerns about mathematics and science content standards to demonstrate conflict and tensions that surround the process of setting standards. While subject matter specialists are an important component of any resolution, this Occasional Paper stresses the multiple perspectives that must be considered.

Four "systemic seminars" were convened in Madison for the purpose of gathering more information relevant to the research agenda from written research and discussion with NISE and NSF personnel. The systemic seminars brought together small groups of reformers, scholars, and evaluators with in-depth knowledge of reform. The small groups, which included people from Statewide and Urban Systemic Initiatives (SSIs and USIs) as well as the NSF evaluation personnel, addressed such issues as the proper criteria for evaluation and what works and does not work in systemic reform. This phase of developing the research agenda yielded a new set of refined links between process and outcomes in systemic reform that guided further research.

The theme of the 1997 NISE Forum was "Research on Systemic Reform: What Have We Learned? What Do We Need to Know?" The goal of the Forum was to generate and share knowledge of systemic reform, including the role of curriculum, the role of teaching and learning, and the role of evaluation. To reach this goal, panelists from around the nation shared their expertise in these various areas with participants, who themselves brought varied expertise to structured conversations and networking sessions. The Forum resulted in a set of papers identifying important issues and a synthesis paper of the think pieces that the participants submitted around the central issues (Clune, Millar, Raizen, Webb, Bowcock, Britton, Gunter, & Mesquita, 1997).

Development of a Theory of Systemic Reform

The Policy Team conducted a telephone survey of the staff of all SSIs funded by NSF. An interview protocol on the history of each initiative and lessons learned for policy was developed, and 48 telephone interviews were conducted (involving 22 states, 21 principal investigators, 22 program directors, and 5 others). Documents from each state were collected (for example, proposals, annual reports, program evaluation reviews). Based on the interviews and documents, summaries of individual SSIs were prepared. Analysis of these summaries was included in a symposium conducted by the Policy Team at the 1999 annual meeting of the American Educational Research Association. Comprehensive analysis will be included in the book on the theory of systemic reform.

Members of the Policy Team met regularly to discuss the results of the survey and develop a theory of systemic reform that could be tested by the accumulating data. Initial formulations of the theory and examples of how it might be used to guide analysis of data on SSIs were presented at an NISE Brown Bag Lecture. The theory that emerged from these activities has provided the framework for a book on systemic reform, *Theory and Practice of Systemic Reform of Mathematics and Science Education*. The theory presented in

the book will contribute to the knowledge of reformers, policymakers, researchers, practitioners, and educational administrators about the design, implementation, and effects of systemic reform and represents the only attempt to date to concretely specify the full range of substantive and strategic factors that drive successful systemic reform. An NISE Research Monograph is currently available on systemic reform theory (Clune, 1999).

Evaluation of Systemic Reform

I. Evaluation Team Mission

At its outset the Strategies for Evaluating Systemic Reform Team developed an overall sequence of research and development. It set a general progression for its work over the five years beginning with (1) identifying the major issues and questions about evaluation of systemic reform followed by (2) outlining specific strategies and models for evaluating systemic reform and then finally (3) putting into practice what we learned. Over the five years our work has followed this general direction and has become more focused with the joining of the evaluation and policy teams. What we did not anticipate in 1995 at the beginning of this effort was the nature or the magnitude of our current efforts to advance the study of large education systems.

In parallel and in cooperation with the Policy Team, the overall mission of the Evaluation Team is to advance knowledge on evaluating large systems. The Evaluation Team has striven to expand the existing knowledge base on systemic evaluation. We have done so by accumulating, synthesizing, and producing knowledge about systemic evaluation along with developing models for doing evaluation of large systems. Our work has drawn from the practitioners who have engaged in evaluating systemic reform; scholars who have studied change in large education systems; the insights and work of fellows; an interdisciplinary team of scientists, mathematicians, and educators; literature on systems and measuring change in education; and our own research. Our work continues into the future by applying an embedded research model to build capacity in Milwaukee Public Schools (funded by a second two-year grant from the Joyce Foundation from September 2000 through August 2002); developing models for analyzing student achievement in large education systems (funded by a one-year grant from NSF from May 2000 through April 2001); and analyzing the impact of systemic reform on states (funded by a three-year grant from NSF from January 1999 through December 2001).

II. Accomplishments

Convening an Interdisciplinary Team of Scholars and Practitioners

A working group of scholars and practitioners met over two years to launch the study of evaluation of systemic reform. This group included Christopher Anderson, professor of astronomy; Vicki Bier, professor of industrial engineering/applied mathematics; Steven Bauman, professor of mathematics; Thomas Carpenter, professor of mathematics education; Donald Chambers, former state supervisor of mathematics education; Susan Millar, anthropologist and evaluator; Senta Raizen, science educator and evaluator; Thomas Romberg, professor of mathematics education; Pat Rossman, elementary science teacher and 1994 Wisconsin Teacher of the Year; John Witte, professor of political science; and John Wright, professor of chemistry. This group met bimonthly to help identify the major issues that should be addressed in evaluating systemic reform, the questions that should be addressed by an evaluation of systemic reform, and the profound changes in student learning and important

knowledge in SMET. Members of the working group actively participated in two conferences that included discussion of papers and small working groups to identify important design features of evaluations of systemic reform. The working group was very valuable in informing the early thinking about evaluation of systemic reform. Members of the group identified knowledge necessary for success in higher education, qualities of education not necessarily assessed by standard measures of achievement, equity issues in a male-dominated field such as engineering, the difficulty in identifying prerequisite SMET knowledge in a range of higher education courses, and the importance of using value added analysis of standardized norm-referenced tests.

Networking and Conferences

Networking among evaluators of NSF's SSIs was encouraged by convening two conferences and holding other small focus meetings. Twenty-six people from across the nation attended the first conference held in Madison on January 4-5, 1996. Four papers were prepared for this conference to direct the discussion. Kathy Comfort, then of the American Association for the Advancement of Science, prepared a paper titled "Student Outcomes in Science." Jim Ridgway, University of Lancaster, England, and Hugh Burkhardt, Shell Centre of Mathematical Education, England, prepared two joint papers, one entitled "Student Outcomes in Evaluating System Change" and the other entitled "System Alignment and System Change." Andrew Jackman, Mt. Hood Community College, Oregon, wrote a paper on assessment and educational reform that raised many questions about education reform, particularly as it pertains to community colleges.

One year later, on March 13-14, 1997, over 50 people attended a conference in Madison on systemic evaluation. Attendees included SSI and USI evaluators, working group members, NSF staff, other evaluators, and other NISE staff. The conference successfully met its goals: strengthen the intellectual qualities of the research monographs and papers of the evaluation working group and its fellows, further the networking among those engaged in doing systemic evaluations, and disseminate NISE work to others. Besides hearing presentations from four evaluators of SSIs and John Witte, a UW–Madison political scientist, the participants provided feedback to NISE Fellows who were preparing papers (Bruckerhoff, Kahle, Lee, and Ridgway) and gave their thinking on designing systemic evaluations. The participants gave cogent advice on questions about outcomes, education systems, evaluation, issues related to design, and characteristics of evaluation designs. In addition to the two conferences, on two occasions SSI evaluators and other researchers were invited to a small focus meeting to discuss their work and insights. Daniel Heck and Norman Webb (2000) wrote a monograph synthesizing information learned from these conferences, meetings, and the evaluations of SSIs. NISE Fellow Ridgway contributed to advancing thinking about systemic reform by synthesizing information from a number of fields. His monograph on modeling of systems and macrosystemic change (Ridgway, 1998b) drew on the sciences, learning theory, epidemiology, and ecology to distinguish among different system models and indicate ways for building the evidence base for evaluating systemic reform.

Alignment Criteria Studies

In close cooperation with the Council of Chief State School Officers (CCSSO) and through a grant to CCSSO from the National Science Foundation, Webb completed an alignment study of state standards in mathematics and science and

the state large-scale assessments in each of four states. This analysis was based on Webb's NISE monograph on alignment (1997a). An NISE brief on alignment was published in January, 1997. At the end of June 1998, 15 reviewers attended a four-day institute in Madison and applied four alignment criteria identified in the NISE monograph. An important purpose for this institute and the analysis of the data was to refine the process for judging the alignment between standards and assessments. The coding by reviewers was tabulated and summarized. The report on each state describes the degree of alignment between standards and the corresponding assessments on the criteria of categorical congruence, depth-of-knowledge consistency, range-of-knowledge correspondence, and balance of representation (Webb, 1999c, d, e, and f).

The summary report presents the major findings and the recommendations for improving the coding and analysis process (Webb, 1999a). Based on the analyses performed, clear differences among the states were evident along with common issues faced by all. A high percentage of standards and assessments across the four states failed to achieve depth-of-knowledge consistency. In general, too many items were below the depth-of-knowledge level of the corresponding objectives for there to be alignment. One benefit found for doing an analysis using the specific criteria is that specific feedback was provided to states on what could be done to improve alignment. The criteria and the underlying structure of the analysis proved to be viable for detecting the degree of alignment and how alignment can be improved.

Based on his work on alignment through NISE and CCSSO, Webb made presentations at a number of conferences (American Educational Research Association; CCSSO Large-Scale Assessment Conference; Rand Conference on Assessment; National Center for Research on Evaluation Standards and Students Testing (CRESST); Abo Akademi University, Vasa, Finland; and the National Council of Teachers of Mathematics). He also served as a consultant, advised, or conducted training on alignment for the Department of Education (Title I), Indiana Mathematics Initiative, Achieve, Inc., and the American Association for the Advancement of Science (AAAS).

Book on Evaluation of Systemic Reform

Two NISE Fellows, Jeanne Rose Century (Education Development Center, Newton, Massachusetts) and Norma Dávila (University of Puerto Rico), and Evaluation Team staff Webb, Heck, and Osthoff have completed 13 of 19 chapters of a book, *Evaluation of Systemic Reform in Mathematics and Science*. The work on this book paralleled and interacted with work done by the Policy Team on its book, *Theory and Practice of Systemic Reform of Mathematics and Science*. The evaluation book will serve as both a practical and a theoretical guide. Systemic reform is still a theory waiting for an accumulation of evidence that will make the theory credible. The book details an approach to evaluating systemwide education reform at a state, district, or school level. Central to this approach, and the centerpiece of the book, is studying and measuring an education system's progress on the basis of nine attributes. These attributes cluster into three groups that are distinguished by how the attributes relate to systemic reform and to improving student outcomes within the system. A prospectus has been submitted to two publishers for their consideration. One publisher expressed interest, but has not issued a firm commitment.

Synthesis on Evaluation of Systemic Reform

On February 1 and 2, 1999, the Fourth Annual NISE Forum was held. This forum was devoted entirely to evaluation of systemic reform. Over 260 people attended from a wide range of organizations including professional organizations, universities, school districts, states, government agencies, corporations, and foundations. The Forum was organized into five sessions including the overview of the conference given by Porter and Webb from NISE and John Hunt from NSF; a panel on understanding evaluation of systemic reform (chaired by Bernice Anderson of NSF and including Juanita Clay Chambers [Detroit Public Schools], Daniel Heck [University of Illinois], Zoe Barley [Western Michigan University], and Iris Weiss [Horizon Research]); a panel on models and approaches to evaluation of systemic reform (chaired by Larry Suter of NSF and including Patrick Shields [Stanford Research International], Jeanne Rose Century [Education Development Center], Norma Dávila [University of Puerto Rico], and Mark St. John [Inverness Research]); and a panel on findings about systemic reform from evaluations and research (chaired by Julio Lopez-Ferrao of NSF and including Jane Butler Kahle [Miami University], Daryl Chubin [NSF], Robert Meyer [University of Wisconsin–Madison], and Clune [NISE]). After each panel, participants were divided into groups of 8 to 10 for breakout sessions of focused discussion on the topic of the proceeding panel. Ernest House (University of Colorado) and Cora Marrett (University of Massachusetts-Amherst) gave their syntheses of the conference considering the presentations and small group discussions. Marshall Smith, U.S. Department of Education, gave summary remarks. *Evaluation of Systemic Reform in Mathematics and Science: Synthesis and proceedings of the Fourth Annual NISE Forum*, includes papers from all of the presenters (Webb, 1999b).

Criteria for Evaluating Education Information Networks

Information systems are arising as an essential component of systemic reform. Reform itself and the evaluation of improvement in student achievement are greatly hampered by insufficient data, fragmented data bases, and low knowledge of how to use data to make important decisions necessary to improve student achievement. One of the key findings from our studies is that states, districts, and schools do not have data in a form that can be used to monitor progress toward systemic reform. In 1998, the Evaluation Team began a discussion group focusing on InfoNets, information networks for education systems. The multidisciplinary group included Susan Daffinrud, master's degree in both mathematics and computer science; Christopher Thorn, director of WCER technical services; Barrett Caldwell, professor of industrial engineering; Jeffery Watson, graduate student in industrial engineering; Susan Zeyher, master's degree in library science; and Jeffery Choppin, former high school teacher and graduate student in mathematics education.

We inventoried existing products and activities that are being advanced for processing and meeting the multiple functions for an education information system. On June 28-29, 1999, 18 people attended a conference to identify current electronic network systems and to help plan what role NISE should serve. Attendees included electronic system developers, a researcher in technologies, computer systems consultants, district technology staff, an educational psychologist, and NISE staff. Based on the outcome of this meeting and other discussion, we began to develop a framework that could be used to evaluate and analyze electronic information systems used in education. Thorn (2000) wrote a

paper on knowledge management for education information systems. Watson and Zeyher (2000) wrote a paper on education system information needs and systemic reform.

The Joyce Foundation made a two-year grant, August, 1999, through July, 2001, to study electronic information systems in schools in general and the trial of Quality School Portfolio in particular. We are conducting this study in six schools in Milwaukee in coordination with our study to develop analytic capacity in the district.

Dissemination of Information on Evaluation of Systemic Reform

At the American Evaluation Association annual meeting in San Diego, November 6, 1997, a panel on the role of evaluation in education systemic reform was organized by Webb based on the NISE conference held in March 1997. Panelists included Lloyd Bond (University of North Carolina, Greensboro), Zoe Barley (Western Michigan University), and Patrick Shields (SRI International). At the American Educational Research Association annual meeting in San Diego, April 16, 1998, Webb and NISE Fellows presented a symposium on evaluating systemic initiatives. NISE Fellows who presented were Ridgway, Kahle, and Lee. Joan Herman, CRESST/UCLA, was the discussant. At the American Evaluation Association annual meeting, November 7, 1998, in Chicago, members of the systemic evaluation writing team gave a session on issues in evaluating student achievement in the context of systemic reform. Presenters were Webb, Dávila, Heck, and Osthoff with Barley providing reactions. At the American Educational Research Association annual meeting, April 23, 1999, in Montreal, members of the writing team gave a session entitled *Beyond Tradition: The Realm of Systemic Educational Reform*. Members of the writing team who participated included LeMahieu, Heck, Century, Dávila, and Webb. Barley served as the discussant.

Accomplishment 8. Directorate of Education and Human Resources (NSF) Special Emphasis Panel on Evaluation.

The Special Emphasis Panel on Evaluation provided technical assistance and recommendations on the full range of activities supported under the evaluation program of the NSF Education and Human Resources Directorate (EHR).

EHR's highly visible programs needed the support of ongoing formative evaluation for their continuous improvement. In addition, many external audiences, including the United States Congress, wanted to know what EHR's programs were accomplishing in relationship to their stated purposes. The Division of Research, Evaluation, and Communication (REC) provides leadership for EHR program evaluation.

Joint Accomplishments of the Evaluation and Policy Analysis of Systemic Reform Teams

Research on Equity

A joint accomplishment of the Systemic Reform Teams is a set of papers, discussions, and a forum concerning equity in student achievement. Two research monographs were written, by William Tate (1997, mathematics) and Alberto Rodriguez (1997, science), exploring differences in student achievement on a variety of measures and data sets disaggregated by race, ethnicity, and gender. The papers showed various kinds of differences and trends across genders and ethnic groups—European, Asian, African, Latino, and other. One finding, for example, was of small differences between the genders on tests of science, but a substantial difference in favor of males on the

mathematics portion of the SAT. This mathematics/gender difference remained constant across ethnic groups, which themselves differed substantially from each other in average scores. Another finding was mixed evidence for the proposition that similar course taking will produce similar results. Such course taking narrows but does not eliminate achievement gaps and does not occur with sufficient frequency to allow comparisons for many students. Discussion of these papers was far ranging and indicated a possible need for new insights and approaches toward equity. However, the value of longitudinal data on outcomes disaggregated by ethnicity, gender, and subject matter was evident. Systemic reforms that do not collect and analyze such data are ignoring an important tool.

Jane Butler Kahle, who served as NISE Fellow on the Policy Team, prepared a research monograph (1998b) and an NISE Brief (1998a) on reaching equity in systemic reform. Both the brief and the monograph provide analysis of educational equity in science and mathematics and, using a research paradigm, build a practical model that is applicable for districts, schools, and classrooms around the country. Key indicators, applicable across many types of educational systems, are enrollment and achievement in eighth-grade mathematics, quality of the content and instruction of science and mathematics courses, narrowing of achievement gaps among subgroups of students, and changes in teaching practices to align them with the mathematics and science standards. Sharon Lynch, who also served as NISE Fellow, published a book on *Equity and Science Education Reform* (2000) in which she uses both research-based studies and classroom experiences of teachers and students to analyze the complexities of equity concerns across ethnicity, class, gender, and location. Okhee Lee prepared an NISE research monograph on equity in content standards (Lee, 1998), which resulted in a *Review of Educational Research* publication (1999).

The 2000 NISE Forum on Equity Issues in Mathematics and Science covered several important aspects of equity, including what we know about effective methods to address equity issues and what research is needed. Panelists represented a wide range of expertise in equity issues from across the nation. Discussion and networking opportunities aided the Forum in achieving its overall goal: to draw together leaders in the field and stimulate intellectually rich conversations to develop a better understanding of diversity and equity issues in mathematics and science education. In the papers, presentations, and small group sessions, participants stressed the importance of learning how to make diversity an asset rather than a problem to overcome by thinking of students as individuals, not as broad categories, by training teachers to be sensitive to equity and diversity issues, by using strong models of disseminating information, by aligning curriculum, instruction, and assessment, and by conducting cross-cultural research. A synthesis of the think pieces from the discussion sessions is available (Britton, Raizen, Kaser, & Porter, 2000).

The Study of Systemic Reform in Milwaukee Public Schools (SSR-MPS)

In April 1998, the Joyce Foundation agreed to fund this project for an initial period of two years at about $1 million per year. Additional funding for this project was obtained from the Helen Bader Foundation, Inc., of Milwaukee. A second two-year Joyce grant has been awarded.

Clune and Webb codirect this project. The ultimate goal of the research is understanding how systemic policy can fulfill its promise as a powerful method of sustaining widespread school

improvement and major gains in student achievement over the long run in the Milwaukee Public Schools (MPS). To reach that goal, the project has three principal purposes:

1. generate useful knowledge and recommendations for policy in the district;
2. allow impartial observers, funding agencies, and system managers to understand the system and its performance at a deeper level; and
3. impart analytical capacity to the district so that SSR-MPS can be phased out, or assume a reduced role, after a period of years.

Research is being conducted in six areas: policy and governance; alignment of curriculum standards, student assessments, and classroom instruction; capacity of data systems and analytic expertise to deliver relevant information about student and system performance; school improvement; professional development; and students with exceptional educational needs.

Research is currently being conducted in the projects listed below.

- Technical assistance and quantitative analysis on *implementing the value-added system of standardized testing* currently under consideration by the School Board.

- Technical assistance and analytical research on how *individual schools* in Milwaukee can best *acquire data from the district data system*, and *analyze these and other data*, to best meet the needs of schools.

- Research on the extent to which the *middle school proficiencies* have been successful as a means of raising standards for all students, focusing professional development, and stimulating school improvement.

- Research and technical assistance on how the *proposed system of embedded classroom assessments* in high school can be optimally successful in meeting district and school goals.

This project will both build capacity in the district and produce written reports and publications for a national research audience.

Over the first 2+ years of funding, the project made great progress.

- Focused the entire project more closely on student achievement, acquired a new project liaison at a higher level in the district (Deputy Superintendent Jacqueline Patterson), and obtained a letter of endorsement for the work of the project from the new Superintendent.

- Became a regular and influential participant in advising the Department of Research and Assessment and other departments on the new system of assessment and accountability currently being designed and implemented in the district.

- Placed a team member on the district's data warehouse development team. His charge is to work on translating district-level and school-level analytical models for the Team.

- Worked with two middle schools on how to report achievement data for accountability.

- Worked with the Audit Office of the Board of Governors on how to analyze and report adequate school performance.

- Held a one-day workshop with MPS leadership and consultants from Minneapolis on assessment and accountability.

- Produced and presented the first value-added analysis of student achievement scores in MPS.

- Gained access to and/or set up on our computers longitudinal and other data on student achievement in middle schools in four subjects.

- Obtained middle school proficiency data for all students in spring 2000 and consulted on the database and reporting for these data.

The project research staff also presented a symposium at the annual American Educational Research Association meeting in April 2000. The session was entitled *Interdisciplinary Action Research on Systemic Reform in an Urban District*. The session featured the following presentations and related papers:

Embedded Research on Systemic Reform and the Design Experiment: Similarities and Dissimilarities by William H. Clune

Embedded Research in Practice: A Study of Systemic Reform in Milwaukee Public Schools by Norman L. Webb

Looking for School Improvement in Milwaukee: An Example of Embedded Research by Jennifer O'Day

Including All Students in Accountability Assessment by Jeffery P. Braden

Value-added Measures of Student Achievement by Robert Meyer

III. Staff, Fellows, and Collaborators

Staff: William Clune and Norman Webb (Team Leaders), Jeffery Braden, Janice Downer, Ron Jetty, Sarah Mason, Robert Meyer, Susan Millar, Jennifer O'Day, Eric Osthoff, Andy Porter, Senta Raizen, Alberto Rodriguez, William Tate, Christopher Thorn, Paula White, and John Wright.

Fellows: Charles Bruckerhoff, Hugh Burkhardt, Judith Burry-Stock, Jeanne Rose Century, Kathy Comfort, Norma Dávila, Andrew Jackman, Jane Butler Kahle, Okhee Lee, Paul LeMahieu, Sharon Lynch, James Ridgway, and Uri Treisman.

Collaborators: Christopher Anderson, Steven Bauman, Vicki Bier, Thomas Carpenter, Donald Chambers, Deborah Tepper Haimo, Michael Kirst, Michael Knapp, Judy Roitman, Tom Romberg, Pat Rossman, Richard Rossmiller, Bassam Shakhashiri, and John Witte.

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College Level One

I. Team Mission

The objective of the NISE College Level One (CL-1) Team is to enhance the quality of introductory postsecondary SMET courses, reflecting their role as curriculum "pressure points" in shaping student career trajectories, influencing science literacy, and promoting equity. The National Science Foundation (NSF) published the report *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* that summarized practices and innovative approaches for teaching postsecondary SMET courses and provided recommendations that could lead to improved outcomes in these courses. The *Shaping the Future* report helped the CL-1 Team align its program with NSF and stakeholder aspirations for CL-1 SMET courses. Our efforts focused on conducting research that identifies and validates effective practices in these courses and on disseminating this information to key stakeholder audiences. We identified and validated practices for dissemination through annual CL-1 Institutes. Each CL-1 Institute focused on a topic of critical importance to college SMET instruction to bridge the large gulf between the knowledge resulting from education research and the knowledge base and practice of college SMET instructors. The topical expertise was generated by a select group of NISE Fellows, representing both SMET instructors and education researchers; the CL-1 Team provided the ongoing infrastructure. Major themes addressed by the CL-1 Institutes were cooperative learning, classroom assessment of student learning, and the appropriate use of technology in student learning. Each CL-1 Institute synthesized what is known in higher education SMET research, prepared products based on this synthesis, including Web sites (all available at *http://www.wcer.wisc.edu/nise/cl1*), and disseminated these products to the college SMET instructional community. The ultimate goal of the CL-1 Team has been to develop a comprehensive, integrated Web-based resource of effective teaching practices. The CL-1 Innovations in SMET Education Web site provides a launch pad for reform-ready instructors, a support base for campus and national professional development centers and workshop providers, and a reference site for the education and research directorates of the National Science Foundation.

II. Accomplishments

Institute on Collaborative Learning

In consultation with colleagues at the National Science Foundation, the CL-1 team investigated the scholarly basis for the use of cooperative learning in introductory college SMET courses. A meta-analysis convincingly demonstrated that using small group learning methods in SMET courses, rather than traditional methods, produce significant gains in student achievement, persistence, and attitude. The effect size of 0.5 that was found is highly significant. This study, "Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering and Technology: A Meta-Analysis," was published in *Review of Educational Research* (Springer, Stanne, & Donovan, 1999) and represented the first such analysis spanning SMET disciplines and the spectrum of postsecondary institutions. A summary article of this research for chemistry audiences was published in the *Journal of Chemical Education* (Bowen, 2000).

Given the importance of the findings from the meta-analysis, the CL-1 Team implemented an aggressive strategy for bringing collaborative

learning methods to the attention of college SMET instructors, advisors, and administrators through the development of a Web site. The heart of the Collaborative Learning Web site, developed under the leadership of Anthony Jacob and Ann Burgess, is an instructor-friendly tutorial on collaborative learning techniques. In addition, the site provides personal stories and advice from SMET instructors who have adopted this pedagogical approach; the research foundation for collaborative learning (including the meta-analysis report); an annotated bibliography on collaborative learning that is available through NISE; a perspective article in *Journal of College Science Teaching*, "Small-Group Instruction in Science, Mathematics, Engineering and Technology: A Discipline Status Report and a Teaching Agenda for the Future" (Cooper & Robinson, 1998); and a compilation of frequently asked questions. Constructive suggestions that improved the site were obtained from the Communicating with Mass Audiences (CMA) Team and from national experts who attended a workshop hosted by CL-1. To advertise the Web site, Kate Fahl developed a brochure that has been distributed to thousands of college SMET instructors and administrators through disciplinary professional meetings and collaborations with organizations such as Project Kaleidoscope.

Institute on Assessment of Student Learning

As college SMET instructors begin to experiment with new forms of pedagogy and content, the question inevitably arises about whether their students are learning more as the changes are implemented. A CL-1 Institute was developed to explore issues associated with the classroom assessment of student learning. An NISE Forum and a book developed by an NISE Fellow helped to launch this effort, which resulted in the development of a Web site, the Field-tested Learning Assessment Guide (FLAG).

The theme of the 1998 NISE Forum was "Indicators of Success in Postsecondary SMET Education: Shapes of the Future." The Forum engaged a broad cross-section of college SMET stakeholders in a dialog regarding the importance of assessment. A proceedings volume was prepared by Susan Millar and is available from NISE. As background scholarship for the Institute's work, a book on assessment research, *Assessing Science Understanding. A Human Constructivist View*, was co-edited by NISE Fellow Joel Mintzes and published by Academic Press. The volume presents critical analyses from national experts on various assessment tools.

Part of the vision underpinning the Institute on Assessment of Student Learning was that the Institute's products would help reform-ready practitioners to think of assessment beyond the traditional awarding of grades. Many methods of assessment—including portfolios, concept maps, and interviews—are being introduced into college SMET courses to better characterize student learning. A practitioner-oriented resource developed by the Institute is the Field-tested Learning Assessment Guide (FLAG) Web site, which can be accessed through the above URL. The content of the site comprises a primer that provides a rationale for integrating assessment with college SMET courses and introduces common terms associated with assessment; a facilitator that helps college SMET instructors identify appropriate goals and align them with assessment methods; and a collection of so-called Classroom Assessment Techniques, or CATs, and associated tools. The CATs were commissioned from nationally recognized leaders in the assessment of student learning and include contributions from the NSF-funded Math Assessment Resource Service (MARS) project. All contributions were vetted through an Editorial Board drawn from national experts. Like the

Collaborative Learning Web site, the FLAG Web site was created to serve as a core resource for the CL-1 SMET instructional community. Through a successor NSF grant to former NISE Fellow Michael Zeilik, one of the original developers of the Web site, the FLAG will continue to be updated and expanded, as befits a moving target like assessment. The NISE Formative Evaluation Team's initial evaluation of the FLAG site indicates that it is meeting its objectives of serving the college SMET instructional community as a central assessment resource. As was done for the cooperative learning project, an aggressive dissemination effort was implemented, including preparation of a widely distributed brochure and presentations at high-profile conferences, including meetings of the American Educational Research Association (AERA) meeting and the American Association of Higher Education (AAHE).

Institute on Learning Technology

The introduction of technology into college SMET courses is changing the landscape associated with these courses. New technologies include computers, sensors, and multimedia presentation tools. Collectively, such technologies are reshaping college SMET education by providing opportunities for distance learning, access to enormous databases, and remote use of state-of-the-art instrumentation, to cite just a few examples. The CL-1 Institute on Teaching with Technology was established to explore the impact of technology and to help college SMET instructors identify appropriate uses of technology. A Technology Education workshop served as a springboard for this effort, and the Institute has developed a Web site that is intended to serve as a resource for the college SMET teaching community.

A three-day workshop was held at NSF headquarters during the summer of 1999. The workshop brought together leading scholars in education and cognitive research and college instructors who are pioneers in the use of technology in SMET at the college level. The workshop report (TechEd 99; http://www.wcer.wisc.edu/teched99/) resulting from this meeting identified key technical, pedagogical, political and economic issues associated with the introduction of technology.

With support from the NSF CISE Directorate's National Partnership for Advanced Computing Infrastructure (NPACI), the 1999-00 CL-1 Institute on Learning Technology studied how SMET faculty are successfully using new technologies in their classrooms and laboratories. Under the leadership of NISE Fellow Susan Millar, the CL-1 Institute was to provide college SMET instructors with better resources for understanding why and how they should use technology-enhanced learning strategies. The Team (a) conducted ten case studies of exemplary technology use in a variety of SMET disciplines and higher education environments; (b) developed a set of twenty "vignettes," illustrating a range of technology-enhanced practices in disciplines and types of institutions not represented in the case studies; and (c) gathered from a diverse sample of 200 SMET faculty responses to frequently asked questions about the use of technology in college SMET courses. Analysis of all these materials revealed key factors for successful innovation and adaptation of technology in support of student learning. A comprehensive taxonomy of learning technologies that informs the case study analysis and helps shape future research in learning technology was also developed. The materials resulting from these studies have been incorporated into another CL-1 Web site. In addition, the findings will be developed into workshop materials for distribution by professional organizations.

III. Staff and Collaborators

Staff: Arthur B. Ellis (Team Leader), Robert D. Mathieu (Director, CL-1 Institute), Briana Bright, Gina Brissenden, Aaron Brower, Ann Burgess, Susan Daffinrud, Samuel Donovan, Jack Husted, Anthony Jacob, Kate Loftus Fahl, Walter Secada, and Leonard Springer.

Fellows: Jean-Pierre Bayard, Lia Brillhart, Craig Bowen, Steve Ehrmann, John Jungck, Eileen Lewis, Flora McMartin, Joel Mintzes, Marco Molinaro, Elaine Seymour, Sheila Tobias, and Michael Zeilik.

Collaborators: Clifford Adelman, James Cooper, Patricia Cross, Douglas Duncan, Roscoe Giles, Mary Kennedy, Louise Liao, Catherine Middlecamp, Susan Millar, Terrence Millar, John Moore, Greg Moses, Jeanne Narum, James Ridgway, Pamela Robinson, Gloria Rogers, Karl Smith, and Mary Beth Stanne.

Products

Collaborative Learning Web site: *http://www.wcer.wisc.edu/nise/cl1/CL/default.asp*

College Level One Web site: *http://www.wcer.wisc.edu/nise/CL1*

Field-tested Learning Assessment Guide (FLAG) Web site: *http://www.wcer.wisc.edu/nise/cl1/flag/default.asp*

Learning Through Technology Web site: *http://www.wcer.wisc.edu/nise/cl1/ilt/default.asp*

Student Assessment of their Learning Gains (SALG) Web site: *http://www.wcer.wisc.edu/salgains/instructor/*

Collaborative Learning brochure (available through NISE central office)

Field-tested Learning Assessment Guide brochure (available through NISE central office)

Learning Through Technology brochure (available through NISE central office)

Student Assessment of their Learning Gains brochure (available through NISE central office)

NISE Publications of the College Level One Team

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NISE-Related Publications of the College Level One Team

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Professional Development

I. Team Mission

The NISE Professional Development Team dedicated itself to identifying what constitutes effective professional development for science and mathematics teachers and spreading that knowledge to education leaders working to improve science and mathematics teaching in K-12 classrooms. Through its five-year program of work the Team has had a significant impact on the professional development practices in many reform initiatives, school districts, and state departments of education. It has helped staff developers throughout the nation to think more critically about their own practices.

The questions that drove the Team's work were:

- What is currently known about science and mathematics, learning, teaching, professional development, and the change process that can improve the design and effectiveness of learning opportunities for teachers?
- How should the specific goals of professional development for a particular set of teachers and the context in which teacher learning opportunities are being planned influence the design of professional development?
- What alternative strategies and approaches to professional learning exist, how are they used, and how effective are they in assisting teachers to learn what they need to know to effect student learning of science and mathematics?
- What practices help to bridge the gap between preservice education and teacher professional development?
- What skills and knowledge do professional developers need in order to provide high quality learning experiences for teachers?

II. Accomplishments

The Team's accomplishments in addressing each of the seven goals are outlined below.

Goal 1: To document the characteristics of effective professional development for science and mathematics teachers and develop a framework to guide the redesign of professional learning opportunities for teachers.

- Developed and disseminated NISE Brief, *Principles of Effective Professional Development for Mathematics and Science Education* (Loucks-Horsley et al.), a synthesis of the professional development standards produced by the National Council of Teachers of Mathematics (NCTM), the National Research Council (NRC), the National Staff Development Council (NSDC), and the National Center for Improving Science Education.

- Created the Professional Development Design Framework. In collaboration with NISE fellows Hubert Dyasi, Susan Friel, Judy Mumme, Cary Sneider, and Karen Worth and advisors Josefina Arce, Joan Ferrini-Mundy, Deborah Schifter, Vernon Sells, Mark St. John, and Iris Weiss, the Team developed and documented the process through which effective professional development is designed. The goal of developing a framework for the design of professional learning opportunities for K-12 inservice science and mathematics teachers evolved during the first year as a direct result of work with the NISE fellows. The intent was to capture the learning of current professional development efforts to increase the knowledge base from both "craft wisdom" and disciplined inquiry and make that information accessible to practitioners and

researchers alike. At team meetings, professional developers shared their work by describing how they had developed their programs and by explaining the critical decisions they had made that contributed to the particular forms their programs had taken. The outcome of these deliberations was a consensus that effective professional development practice could best be characterized by means of a Design Framework. The decisions that are made in designing professional learning opportunities for science and mathematics teachers are the product of a cyclical design process that is informed and influenced by various inputs. The Team identified the inputs to professional development design that must be considered, including (1) contextual factors such as existing policies, teacher knowledge and skills, curriculum, student achievement levels; (2) the knowledge base on teaching, learning, the nature of science and mathematics, professional development, and the change process; (3) critical issues such as how the project will reach scale, how it will develop professional culture, address equity, and evaluate its results; and (4) the professional learning strategy or combination of strategies (e.g., coaching, study groups, workshops) that will best address the professional development needs and purpose.

- Wrote and disseminated a book on the Professional Development Design Framework. The Team summarized findings and recommendations in the book *Designing Effective Professional Development for Teachers of Science and Mathematics*, published by Corwin Press in 1998. Over 11,000 copies have been sold. Each of the key sections of the framework is elaborated with illustrations and vignettes, often drawn from the work of the NISE Fellows. The audiences for the book are, first, those in positions to design and conduct professional development and, second, those who fund, consume, conduct research on, evaluate, and develop policies for professional development.

- Collaborated with the Eisenhower National Clearinghouse to disseminate findings more broadly. Summarized the Design Framework and the 15 major professional development strategies in two publications—one for science educators and one for mathematics educators. Over 50,000 of these books have been disseminated throughout the nation.

Goal 2: To create a dialogue among professional developers and other education leaders for elaborating and understanding what constitutes effective professional development and for promoting the use of the NISE Design Framework and other findings.

- Engaged with leaders in professional development. The project engaged with professional development leaders around the NISE findings through annual and regional professional meetings and ongoing email communication. The Team conducted sessions at conferences of NCTM, the National Science Teachers Association (NSTA), and NSDC each year and invited participants to try out the findings and recommendations of the project and communicate with staff about their results. Many participants maintained contact through email and follow-up at other meetings. The Team also conducted learning sessions for NSF systemic initiatives and teacher enhancement projects, the Glenn Commission, WestEd's National Academy for Science and Mathematics Education Leadership, large school districts, and many regional and state service providers. Through these efforts over 3,000 leaders of professional

development became aware of the NISE Professional Development Design Framework and ideas for improving learning for science and mathematics teachers. The Professional Development Team has also interacted with preservice educators and professional developers from around the country in an ongoing dialogue about what is known about effective development of science and mathematics teachers and the critical issues that surround professional development.

- Conducted First Annual NISE Forum, 1996. The Forum's primary purposes were to (1) extend and strengthen understanding of practices and issues in professional development, with implications for design of more effective programs and initiatives in mathematics and science education, and (2) build a community of those seeking ongoing interaction around professional development practices and issues. A secondary purpose was to design a conference that modeled many of the principles of effective professional development. The Forum included a plenary presentation of the Design Framework, discussions of eight case studies of professional development in science and mathematics, and discussions of critical issues that cut across all professional development efforts, e.g., equity, leadership, scaling up.

Goal 3: To develop case examples of the NISE Professional Development Design Framework in action.

- Developed four case studies of professional development practice. The Team studied the ways in which the Design Framework and its central components are implemented in different contexts and the organizations, structures, and methods that serve to facilitate their effective implementation and dissemination. The case studies were committed to using the NISE Design Framework to analyze the results of completed efforts or plan ongoing efforts and documenting and analyzing their implementation efforts.

Edward Silver, Margaret Smith, and Mary Kay Stein wrote retrospective case studies of two sites that were part of the QUASAR Project, a multiyear project funded by the Ford Foundation (1990-1995) that focused on the teaching of mathematics in middle schools in large urban school districts. Cases examined the professional development efforts at these two sites, using the design framework as a tool for describing and analyzing the professional development decisions that were made. The case studies drew on existing data about teachers, resource partners from local universities, and the professional development experiences collected over the five years of the project. The cases detail the curricular decisions made (one site implemented a reform-oriented mathematics curriculum developed through funding from the NSF; the other site used a curriculum to be created by the teachers and unified by the concepts of ratio and proportion) and the professional development activities used to support these curricula. These cases are valuable in helping professional developers understand the importance of key factors such as the mentoring by teachers of their new colleagues while they adopted the school's innovative curriculum and relationships between teachers and resource partners from local universities.

NISE staff Susan Mundry and fellow Ned Levine wrote a case study about a staff development project funded by the NSF as a Rural Systemic Initiative project involving 42

schools in 22 school districts in southwestern Montana. The project goal was to implement new strategies in science and technology education in these schools through a variety of professional development strategies such as teacher institutes, leadership training, mentor teacher training, and direct classroom support. The case considered three schools: a small school (about 300 students), a one-room school, and a school serving predominantly Native American students. It focused on the question of the integrity of the curriculum as it was implemented across distance and in different contexts of culture and local control. The case is valuable in providing professional developers with insights into the difficulties imposed on effective professional development by distance, isolation, and cultural context.

Team member Kathy Stiles wrote a case study about science and mathematics professional development in a large urban school district that is culturally diverse. In the district, professional development in science and mathematics was designed and coordinated by six people who formed a team that worked with the district Staff Development office to ensure that district and program goals were met. For science and mathematics, curricular goals included application of science and mathematics in the real world, competence in the use of technology, and a diversification of teaching strategies. Professional development activities were designed to increase teacher skills and confidence in the use of reform-oriented teaching strategies and to facilitate interdisciplinary, thematic instruction. The case describes the history of professional development planning, implementation in the district, and the intervention of Stiles' application of the Design Framework with the Team.

- Published case study findings. The Team and collaborators conducted a cross-case analysis and identified a number of dilemmas faced by professional developers as they planned and carried out their efforts. These were described in three publications—in the *Harvard Educational Review, The High School Principal Magazine,* and the NISE *Brief.* (See product list.)

- Presented cases at 1998 AERA annual meeting

Goal 4: To investigate and document conditions and/or programs that bridge the gap between preservice and inservice education.

- Conducted a literature review and prepared a summary paper on the relationship between the preservice and inservice components of science and mathematics teachers' professional development and the principles that should guide the development of this relationship in the future.

- Convened collaborators with expertise in particular approaches to connecting pre- and inservice teacher education (e.g., in professional development schools, in novice teacher mentor and induction programs, in teacher assessment). The collaborators were chosen because they had implemented programs or approaches to bridge the preservice-inservice gap, brought different perspectives, e.g., from colleges, schools, or state education agencies, and had disciplinary backgrounds in mathematics and/or science. They wrote a detailed statement of the problem and the factors that contribute to the disconnect between preservice and inservice and generated recommendations for

developing stronger, more coherent relationships between schools and colleges.

- NISE Fellow Barbara Spector, with Susan Mundry, Katherine Stiles, and Susan Loucks-Horsley, documented initiatives and conditions that build connections between preservice and inservice education and summarized them in a compendium and report prepared as NISE Research Monograph No. 17. (See product list.)

Goal 5: To deepen understanding of three different professional development strategies, their impact in different contexts, with different teacher learning goals, and in different combinations.

- Prepared a literature review on three specific strategies for professional development—curriculum implementation, immersion in inquiry and problem solving, and case discussions—entitled "Strategies for Professional Development: What Do We Know and Still Need to Know?"

- Documented three specific professional development strategies that build pedagogical content knowledge in science and mathematics. The Team recruited NISE collaborators to investigate three strategies—curriculum implementation, immersion in inquiry and problem solving, and case discussions—more deeply. The staff, collaborators, and team fellow Cheryl Brown-Kovacic convened three times to explore the purpose and outcomes of these strategies and to demonstrate how teachers engage in them. Collaborators wrote papers that describe an intervention using the different strategies. Staff and Brown-Kovacic wrote an introduction chapter and worked closely with the collaborators to develop a coherent set of cases on the three professional development strategies.

Goal 6: To study the effects of knowledge utilization strategies to improve professional development practice.

- Established and convened a cadre of professional developers who are using the project's research to make improvements in professional learning experiences for teachers of science and mathematics. The Professional Development Team documented how the cadre uses knowledge from NISE research to make improvements in teacher learning.

- Drafted guidebook of learning activities for preparing professional developers to design and provide quality teacher learning experiences.

- Designed and conducted professional learning activities. The Professional Development team and PD cadre developed and tried out over 40 learning activities designed to increase professional developers knowledge of effective professional development and professional development design. Activities that were successful in meeting the desired outcomes are included in the guidebook draft.

III. Staff, Fellows, and Collaborators

Staff: Susan Loucks-Horsley (Team Leader), Peter Hewson, Nancy Love, Susan Mundry, Katherine Stiles, Kathy Dunne, and Mary Stenson.

Fellows: Cheryl Brown-Kovacic, Hubert Dyasi, Susan Friel, Uwe Hilgert, Ned Levine, Judith Mumme, Margaret Schwan Smith, Edward Silver, Cary Sneider, Barbara Spector, Mary Kay Stein, and Karen Worth.

Collaborators: Josefina Arce, Carne Barnett, Virginia Bastable, Cathy Carroll, Karen Cerwin, Kathy DiRanna, Mark Driscoll, Kathy Dunne, Joan Ferrini-Mundy, David Hartney, Gregg Humphrey, Barbara Miller, Jean Moon, Jan Phlegar, Lynn Rankin, Ann Rosebery, Susan Jo Russell, Deborah Schifter, Vernon Sells, Jerome Shaw, Mark St. John, Rita Starnes, Jo Topps, and Iris Weiss.

NISE Publications of the Professional Development Team

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Secondary Teacher Education Project

I. Team Mission

Reforming teacher education is a current national priority (NRC, 1996). This continuing project is about promoting standards-based reform in teacher education through Web-based instructional design. An important question addressed through our work is how to effectively build Web-based instruction that helps teachers acquire truly useful knowledge that supports them at work and in other real-world contexts. Such knowledge encompasses not only pedagogical and subject-matter concepts and skills that underlie teaching, but also the tools of lifelong, self-directed professional development.

The phrase *useful knowledge* emphasizes an ambitious goal for knowledge transfer, that knowledge acquired in one context (e.g., school, Web sites) be recalled and used in another context (e.g., the workplace). Knowledge transfer has been an elusive goal for education; researchers, instructional developers, and knowledgeable educators eagerly seek ways to obtain it. Studies by cognitive psychologists and anthropologists have repeatedly shown that nontrivial knowledge transfer is difficult to achieve (e.g., Salomon & Perkins, 1989).

The premise is that high level transfer of professional knowledge and skills, including the skills of reflective practice and lifelong learning, can be attained through Web-based instructional design. By Web-based instructional design we refer to both design of Web environments and their communication tools, and the social structures of their use. Little is known about how to engineer effective instructional Web environments. This work will lead to general design solutions and principles that may apply to many professional fields involving application of complex domain knowledge to real-world practice (e.g., medical education).

II. Accomplishments

Development of STEP Web Prototype

Our work involved design and implementation of the STEP Web (*http://www.wcer.wisc.edu/step*), a learning environment on the World Wide Web for supporting scientific instruction for teacher education. The phrase *scientific instruction* refers to both the design of the Web site and its subject matter content; both are based on current principles of learning and development drawn from cognitive psychology and other learning sciences. STEP Web and its associated instructional approaches were tried and evaluated in teacher education programs at UW-Madison and Rutgers University in the 1999–2000 spring semester. The field trials were successful; an upgraded version of STEP Web is currently being used and evaluated in the UW-Madison teacher education program. In the following we describe the STEP site, the theoretical rationale for its design, and its use in teacher education. We then summarize the results of our field trials and other research.

The STEP Web goals are to help future teachers acquire pedagogically relevant structural knowledge about the disciplinary concepts they are teaching; scientific knowledge about how students learn and develop within disciplines; and the ability to combine, adapt, and apply this knowledge base to analyze and improve teaching and learning.

A theory about how to design instruction that will insure transfer of learning to professional life is Cognitive Flexibility Theory (CFT; e.g., Spiro, Feltovich, Jacobson, & Coulson, 1991).

Appropriate domains for the application of CFT include professional-level education, such as medical and teacher education. A central argument of CFT is that many instructional approaches fail because they represent complex subject matter in an unrealistically simplified and well-structured manner. The most common kind of failure observed is reductive bias—the tendency to oversimplify approaches and solutions to complex problems. The remedy for learning deficiencies related to domain complexity requires instructional designs that afford greater cognitive flexibility.

> This includes the ability to represent knowledge from different conceptual and case perspectives and then, when knowledge must later be used, the ability to construct from those different conceptual and case representations a knowledge ensemble tailored to the needs of the understanding or problem-solving situation at hand. (Spiro et al., 1991, p. 24)

A decade ago the developers of CFT suggested that instruction with multidimensional, nonlinear hypertext systems has the power to convey knowledge complexity and promote features of cognitive flexibility. Today this observation applies to site design on the World Wide Web. A CFT approach to instructional Web design proceeds as follows: (1) A problem-solving domain is defined (such as application of subject-matter knowledge and scientific learning principles to teaching); (2) a library of cases representing real-world problems and solutions is constructed (such as video-based stories about actual classroom lessons); (3) a library of resources for understanding and analyzing the cases is developed (such as Web pages about learning theories and educational research); and (4) a system of connections is created to permit navigation through the Knowledge Web (such as Web links among video cases and case-relevant learning research and theories). The resulting Knowledge Web represents a realistically complicated, nonlinear network of conceptually complex relationships among cases and ideas within a domain.

Accordingly, STEP Web is a highly interconnected network of pages that interlink the following types of resources in a conceptually meaningful manner:

- cases—stories of student learning and development resulting from lessons in actual classrooms—that include edited video of the classroom plus additional materials that supply information about context
- instructional problems and projects that make use of cases and are designed to promote in-depth analysis for development of knowledge about how to support student learning
- a network of case-related links to Web pages and other resources discussing core concepts from cognitive psychology and other learning sciences that teachers need to know
- access to expert case analyses
- links to online discussions and human expertise
- links to additional tools and resources that teachers can use to help them adapt and implement ideas acquired from study of cases

Implementation and Evaluation of STEP Web

In the 2000 spring semester, 55 teacher education students were assigned to small groups of 5–7 students that studied together within a Problem Based Learning (PBL) format. During the semester, each student participated in two different PBL groups. Each group was assigned a

problem and a case to study. For example, a case assigned to a group of science majors was "Students Get a Charge out of Static Electricity." This case, presented on STEP Web as readings, videos, and inquiry materials, tells the story of an actual science unit in a public school taught by a popular teacher and representing a good case of traditional instruction. The problem was to redesign the unit and justify that redesign in psychological terms.

The work of the students was guided in class by a tutor—a TA who received training in guiding PBL. After studying the case individually on STEP Web, students began their group work in class by discussing the case and identifying learning issues—things they needed to learn more about to solve the redesign problem. Between classes, students researched their learning issues, bringing findings to their group discussions. STEP Web was made available as an optional research tool that could be used outside of class. The links and navigational tools in STEP Web guided students' research; by exploring paths from links, students were able to obtain information about case-relevant concepts and other resources and pursue them to a desired depth. Research beyond the materials in STEP Web was also promoted, since links led to other library and Web resources. Some students also purchased and used optional textbooks.

The problem required about four weeks to complete. A tutor guided students through class discussions of their research, during which time they identified positive and negative aspects of the instruction within the case and proposed new instructional solutions. In the third week they posted their redesign with explanations on a Web conference site for peer evaluation and consultation with experts, including scientists and educational experts. After revision, a group report was submitted as a course requirement.

The STEP implementation at UW-Madison during the 2000 spring semester represented a process of continuous user-centered design in which students provided feedback that was used to upgrade and improve STEP Web throughout the semester. Early in the semester, intensive feedback was obtained from a small number of students who volunteered to be research subjects, but on March 7 and again on April 18, all students were surveyed to obtain their feedback and satisfaction ratings regarding the Web site.

Fifty-four of the 55 students returned surveys on March 7; 50 returned surveys on April 18. On these dates, 48 and 46 students respectively reported using the Web site as an instructional resource for their study and PBL research. Satisfaction with STEP Web as an instructional resource was 3.9 on March 7 and 4.1 on April 18, based on a rating scale of 1–5 (not very satisfied to very satisfied). Students' comments initiated a number of improvements and changes throughout the semester. For example, the addition of a search engine was based on students' requests. Students' satisfaction with STEP Web increased as the site was improved and students gained experience. For example, one student who participated in three surveys commented:

- Feb 22: "KW (Knowledge Web) - impressed me this week. . . . I did not research outside of it." (No rating requested)
- Mar 7: "I am getting better at navigating the KW." (Rating = 4)
- Apr 18: "I am starting to appreciate the Knowledge Web." (Rating = 5)

Other representative student comments:

- "When I finally figured out how to use it, it was great." (Rating = 5)

- "I like the newer KW." (Rating = 4)
- "Much improved!" (Rating = 4)
- "Some pages that could have helped weren't up." (Rating = 4)
- "They [Web pages] were quite useful, but KW needs to be more easily navigated." (Rating = 3)
- "I found the KW to be confusing in some of its explanations." (Rating = 3)

In sum, most students in the UW-Madison course were pleased with the Knowledge Web by midsemester, but their comments indicated that further development and improvement is needed. Based on students' concerns, there is need to (1) add to and improve resources on STEP Web, (2) improve navigation, and (3) provide instructional supports within the course to speed the process of learning how to use the site. We are currently working on these improvements.

STEP Web was also used at Rutgers University in a smaller course taught by an experienced PBL instructor. There it was positively rated, despite being at an early stage in its development. Based on fourteen students and a scale of 1–5 (not very satisfied to very satisfied), the Web site was rated 4.6. The textbook used in the course, a best-selling educational psychology text, was rated 4.5.

The evaluation study at UW-Madison produced statistical evidence of significant growth in students' ability and propensity to activate and combine concepts from the learning sciences in the analysis of videotaped lessons. In addition, a microgenetic analysis of a single PBL group, composed of science education majors, demonstrated that discussions of cases provided opportunity for learners to socially construct meanings, share knowledge, negotiate conflicts, and integrate ideas from other teacher education courses and experiences. Significant shifts in individuals' conceptual understandings of student learning and development were documented. These findings suggest that the STEP instructional model as a whole is viable in terms of course goals.

Development of Video Cases for STEP

Recent work suggests that teachers improve their instruction when presented opportunities to view and discuss cases of classroom practice (e.g., Merseth, 1996; Shulman, 1992). Facilitated case discussions are deemed an especially promising method for teacher education, since preservice teachers often do not have control of classrooms in which to try out their teaching ideas (Putnam & Borko, 2000).

Publications from the Third International Mathematics and Science Study (TIMSS; e.g., Stigler & Hiebert, 1999), coupled with release of videotapes of 235 eighth-grade mathematics lessons (*http://timssvideo.psych.ucla.edu*) from three countries, has increased enthusiasm for using *video* cases of classroom practice as a basis for case discussions. Many researchers are now designing and investigating various strategies, technologies, and social structures for helping make video case discussions an aspect of teaching culture (e.g., Barab et al., 2000; Frederiksen et al., 1999; Lampert & Ball, 1998; Marx, Blumenfeld, Krajcik, & Soloway, 1998). For example, Barab et al. developed a video-based Internet technology that enables teachers to upload video of their classes and remain in their classrooms while they go online to observe and discuss how teachers in other sites are implementing state standards. Marx et al. (1998) describe a multimedia system called CAPPS (Casebook of Project Practices) that scaffolds teachers as they study and learn from video cases of classroom practice. Stigler (personal communication) and Goldman-Segal (personal communication) are developing Internet technologies to support teachers' group

discussions and learning from instructional video cases.

Unlike most approaches mentioned above, STEP requires Internet video cases that are carefully selected, edited, and designed to teach a particular body of curricular knowledge (Derry, Kim, Steinkuehler, Street, Canty, Fassnacht, Hewson, Hmelo, & Spiro, 2000). Cases include many components: edited video of classrooms, expert analyses, teacher commentary, and supplementary materials. We have developed six instructional video cases and associated instructional materials. These cases represent lessons in middle and high school science (2 cases); high school mathematics; high school foreign language; high school English; and high school social studies. More cases are currently under development, and we are seeking funds to continue and expand this work.

Web Tools for Supporting Distributed (distance forms) of PBL

Building tools to support a distributed form of PBL is necessary due to the widespread problem of resources for undergraduate education. By putting STEP PBL activities online, we will avert many physical, temporal, and human resource constraints that face STEP and greatly increase the potential number of students served. Our strategy involves adding features to STEP Web that will better prepare each individual group member to use the STEP Web site and to participate in group work. Also, most group discussions will be removed from the classroom to an asynchronous online environment. This approach will permit facilitated PBL groups for distance courses and will have a number of other advantages over our current STEP implementation, which requires that each group meet face-to-face in class each week with a trained tutor.

We have made significant progress in building and testing a new conferencing tool that supports distributed (distance) PBL in STEP. This addition will also provide new users with early guidance in use of STEP Web and will therefore minimize some reported difficulties in learning to use the site effectively.

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III. Staff and Collaborators

Staff: Sharon J. Derry (Team Leader), Brian Bietzel, Barrett Caldwell, Nicole Canty, Kate Hewson, Jong-Baeg Kim, Julia Lee, Julie Posselt, Constance Steinkuehler, John Street, and Jeffrey Watson.

Fellow: Marcelle Siegel

Collaborators: Paul Feltovich, Cindy Hmelo, and Rand J. Spiro.

Products

Canty, N. G., & Caldwell, B. (1999, May). *Information flow and Web site design: Using the World Wide Web to support resources*. Paper presented at and appearing in the proceedings of the Eleventh Annual National Black Graduate Student Conference, Baton Rouge, LA.

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NISE-Related Publication of the Secondary Teacher Education Project

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Interacting with Professional Audiences

I. Team Mission

The IPA team reaches out to diverse professional audiences to encourage use of NISE products and research results, obtain reactions to them, and elicit suggestions for future research directions. The IPA Team does this directly through organizing the annual NISE Forums, but also assists other NISE teams in planning and conducting dissemination activities. Each Forum convenes representatives of the many NISE target audiences to share research and developments in an area of science and mathematics education reform selected for its timeliness and salience. The IPA Team also has recruited and is working with some 25 selected professional organizations that are collaborating with the NISE more intensively. These collaborating organizations assist in the work of NISE and in disseminating NISE results in ways that are tailored for reaching the organizations' members.

Specifically, the IPA team's goals are

- to share knowledge and information generated by the NISE with key stakeholders;
- to promote interaction and dialogue about the knowledge and information generated by the NISE among key stakeholders; and
- to encourage policymakers and practitioners to use research knowledge to improve science, mathematics, engineering, and technology education.

II. Accomplishments

The Annual NISE Forum

The five annual NISE Forums have been very successful in four ways: (1) creating awareness and a generally favorable perception of NISE and its work, (2) generating state-of-the-art knowledge on pressing topics in the SMET community, (3) helping shape NISE's and individual teams' research agendas, and (4) developing an effective process for all participants to contribute to the substance and results of large-scale SMET education meetings. Throughout the five years, the NISE Forum has been fully subscribed, drawing on a rich mix of some 300 participants at each Forum; it also has attracted supplemental corporate support each year. Individuals from virtually every U.S. state have represented many kinds of institutions (dozens of professional organizations, all types of postsecondary institutions, a variety of research and development projects, and diverse types of school districts). Participants' feedback from the formal evaluation questionnaire as well as anecdotal comments have been overwhelmingly positive. The feedback from each Forum has been used to shape the succeeding one.

The caliber of Forum participants has made it very worthwhile to collect and analyze the perspectives offered in the Forum's small-group discussions and include them in the Forum reports. The experts who have been enlisted to speak also have contributed to the reports through their prepared papers that are circulated in advance of the Forum. The continuing value of the Forums is

evidenced by the publications resulting from them or having been partially shaped by the panel papers and discussions. For example, the Year 1 Forum discussions led to the commercially published book by Susan Loucks-Horsley and her PD team. Teachers College Press has expressed interest in monographs authored by the Systemic Reform Team, one on policy analysis and one on evaluation of systemic reform initiatives, with inputs from the Forums held in Years 2 and 4. The Year 3 Forum on assessment issues in postsecondary education helped launch the Web site FLAG (Field-tested Learning Assessment Guide), an interactive site posting assessment examples designed and used by SMET faculty. The Year 5 Forum on equity issues in SMET has proved important enough that the U.S. Department of Education supported the writing and production of a summary report, to be widely distributed.

Some papers written by the Forum speakers have independently been receiving acclaim. Susan Loucks-Horsley's Year 1 paper was reproduced in *Science Educator*, the newsletter of the National Science Educational Leadership Association. Many requests for Uri Treisman's Year 2 paper led to the Institute plans to transform it into an NISE Brief. The National Research Council circulated several papers from the Year 3 Forum to participants in one of its conferences on undergraduate education.

The effectiveness of the Forum processes to generate and disseminate knowledge is evidenced by the fact that NSF requested the NISE IPA Team's assistance in conducting two other similar conferences in SMET education, one on teacher preparation and one on graduate education. Moreover, a guide to designing effective meetings and conferences, based on the NISE development and experience with the Forums, was prepared by the IPA staff and has been published by Corwin Press.

The Forum is a good example of how the Institute has successfully drawn together the work of its teams. For the first four Forums, though the IPA Team coordinated all aspects of the Forum, the cognizant research team was responsible for the substantive content and agendas. The research teams have worked hard not only to highlight their NISE work but also to draw in leading experts from other organizations. The Year 5 Forum was an all-Institute effort, since equity issues cut across all the teams' research. The NISE management regularly monitored and facilitated the development of each year's Forum. The Formative Evaluation (FE) team has helped design the details of the Forum evaluations as well as analysis of small-group discussions to feed into the published reports.

Collaborating with Other Organizations

The IPA Team initiated relationships with some 25 organizations interested in collaborating with NISE. As a result, several organizations have formally lent their names and/or efforts to putting on one of the annual NISE Forums: American Association of Higher Education, Consortium for Policy Research in Education, Council of Chief State School Officers, National Council of Teachers of Mathematics (NCTM), National Governors' Association, National Staff Development Council (NSDC), and National Science Teachers Association (NSTA). Also, the publication divisions of NCTM and NSDC formally codistributed the PD Team's book, and the Eisenhower National Clearing House produced two spin-off publications based on the book, one in mathematics and one in science. Senior staff of several of the collaborating organizations have provided critical reviews of draft NISE publications and attended working meetings of NISE research teams. Based on their knowledge of NISE work, NCTM, NSDC, and

(particularly) NSTA have invited NISE staff to make featured presentations at their annual and/or regional conferences, and several organizations have asked NISE staff to confer with them on issues of mutual interest.

Dissemination Assistance

The most notable success of the IPA Team's efforts to work with NISE staff on dissemination activities is its work to negotiate and execute the commercial publication of the PD team's work by Corwin Press and the secondary distribution of the book by NCTM and NSDC. This book is making far more impact than if it had been self-published by NISE. For example, in its first month, the book already had become one of Corwin's top three all-time sellers. As noted earlier, the Institute looks forward to two further externally published monographs, initially facilitated by the IPA team. Also, *Education Week* accepted two articles submitted by the Team (see NISE-Related Publications).

III. Staff

Senta Raizen (Team Leader), Edward Britton, Mary Ann Huntley, and Susan Mundry.

Products

1996 First Annual NISE Forum. "Professional Development for Mathematics and Science Education: Putting Knowledge into Action"

1997 Second Annual NISE Forum. "Systemic Reform: What Do We Know? What Do We Need to Know?"

1998 Third Annual NISE Forum. "Indicators of Success in Postsecondary SMET Education: Shapes of the Future"

1998 Special NISE Forum. "Strengthening Graduate Education in Science and Engineering: Promising Practices and Strategies for Implementation"

1999 Fourth Annual NISE Forum. "Evaluation of Systemic Reform in Mathematics and Science"

1999 Special NISE Forum. "From Preparation to Practice: NSF Teacher Education PI Workshop"

2000 Fifth Annual NISE Forum. "Research on Equity Issues in SMET Education" (Report to be published and distributed in fall 2000.)

NISE Insider, quarterly electronic newsletter to NISE Collaborating Organizations

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NISE Publications of the Interacting with Professional Audiences Team

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I. Team Mission

The general objectives of the CMA Team have been to promote public understanding of SMET-related concepts and issues and to understand how the new communication channel of the World Wide Web can be used most effectively to communicate SMET concepts to mass audiences. During the first three years, the CMA Team's primary effort was designing and producing The Why Files (*http://whyfiles.news.wisc.edu*), the award winning World Wide Web science magazine created by NISE. At the end of Year 3, funding for The Why Files site was shifted from NISE to the Graduate School of the University of Wisconsin-Madison. At that time, the focus of the team became conducting research on the communication of science via the World Wide Web, an endeavor the team began in Year 2.

Production Component

While traditional mass media such as newspapers, television, and radio play a critical role in informing the public about news and issues of science and technology, they are often limited in their resources and ability to provide depth and context. And while traditional media pique public curiosity about science and technology, The Why Files seeks to satisfy that interest by offering in-depth, informed, and critical looks at current topics such as Lyme disease, planets discovered beyond our solar system, and genetic engineering.

Within the last two years, the media landscape has been altered as new science news venues have emerged on the World Wide Web. While a few of these sites seek to capitalize on popular interest in science, many cater to specific constituencies. For instance, there are a number of science news venues that provide news and information for audiences connected in some way to the life sciences. However, these and most other general science news sites tend to recycle print news or to simply post news releases from research organizations. Curiously, there are very few venues developing purely online science content such as that produced by The Why Files.

Research Component

Beginning in Year 2, the CMA team conducted evaluative research on The Why Files specifically and more general research on how science learning takes place on the World Wide Web. This latter work became the sole focus of the team beginning in Year 4, resulting in a change in the CMA team leadership. The research plans for the 4-year period were to (1) understand the users of science information on the Web (e.g., demographics, motivations), particularly users of The Why Files; (2) understand how individuals use science information on the Web, particularly their navigation patterns through Web sites; and finally, (3) understand the effects of Web presentations of science information on information processing and learning. Thus, our research program began with a descriptive focus during Years 2 and 3 and moved into a more explanatory phase for Years 4 and 5.

II. Accomplishments to Date

The Production Component

The Why Files continues to expand its unique content base, producing between 45 and 50 new illustrated feature articles per year. In the past year, The Why Files has covered an array of topics such as moving species from the endangered list and the discovery of marine

worms that live to be an astounding 250 years of age. Other packages covered the battle to teach evolution in Kansas, the world's malaria epidemic and the technology that underpins a proposed missile defense system. The Why Files production team is now engaged in a site redesign exercise to improve navigation and accessibility for Why Files readers. A number of those changes have been driven directly by the research conducted on The Why Files site by members of the CMA Team.

Changes in package design and approach to a given topic may be subtle or pronounced, but the basic formula that has made The Why Files a popular success remains. That formula involves a carefully crafted combination of accurate but humorously written text, eye-catching graphics, photos, selected hot links to other Web sites, and occasionally video and sound. That formula is now employed on a weekly basis to produce a feature package that keys off of events in the news. By keeping to a rigorous production schedule, the site has expanded considerably in the past year, and the dynamic nature of the site is a feature that draws a loyal and growing following. Another key feature of the site is the Cool Science Image gallery, which draws on pictures and images from the front lines of scientific research. The site also hosts an active net forum and the occasional contest, both of which boost the site's drawing power.

During Years 4 and 5, there have been several new developments. The most significant development was the move of The Why Files production team from the National Institute for Science Education to the Graduate School of the University of Wisconsin-Madison on July 1, 1998. The move has placed The Why Files on a permanent institutional footing and enabled it to expand its activities and collaborations to take The Why Files in important new directions. Moreover, it has permitted us to expand Why Files staff through the addition of a graduate student project assistant, a valuable asset that has helped the production team maintain its rigorous publication schedule and improve the site in numerous ways. Inclusion of a project assistant also provides important opportunities for graduate students who can take the Web-content production skills they learn at The Why Files to their future employers.

An important new extension of The Why Files now exists in the form of an online introductory geoscience course taught through the UW-Madison Department of Geology and Geophysics. Inspired by geology professor and MacArthur Foundation Fellow Jill Banfield, and developed in collaboration with geology professor Phil Brown, the course was taught for the first time in spring 2000 to a three-figure enrollment. The department plans to continue offering the course at least once every academic year. The course is based entirely on Why Files content with added material to ensure adequate coverage of basic ideas and principles in the geological and physical sciences.

During Years 4 and 5, The Why Files continued to maintain a profile as one of the most popular and critically acclaimed science-related sites on the World Wide Web. By providing an in-depth look at the SMET content of current affairs and news, The Why Files has developed an informational niche that attracts a broad audience in terms of both demographics and interest.

Use of the site remains steady. Statistics gathered indicate that more than 100,000 individual computers tap into The Why Files in any given month. People from at least 120 different countries have visited the site. The Why Files also continued to enjoy critical success and garners awards and citations at a steady pace. Some examples include selection as one of the "50 Hottest Sci-Tech Sites" by

Popular Science, a site award from *SchoolZone* where teachers serve as judges, a Top Site Award from *Education Planet*, inclusion in Web Feet: The Internet Traveler's Desk Reference, a featured site award from *StudyWeb*, and a 1999 Best of the Web Award from *HotSheet.com*. Positive critical reviews of The Why Files site appeared in numerous publications, including the *Chicago Tribune*, the *Florida Times-Union*, the *Los Angeles Times*, *Discover* magazine, the *Riverside Press-Enterprise*, and *4kids.org*, a syndicated feature appearing in more than 150 newspapers in the United States and Canada.

Anecdotal evidence that The Why Files is used and enjoyed by many arrives daily. Some samples of readers' comments:

- "Serendipity or divine intervention. Whatever the reason behind the find, I happened upon the Why Files. You've done a fine job with varied subjects; the articles are well done, full of wit, educational, and a pure delight (despite the sometimes straight truth that may create thoughts of becoming a vegetarian).
- "Way to go Why Files! Why do I enjoy the Why Files so much? Why me, Lord?"
- "I am doing a science Web site review for school and was really impressed with your Web site. Especially with the way you present both sides of evolution vs. creationism. Anyway, you guys are getting a great review from me!"
- "Good site! It doesn't treat me like a moron."
- "I am a home educator and have just 'discovered' your page. It is great. Thank you."

The Why Files continues to build collaborations with other organizations. The team worked closely with the NSF Office of Legislative and Public Affairs to produce a package in concert with the 1999 and 2000 National Science and Technology Weeks. Requests for links are routine, and numerous schools, businesses and other organizations have established direct links to The Why Files over the course of the past year. An invited presentation was given in Salt Lake City at the first annual Science Education on the Internet meeting in the fall of 1999. This meeting was open only to a select, invited group of science education Web site developers from the United States and Canada. In addition, Why Files presentations and informational sessions were provided at Madison's 1999 Future Fair and the spring 2000 meeting of the Wisconsin Society of Science Teachers.

With the support of NISE colleagues, The Why Files continued to draw together experts on the news media and science communication as well as the scientific community to forge a product that transcends the interests of any single institution or organization. The work of The Why Files continued in that vein as the program made the transition from NISE to the University of Wisconsin–Madison Graduate School. We anticipate that The Why Files will maintain its global perspective and ties to NISE and NSF.

The Research Component

Over the four-year period that the CMA Team has been conducting empirical research, we have had a number of accomplishments. Below we list our accomplishments in a rough chronological order, grouped by major research projects.

Review of Literature on Uses and Cognitive Effects of Hypermedia

The first stages of our research program in Year 2 began with an extensive review of the literature examining how individuals use the technology of hypermedia—the foundation of the World Wide Web—to learn. Integrating research from fields as diverse as educational

psychology and technology, computer science, cognitive psychology, geography, library and information science, and communication, we developed a review of the literature on how individuals use hypermedia and its effects on their learning. This review, an early version of the paper that won a top-three paper award from the Communication Technology & Policy division of the Association for Education in Journalism & Mass Communication (AEJMC), included a discussion of theories of information processing that could inform research on learning about science from Web sites like The Why Files. Evidence pointed to a number of important variables that might moderate or mediate the effects of this new technology, such as the design of Web sites and the expertise and goals of users. This review of the literature was published by the NISE as a Research Monograph. A revised version is in press at *Communication Yearbook*, the major outlet in the field of communication for extensive literature reviews.

Audit Trail Analysis of Web Site Navigation; Survey of Repeat Users of The Why Files

In Year 2 we conducted a number of studies to evaluate The Why Files Web site. The first of these studies unobtrusively tracked natural user navigation throughout The Why Files site. During three separate two-week periods, we developed a data base that allowed us to observe patterns of movement within and among science stories on the site, as well as movements from outside of the site into it, and from inside following links to other Web sites. Contrary to the proposed advantages of hypermedia systems like the World Wide Web, we found that the majority of users did not make frequent use of nonlinear navigation features within the site or links to additional information outside of the site. Instead, they tended to follow linear navigation patterns, in many ways using The Why Files Web site like a traditional print magazine.

We also conducted a scientific survey of repeat users of the site to better understand the demographic profile of The Why Files user. We found that, much like users of traditional print science magazines, and much like the users of the Web at the time (1997), repeat users of The Why Files tended to be male, relatively young, well-educated, and very interested in science topics. It was unclear from this initial finding whether or not these demographic characteristics were due to the nature of access to the Web at the time, the nature of individuals who tend to be interested in science, or some combination of the two.

The results of these two studies were initially published by the NISE as an NISE Brief. A much more detailed analysis of these data was later published in *Public Understanding of Science*, an international journal specializing in informal science learning research.

Think-Aloud Analysis of Web Site Navigation and Information Processing

Our finding of linear navigation patterns required a more detailed analysis of process data to better understand their implications. Therefore, in Year 3 we designed and conducted a study in which we observed a sample of adults using science information on the Web and thinking aloud as they did so. This study initially allowed us to provide advice to The Why Files creative staff about how the site was being used and particular design features that caused users problems. In effect, this study served as a usability analysis of The Why Files. Based on a summary of our findings, the creative staff of The Why Files redesigned the home page of the site as well as a number of its other features.

The results of our think-aloud study also enabled us to analyze the information processing behaviors of individuals as they

navigated through Web sites. We developed a coding scheme to categorize thoughts as indicating different types of information processing behaviors and examined how these thoughts varied across a number of variables. The results of this research were published in *Media Psychology*, a journal devoted to research on the mass media from a psychological perspective.

Experimental Analysis of Learning from Web vs. Print Presentations

Once we understood the demographics of users of science Web sites like The Why Files, and understood their navigation behaviors through these sites and their information processing behaviors during navigation, we expanded our research to understand how using the Web to communicate science might influence learning. Thus, during Year 3 and Year 4 we conducted several studies of varying designs using various stimulus materials to examine how science learning might vary on the Web versus in print, holding content constant. These studies also manipulated variables such as user motivation (i.e., intentional vs. incidental learning) and Web site design. Our findings suggest that learning may suffer when information is communicated via the Web compared to traditional print media. However, some Web site designs, particularly those that provide both nonlinear navigation options and instructional advisement, are not significantly worse for learning science information than their traditional print counterparts.

Incidentally, during the time of these studies The Why Files used just this type of design.

We are currently submitting the findings of these various studies for presentation and publication. The first is currently under second review at *Communication Research*, probably the most selective journal in the area of mass communication. Another has just been submitted to *Journal of Broadcasting & Electronic Media*, the major outlet of the Broadcast Education Association.

Experimental Analysis of Elaboration Instructions on Learning from Web and Print

Another series of studies, begun late in Year 3 and continued through Year 5, examined the influence of various manipulations of the elaborative processing of individuals as they learned about science, primarily from Web sites but in some cases also print. Numerous studies in education have indicated that learning is increased substantially by elaborative processing of new information. However, these studies tend either to focus on very micro-level learning situations (e.g., paired associate learning; short prose paragraphs) or to use manipulations that are extremely powerful (e.g., semester-long learning strategies training). We have endeavored to design elaboration manipulations that could be incorporated into science Web sites to increase elaboration among users. Our outcome measures have varied from measures of immediate recognition in some studies to measures of immediate and delayed cued recall in others.

Our results, which have not yet been fully analyzed, suggest that there are a number of complexities that may limit the effectiveness of elaboration manipulations in real-world Web sites. Early findings suggest, for instance, that Web sites themselves increase elaboration compared to the same content in traditional print. This finding is encouraging and is consistent with some theories of Web effects. However, other findings suggest that the elaboration manipulation may not be effective on the Web because of a ceiling effect. Further, depending on the wording and placement of elaboration manipulations in a text, learning of the elaborated passages may

increase at the expense of other information that did not receive the elaboration prompt. During the next year we will further analyze these data in hopes that we can better understand the role of elaboration in learning from the Web. We will submit a manuscript or manuscripts to an educational technology or educational psychology journal.

Experimental Analysis of Web Site Structure Effects on Knowledge Structure

Our most recent research (Year 5) has examined how different Web site designs, specifically the use of linear versus nonlinear design structures, can influence information processing, content knowledge (as tapped by measures of recognition and of free and cued recall), and knowledge structure (interconnectedness and organization).

Once these data have been coded and entered, we hope to analyze them to determine whether the design of Web sites can influence information processing, as was suggested in our first think-aloud study. In addition, since all our previous research using measures of content knowledge have found either that print media are superior for learning, or at least that Web sites are *not* superior for learning, we have included detailed measures of knowledge structure. These measures allow us to test the hypothesis that, while Web sites do not increase learning of content compared to print, different Web site designs can have effects on the structure of knowledge, potentially more important than effects on the content of knowledge. We expect that, without further funding, it will take us approximately one year to analyze these data and produce conclusions.

Think-Aloud Analysis of Web Site Structure Effects on Navigation and Information Processing

We have also manipulated Web site structure and user goals in a think-aloud study of adults. This study allows us not only to assess the impact of site design on self-reported information processing strategies, but also to determine from observational data whether site design influences information processing. We will also be better able to identify more microlevel features of site design that may increase beneficial forms (e.g., elaboration) or harmful forms (e.g., disorientation) of information processing. We will also be able to empirically link information processing as measured using the think-aloud technique with measures of both content knowledge and knowledge structure, something our previous work was unable to do. We expect that, without further funding, it will take us approximately one year to analyze these data and produce conclusions.

III. Staff and Collaborators

Terry Devitt, Sharon Dunwoody, and William P. Eveland, Jr. (Team Leaders), Yael Gen, Sue Medaris, HeeSun Park, Jennifer Pearson, Darrell Schulte, David Tenenbaum, Amy Toburen, Susan Trebach, and Tom Wiggins.

Product

The Why Files Web site:
http://whyfiles.news.wisc.edu/

NISE Publications of the Communicating with Mass Audiences Team

Eveland, W. P., Jr., & Dunwoody, S. (1998). *Surfing the Web for science: Early data on the users and uses of The Why Files* (NISE Brief Vol. 2, No. 2). Madison: University of Wisconsin–Madison, National Institute for Science Education.

Eveland, W. P., Jr., & Dunwoody, S. (1999). *Using hypermedia research to advance the study of learning on the World Wide Web*

(Research Monograph No. 15). Madison: University of Wisconsin–Madison, National Institute for Science Education.

NISE-Related Publications of the Communicating with Mass Audiences Team

Eveland, W. P., Jr., & Dunwoody, S. (1997, August). *Applying research on the uses and effects of hypermedia to the study of the World Wide Web*. Paper presented to the Communication Technology & Policy division at the annual meeting of the AEJMC, Chicago.

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Eveland, W. P., Jr., & Dunwoody, S. (2000, June). *A test of competing hypotheses about the impact of the World Wide Web versus traditional print media on learning*. Paper presented to the Information Systems division at the annual meeting of International Communication Association, Acapulco, Mexico.

Eveland, W. P., Jr., & Dunwoody, S. (in press). Applying research on the uses and cognitive effects of hypermedia to the study of the World Wide Web. *Communication Yearbook #25*.

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Cognitive Studies of Interdisciplinary Collaboration

I. Team Mission

A major strategy of the NISE has been to use interdisciplinary teams to work on the Institute's mission of improving SMET education. Within the Institute, experts from a variety of disciplines form working teams, of various durations, that study significant issues and propose and carry out projects related to NISE goals. Such interdisciplinary teams are ubiquitous in educational research. They are increasingly common in industry, government, and society in general. The National Science Foundation encourages formation of such teams through their funding guidelines. For example, EHR's ROLE program and the Interagency Education Research Initiative (IERI) encourage formation of interdisciplinary research teams.

Although a body of literature and much "wisdom of practice" have emerged in recent years (e.g., Chubin, Porter, Rossini, & Connolly, 1986; O'Donnell, DuRussel, & Derry, 1997), we still have little understanding of how social and cognitive processes interact to drive intellectual growth and construction of products in natural interdisciplinary groups researching important social problems. Such knowledge might lead to better facilitation technologies for improving interdisciplinary inquiry, which is known to be a difficult enterprise.

The main goal of the Cognitive Studies of Interdisciplinary Communication (CSIC) team was to better understand interdisciplinary collaboration in educational research. To this end, our team reviewed research, constructed theory, and conducted observational studies of NISE's interdisciplinary teams in action. We conducted a two-year video ethnography of specified NISE teams and conferences in action, collecting data suitable for later analyses by researchers, both within and outside the NISE, who are interested in developing explanations of how groups construct knowledge and how social, physical, and cognitive constraints affect their work. This report describes our progress on theory development, research, and data collection, which comprised the bulk of our work during the three-year funding period. The CSIC team did not operate in years 4 and 5 of the NSF-supported NISE.

II. Accomplishments

Development of Foundational Theory

We grounded our work in a review of scientific literature about how individuals and groups carry out cognitive activity and how that activity is shaped by physical and social contexts. The literature review synthesized research from social psychology, cognitive psychology, small group research, and other fields, highlighting major issues influencing cognitive and social processes in interdisciplinary teams (O'Donnell, DuRussel, & Derry, 1997). Important characteristics of effective work groups were described, and origins of difficulties within such groups were discussed. We determined, however, that much research on group work has focused on groups that come together only in the laboratory, and that these groups differ from true interdisciplinary groups in important ways. We concluded that study of interdisciplinary inquiry must focus more on natural groups that experience special difficulties because of institutional constraints, the combinations of disciplinary cultures represented,

and the implications of disciplinary allegiance to problem representations and solution strategies. Our review examined several examples of interdisciplinary teamwork. Methodologies for studying interdisciplinary interaction were suggested. To fully understand and influence group processes in interdisciplinary groups, we argued there is need for a broad model of cognition within which to interpret the individual-level and system-level variables and the interactions among these variables.

Later in the CSIC program such a model was proposed, the Knowledge Building Community (KBC) model, which is described in two publications (Derry & DuRussel, 1999; Derry, Gance, Gance, & Schlager, 2000) and is just beginning to be adopted by other research teams.

Conferences and Outreach Activities

To further understanding of interdisciplinary teamwork and to help refine research objectives for this field of study, the CSIC team hosted an invitational interdisciplinary conference, cosponsored a national cognitive science conference devoted to the theme of interdisciplinarity, and participated in a community outreach activity featuring members of the Sesame Street production group.

Conference on Understanding Interdisciplinary Teamwork. Thirty scholars attended a small two-day conference in mid-November, 1996, entitled "Understanding Interdisciplinary Teamwork: Challenges for Research and Practice." Conference participants included faculty members of NISE, individuals who have special expertise or experience pertaining to interdisciplinary collaboration and problem solving, and representatives of research projects addressing the topic of interdisciplinarity. A number of questions guided discussion and activities during the conference.

- What is the current theoretical base for understanding interdisciplinary collaboration?
- What is already known about interdisciplinary collaboration that can be applied to NISE work and beyond?
- What are the best known methods for studying interdisciplinary collaboration?
- How can current and developing research findings contribute to the enhanced performance of interdisciplinary teams?
- What technological enhancements and tools might be used to facilitate teamwork within the NISE?
- How might answers to the above questions help other research and educational reform partnership teams?

Following an opening address by Dr. Julie Thompson-Klein of Kent State University, participants began by exploring what is meant by the term "interdisciplinarity" and identifying the key variables associated with interdisciplinary collaboration. The keynote address by Dr. Gavriel Salomon of Haifa University, Israel, a noted expert in the field, focused the conference on the cognitive processes of interdisciplinary teams and current understanding of distributed cognition. Several case studies, some based on developing technologies that support teamwork, were presented. Participants then broke up into five working groups to explore, in more depth, key questions derived from those noted above concerning the role of theory, what the state of the science is, what the roadblocks are, and the most pressing and important questions for researchers in the study of interdisciplinary collaboration, as well as the potential for creating effective environments for collaborative work through the use of technology. As the conference closed, participants acknowledged their own needs as a community of researchers studying

interdisciplinary collaboration to meet more frequently to share research findings and ideas.

A conference report was prepared based on the presentations and working group reports and discussions at the conference. The conference was very positively evaluated by the LEAD Center.

Cognitive Science Society 1998 Annual Meeting. Interdisciplinary scholarship was the theme of the Twentieth Annual Meeting of the Cognitive Science Society, which took place at the University of Wisconsin-Madison, August 1-4, 1998. This conference, attended by 450 international scholars, was cosponsored by NISE and cochaired by Sharon Derry, the CSIC team leader. In addition to a conference proceedings (Gernsbacher & Derry, 1998), the meeting produced a set of special thematic papers that were organized into a collection and will be published by Erlbaum (Derry & Gernsbacher, 2000).

Sesame Street Unpaved. The CSIC team sponsored a graduate symposium with members of the Sesame Street production group, which visited campus for an anniversary performance. The symposium, "Understanding Collaborative Work: The Children's Television Workshop as a Case Study in Successful Interdisciplinary Practice," took place on September 22, 1998, at the University of Wisconsin–Madison, and was advertised to faculty and students.

Data Collection

We collected observational and interview data on three teams within the NISE. These data include approximately 1,000 hours of video and audio recordings of meetings, conferences, and interviews, as well as other team artifacts such as email, agendas, and visual aids. This database documents the work and development of both short-lived and long-term interdisciplinary teams within the NISE. About 60 hours of tape have been transcribed and annotated for specific analyses. In the future we will open this database to a limited number of outside researchers, who will help conduct analyses of interdisciplinary teamwork.

To document our data collection effort, we developed a technical manual that describes data collection, storage, transcription, and indexing: L. A. DuRussel and L. L. Gance, 1997,. *Technical Manual for the Cognitive Studies of Interdisciplinary Collaboration Project.* Included in the manual is our "master tape list" which documents individual pieces of data and status information. The manual illustrates the organization of the database, what is available in it, and how it is being indexed for access.

Summary of Selected Research Findings

We conducted studies of two teams in the NISE—the Strategies for Evaluating Systemic Reform (SESR) team, and a working subcommittee of the College Level One (CL-1) team. In both studies we examined the genesis and development of team knowledge over a lengthy period of time. We examined what roadblocks teams encountered and what constraints shaped their teamwork. Whole working groups were the major units of analysis. Our primary method was discourse analysis of meeting conversations. These analyses focused on collaborative conversations that could be observed and recorded, tracing their impact on the papers, reports, and other products produced by the teams. Our approach was largely qualitative in the sense that we descriptively analyzed team processes to contribute to theory about effective collaborative work and to further knowledge about how interdisciplinary perspectives influence team functioning. We focused less on the private cognitions of

individual members, although we did examine these selectively through interviews. Detailed findings of our work are provided in the research reports and publications listed at the end of this section. Findings from selected studies are summarized briefly here.

Sociocultural Theory and Interdisciplinary Team Building. One study (DuRussel & Derry, 1996) examined the validity of sociocultural theory (e.g., Wertsch, 1991) as a viewpoint for analyzing data from the first few meetings of the SESR team. The major goal of the analysis was to determine whether the Team data "fit" categories and concepts proposed by sociocultural theory as lenses for examining interaction during the team building process. We concluded that sociocultural theory did not adequately describe major aspects of the team building process we observed, leading us to search for a more appropriate theoretical viewpoint.

We found that some knowledge-building processes predicted by sociocultural theory, namely those of apprenticeship and negotiation, did occur occasionally during interdisciplinary collaboration. Wertsch's concept of "voices" was also useful in revealing differences between social and physical scientists and their strategies for finding common ground. However, sociocultural theory had only limited applicability to the kinds of interdisciplinary teams found in the NISE. For example, sociocultural theory implies that successful interdisciplinary teams operate like apprenticeship communities according to a process in which high-status old timers induct lower-status newcomers. Status differences do in fact occur on interdisciplinary research teams, but they probably are not associated with learning the ropes in a team community. Many members of interdisciplinary teams are engaged for their expertise and do not have novice status as newcomers. Still, in order for team members to work together, they must learn from one another and develop a common language. Although this process is not yet fully understood, "apprenticeship" does not appear to be an adequate metaphor for describing the learning that takes place among high-status team members from different disciplines. The need for a new theory became evident. Social scientists who study group interaction should be interested in this study, a critique of a currently popular theory as a basis for research on interdisciplinary process.

A Case Study of an Interdisciplinary Team Trying to Understand Systemic Reform. This qualitative case study by Derry, DuRussel, and O'Donnell (1998) employed group information processing theory (e.g., Hinsz, Tindale, & Vollroth, 1997; Smith, 1994) as a lens for examining the SESR team's dynamics and processes, shedding light on how those dynamics and processes likely influenced the Team's effectiveness as a knowledge building group. The primary contribution of this study is its detailed theory-based description of how an interdisciplinary team, composed of high-status academic advisors constrained by limited time, interacted with a team leader and his staff to foster interdisciplinary knowledge construction. The analysis highlighted difficulties inherent in trying to achieve a truly distributed form of information processing under this form of team organization. Both limits and strengths of the Team's knowledge construction processes were revealed.

The Team's difficulties were of three types. First, the group had difficulty translating discussions into products that reflected those discussions. Second, work accomplished at one meeting often did not serve as input to subsequent meetings; hence the Team had difficulty building on and extending accomplishments. Third, both team and team leader sometimes rejected recommendations and agendas offered by the other.

However, the Team leader was a reflective manager who was able to adjust team organization and functioning as our analyses and other feedback became available. Moreover, significant knowledge building that combined ideas from different disciplines contributed by team members did occur, primarily within the mind and work of the Team leader. The Team leader thus became the locus of successful interdisciplinary knowledge construction because he valued the Team and endeavored to synthesize input selectively and thoughtfully.

Analogical Reasoning and Mental Models in a Natural Working Group. A yearlong study, conducted by Lori DuRussel as her master's thesis, produced several key findings. First, team members held different mental models of the task distribution (who was responsible for doing what). Second, misalignments in participants' mental models of the task itself contributed to conflicts. Finally, it is crucial for interdisciplinary teams to bring team members' mental models of tasks and task distribution into some degree of alignment, so participants can work together successfully.

The Team was attempting to analyze students' transcript data to understand how students, especially minorities and women, move through college curricula in science and mathematics fields. The Team used the analogy of a "pathway" to characterize their viewpoint, and this viewpoint shaped thinking about their data analysis. Ambiguities in participants' definitions of what pathways were and how they should be investigated resulted in conflict. In addition, because participants' models of software's role in the task were not well aligned, the analyst used existing software in a way that did not match other participants' expectations, and his work was criticized. Even apparent alignments in mental models—as in participants' agreement that an inductive analytical approach was necessary—did not alleviate the conflict.

This study identified several factors contributing to mental model misalignments. First, as expected, individuals' differing backgrounds (including their disciplinary history and experience with tools such as software) influenced the mental models they brought to the task. In addition, the distribution of tasks among team members caused each participant's mental models to be shaped by different goals, tools, and task experiences. While these misalignments might have been resolved through group communication, such communication did not occur. The lack of articulation of the task (including the ambiguous nature of the pathway analogy) and the lack of known research approaches hampered team members' attempts to work together successfully. Inconsistent attendance also may have prevented significant alignment from occurring.

This analysis had several implications for management of interdisciplinary teams. Given the diverse nature of interdisciplinary teams, some degree of mental model misalignment is to be expected and possibly desired, since it theoretically enhances the wealth of perspectives that can be brought to bear on a problem. However, it is important that the task be negotiated and/or articulated such that participants come to share an understanding of the crucial steps involved and the expected approach that is to be taken. In addition, task distribution should be clarified so that all team members are aware of who is responsible for what parts of the project. Such articulation and clarification requires attention to communication. One key to ensuring adequate communication is as simple as insisting on consistent attendance at team meetings, thus ensuring that all team members are influenced by the same interactions and increasing the chances that participants' models will evolve in compatible ways.

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III. Staff and Collaborators

Staff: Sharon Derry (Team Leader), Lori DuRussel, and Laura Lee Gance.

Fellow: Angela O'Donnell

Collaborators: Jan O'Neill and Mark Schlager.

NISE Publications and Presentations of the Cognitive Studies of Interdisciplinary Collaboration Team

Derry, S. J. (August, 1997). *Knowledge construction in interdisciplinary teams: Strategies and roadblocks*. Invited address at the annual meeting of the American Psychological Association, Chicago, IL.

Derry, S. J. (October, 1997). *Cognitive case studies of interdisciplinary teamwork*. Seminar presented for the Department of Educational Psychology at the University of Wisconsin–Madison.

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Derry, S. J., Gance, S., & Gance, L. L. (1998). *Cognitive conflict in interdisciplinary teamwork: A case study*. Presentation at SRI International.

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DuRussel, L. A., & Derry, S. J. (2000). *Mental models of teamwork.* (University of Wisconsin–Madison). Manuscript in preparation.

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Information Resource Coordination

I. Team Mission

The mission of the Information Resource Coordination (IRC) Team has been to examine issues in information technology use and knowledge sharing (including information technology systems design) to support improved information flow for science and mathematics education. There have been two focus areas of the mission: information flow and coordination of NISE projects themselves, and the application of research knowledge and design engineering to improve information sharing in education communities of practice.

The IRC Team was formed in spring 1999 by Associate Director Barrett Caldwell, based on his research and teaching interests in information and communication technology systems engineering. As a result, the IRC Team has played a multifaceted role, including consulting to other NISE teams (Secondary Teacher Education Project, Systemic Reform Project), front-office coordination and implementation projects, and direct action research with educational practitioners.

The IRC Team accomplishments will be listed in three sections: NISE Information Coordination Activity, NISE Project Support Efforts, and Independent Research and Development Tasks. Because of the distribution of unique effort by IRC Team members, the third accomplishment area will be the longest.

II. Accomplishments

NISE Information Coordination Activity

The primary coordination activity in this accomplishment area has been focused at improving NISE information availability and dissemination to the public. By early 1999, the online Web presence of the NISE was well established, but was difficult for users to recall or find through commonly used search engines. In addition, the large stock of NISE publications were not available for online viewing. The activities initiated or supported by the IRC Team include the following:

Registration of simpler Web address. The formal Web site URL (universal resource locator) for the NISE is *http://www.wcer.wisc.edu/nise/.* After discussions with campus representatives, it was determined that there was no conflict of interest to register a simpler domain name for the benefit of visitors to the site. The name "nise.org" was available and was registered as an alternative path to the NISE, *http://www.nise.org.* This address takes visitors to the same NISE home page as the longer address above.

Appropriateness of online dissemination. Some academic disciplines and professional organizations have resisted online publication or dissemination of scholarly works due to concerns about intellectual property and copyright infringement. These concerns had prevented NISE from making many of its publications available online. A new evaluation of the practice of online publication was initiated by IRC Team, and, as a result, more NISE Briefs, Reports, and Proceedings are available in abstract or complete form from the Publications section of the Website.

NISE Project Support Efforts

During the 1999-2000 period, IRC Team members provided critical information, expertise, and research capability resources to two other NISE Teams: the Secondary Teacher Education Project (STEP: Sharon Derry, Team Leader), and the Systemic Reform / Milwaukee Schools Team (InfoNet: Norman Webb, Team Leader). Because

IRCT members were functionally integrated into these other teams, relevant project activity will also be summarized in those teams' reports.

STEP Support. STEP has been focused on the development of a "knowledge Web" of resources for preservice and inservice teacher development in the learning sciences. The results of the knowledge Web include a novel Web site design to provide case-based instructional support for cognitive science and learning theory topics in education courses. The human-computer interaction (HCI) design, implementation, and evaluation of that site was conducted in large part by IRC Team member Nicole Canty. A conceptual model of the overall information resource development project is shown in Figure 2.

STEP required substantial detailed development to enable its effective use by educational psychology students in their ongoing coursework. This development work was begun by both Nicole Canty and Jeff Watson and was continued through June 2000 by Nicole Canty.

InfoNet Support. The Systemic Reform/ Milwaukee Schools InfoNet project led by Norman Webb has identified a critical information-sharing problem at the level of individual schools' access, use, and decision-making capability of data and resulting information produced by the schools themselves. This disconnect between the ability to provide data annually or semi-annually to the larger school district, and the ability to effectively utilize local information at shorter time intervals, was a primary focus of the support provided by IRC Team members Jeff Watson and Susan Zeyher.

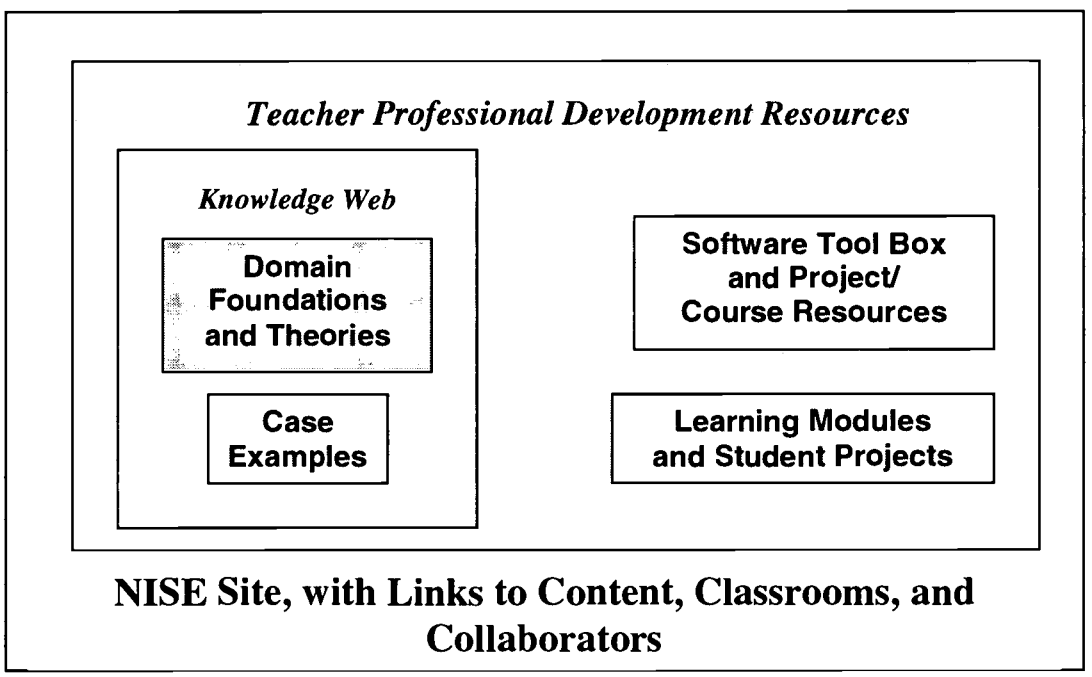

Figure 2. ***Conceptual model of Teacher Professional Development Information Resources used by IRC Team***

Descriptions of the design of an effective InfoNet will be found in more detail in the Systemic Reform Team's reports. However, critical elements of an effective InfoNet architecture include the availability of data at the right time and grain size for local users. Systems to provide appropriate data to schools or classrooms are not well integrated with large scale educational statistics repositories for policymaking or funding evaluations. This separation of local from general information has placed additional burdens on schools to modify or invent their own data reporting and use systems. The IRC Team has provided ongoing assistance to the InfoNet project to describe the necessary and desirable characteristics of data systems and information flow needs for local schools; InfoNet reports on these topics are in production.

Independent Research and Development Tasks

The primary demonstrable outcomes of the IRCT are associated with the independent project task known as the Science, Mathematics, and Engineering Learning Technologies (SMELT) project. SMELT has involved direct outreach and cooperation with teacher practictioners in the Teacher Professional Development Institute (TAPPED IN), an online "education community of practice" hosted by SRI International. In addition, SMELT has produced a CD of teacher-relevant and "teacher-tested" (i.e., submitted by practicing teachers as useful and high quality) Web sites with an improved search functionality based on an XML Metadata architecture (see below). The XML Metadata stands as a unique development task; however, it is integrated into the CD as a method for improving search and selection of resources by teachers with slow or limited internet access.

The SMELT project did not simply result in a set of tools for practicing teachers. Both the TAPPED IN Outreach and SMELT CD Development tasks provided opportunities for undergraduate engineering students to participate in SMELT as part of their educational experience. Members of the Society of Women Engineers (SWE) student chapter have participated as part of their chapter outreach activities; students in HCI design and engineering senior design students have participated in SMELT design tasks in formal classes as part of their design education.

TAPPED IN Outreach. The IRCT interactions with TAPPED IN began as part of STEP project interactions in late 1998. Since then, IRC Team members have participated in TAPPED IN Outreach activities including the TAPPED IN Carnival, held annually in July. In spring 1999, IRCT members Nicole Canty and Susan Zeyher participated in the design of a "virtual suite" for TAPPED IN librarian participants from Kentucky.

At the July, 1999, Carnival, IRCT members hosted a "Web site swap" for teachers who were interested in sharing or learning about useful Web sites for various subjects. Over 75 sites have been collected from TAPPED IN participants since then. This list has been pared to approximately 45 sites primarily focused on science and mathematics topics for middle and high school students. These sites have served as the prototype content for the SMELT CD Development task described below.

In spring 2000, the UW student chapter of the Society of Women Engineers (SWE) began a series of outreach activities with TAPPED IN participants. These activities include (during the academic year) formal "office hours" and scheduled question and answer periods for "Ask an Engineer" to assist teachers and high school students contemplating majoring in science and mathematics disciplines. High school to college transitions, women in science career role models, and general SWE outreach topics are among those

that have been discussed (see, for example, *http://www.tappedin.sri.com/cgi-bin/calendar/calendar.cgi?file=calendar&month=April*). This outreach activity has become integrated into SWE ongoing outreach plans and is now independent from IRCT involvement.

SMELT CD Development. The SMELT development concept of a CD to improve teachers' access and use of online information resources began during online discussions with teachers in TAPPED IN. Their complaints were that there were rarely teacher-oriented descriptions of useful materials that could be used in the classroom, and such materials were difficult to search for using commercial search engines. This problem is compounded for teachers from small and remote schools, who may have limited time, bandwidth, or restricted access (due to firewalls or other local site restrictions) for online searching for Internet resources.

One of the strongest and most frequent requests by members of the TAPPED IN community has been for a central repository of information, including Web sites that are suitable for classroom presentations and student use. Most teachers do not have the time, expertise, or awareness of the resources available on the Web to effectively search for those resources among the tens of millions of Web sites. A repository that can be trusted, easily found, and easily used to bring teachers quickly to sites they can use is a critical technical priority for improving teachers' use of the Web. Such a repository must incorporate a human technical support staff able to assist teachers in its use, answer questions that are raised, and help to maintain the repository as a dynamic learning environment.

The SMELT CD, therefore, was designed for educators and others interested in quickly and effortlessly finding information on the World Wide Web about science and mathematics education resources. From the users' manual:

> The CD's main resource is the "Accurate Search." By clicking on this button, you can search a database included in the CD for a number of resources available on the World Wide Web. You do not need to be connected to the Internet to search and evaluate the resources that are discussed in the CD database. You should connect to the Internet only when you have made your choice of resource(s) and want to download them. In this way, you can be in any location and look for resources without connecting to the Internet and dealing with long search times and a confusing maze of information.

The SMELT CD design process included major development steps in two Industrial Engineering design courses. During the fall 1999 semester, two project teams in IE 552 (Human Factors Engineering Design and Evaluation) were responsible for designing the interface, and support infrastructure, for a self-sustaining SMELT resource. These project teams created the initial interface structure for the SMELT CD, including installation tools and user guides.

This first "alpha" prototype was field-tested with teachers from Madison, as well as during a site visit to Roaring Fork High School, Carbondale, CO. Results from this initial site visit were brought back to IRC Team members to provide practitioner feedback for SMELT improvement. Additional feedback was obtained during a spring 2000 course project in the IE 692 Special Topics in Human Factors design course. Usability data on existing SMELT interface designs were collected from several users, and the results were combined with previous usability findings from Roaring Fork High School and TAPPED IN designers to produce the final SMELT CD prototype.

Educational XML Metadata. The major source of improvements in information search and resource selection in the SMELT CD comes from a novel information architecture based on the emerging Extensible Markup Language (XML) standards. Developing an appropriate architecture for use by teachers requires a focused development of "metadata" (data that describe, classify, and permit search), based on the needs and environment of projected users. The IRCT focus, unlike most XML standards, was on direct use by teacher practitioners for in-class resource use, rather than on educational administration or research applications. In addition, the goal of the IRCT activity was to provide teachers with easily identified and selected terms for searching science and mathematics resources. This direct focus on teacher practitioners as end-users, as well as hierarchical search architectures for science and mathematics, sets the IRCT apart from most XML development efforts.

The IRCT members used as references the Dublin Core Education Working Group and the national XML standards being developed in the U.S. (GEM), Australia (EdNA), and the European Union (ARIADNE). By spring 2000, the IRCT had become (through the efforts of Susan Zeyher) a productive and contributing member of The Dublin Core Education Working Group, providing insights, suggestions, and contributions at a level commensurate with the national groups. As a result, the IRCT XML Metadata can be considered a "world-class" architecture with capability for increasing development and application both at more detailed grains in specific science and mathematics disciplines, as well as parallel extensions to the social and behavioral sciences and humanities.

Discussions are currently underway to license the XML, information architecture, and resource coordination functions developed in the SMELT project to a Wisconsin company providing classrooms with access to live reports and continuing availability of mission data from NASA missions to the moon, asteroids, and Mars.

III. Staff and Collaborators

Staff: Barrett Caldwell (Team Leader), Armand Ardika, Nicole Canty, Virginia "Katie" Emery, Christine Lee, Nualwan Narong, Enlie Wang, Jeff Watson, and Austen Zuege.

Fellow: Susan Zeyher

Formative Evaluation

I. Team Mission

The objectives of the NISE Formative Evaluation team evolved over the course of the NISE's history. The first objective was to provide the NISE leadership with real-time information about the development of the Institute as an organization to guide midcourse corrections and thus maximize its goal achievement. By the middle of Year Three, the NISE team leaders agreed that the NISE had evolved to the point where the value of intensive formative evaluation reached the point of diminishing returns. The formative evaluation work was sustained at a low level in Years Four and Five. During Year Five the formative evaluation objective was completed with the production of *The Role of Formative Evaluation in the Development of an Interdisciplinary Academic Center* (NISE Occasional Paper No. 8). A second objective of the Team was to provide formative and summative evaluation of the NISE Forums. The Team pursued this objective by evaluating the First, Second, and Third Annual Forums and the Graduate Education Forum. The prototype for Forum evaluation having been established, the NISE Central Office assumed responsibility for this activity as of Year Four. During Year Two, the Team began pursuing a third objective, which was to draw on its social science expertise to produce syntheses and proceedings of the Second and Third Annual Forums, and the Graduate Education Forum. During Year Five, the Team pursued a fourth objective—an impact study of the College Level One Team's Field-tested Learning Assessment Guide (FLAG).

NISE's investment in formative evaluation is unique among education research centers and institutes. After 5 years of what we believe to be an especially productive institute, we conclude the investment has more than paid for itself. A research center of NISE's size and challenging scope of work is difficult to create and maintain. Time is of utmost importance; productivity must begin immediately and increase over time. NISE's commitment to interdisciplinary work across the boundaries of science, mathematics, social science, and education added to the challenge. The formative evaluation team efforts identified key problems as they arose and pointed the way to timely solutions.

II. Accomplishments

Formative Feedback on the NISE as an Organization

The feedback that the Formative Evaluation Team provided during the first three years helped Institute leaders understand how various NISE constituents were experiencing and viewing the NISE teams and the NISE overall (NISE Internal Document Nos. 1, 3, 4, 5, and 6). The Management Team, Team Leaders, and most team members used these reports to make organizational improvements. For example, the Formative Evaluation Team's feedback helped the NISE leaders

- redefine their goal for including individuals from heterogeneous backgrounds,
- redistribute their budget to fund people for a higher percentage of their time, and
- improve the quality of cross-team communication processes by instituting retreats and a new members' orientation packet.

The value of this formative evaluation process is described in "The Role of Formative Evaluation in the Development of an Interdisciplinary Academic Center." This paper, written during Year Five, explores the processes and emerging

principles by which one complex, cross-disciplinary organization—the NISE—developed. In addition, it locates the development of the NISE in the context of the research literature on other cross-disciplinary organizations and makes a case for the utility of formative evaluation for the development of academic centers. The primary purpose of this paper is to serve the NISE, NSF leaders and program officers, and others seeking to foster productive multidisciplinary academic research centers. We are moving with ever increasing momentum into a period when key problems in science, mathematics, and engineering education can no longer be solved by people from a single field of expertise, and few experts are trained to work in effective cross-disciplinary teams.

Forum Evaluation

The Formative Evaluation team evaluated the first three annual Forums and the Graduate Education Forum. These findings appear as Report Nos. 2, 7, 8, and 9 of the NISE Internal Document Series. These reports enabled the organizers of each successive Forum to design national events that have improved over time and have established a reputation for excellence with an increasingly wide national audience.

Forum Planning and Proceedings

Starting in the second year, the Formative Evaluation team began supporting the NISE by helping with the planning and analysis of the annual Forums. During 1996-97, the Team worked closely with the Systemic Reform and Interacting with Professional Audiences Teams to plan and organize the Second Annual Forum. In addition, the Formative Evaluation team took major responsibility for managing the production of the forum proceedings and produced a forum synthesis based on participant think pieces (short papers prepared by forum participants while on site). The synthesis comprises a key component of the proceedings and was very positively reviewed. During fall 1997, the Team joined the College Level One Team's forum planning group. Because the members of the Formative Evaluation Team are researchers at the UW-Madison Learning through Evaluation, Adaptation and Dissemination (LEAD) Center, they brought expertise developed through their SMET evaluation research work. From February 1998 through the beginning of Year Four (1998-99), the Team produced the Year Three Forum Proceedings, working closely with a CL-1 Fellow, Elaine Seymour. In addition, throughout Year Three, the Formative Evaluation team participated on the Graduate Education Forum planning group. During Year 4, the Team worked with the leader of the Graduate Education Forum to produce the Proceedings of this event.

Formative and Summative Evaluation of the NISE College Level One (CL-1) Team's Field-tested Learning Assessment Guide (FLAG) Web Site

The Formative Evaluation team conducted an impact study of one of the key products of the College Level One Team's Field-tested Learning Assessment Guide (FLAG) Web site. The FLAG is an online faculty development resource that provides visitors with an introduction to assessment, a description of a dozen or so alternative classroom assessment techniques developed by experts, and various examples of these techniques that can be downloaded and used (with some revision) in a course. The evaluation was designed to determine how well the FLAG fits the needs of instructors who teach introductory science, math, engineering and technology (SMET) courses and to explore ways in which instructors report using the assessment methods in their courses as well as any new understanding of assessment that they develop as a result of using the FLAG. Evaluation data were

gathered through individual interviews with a representative sample of 50 "reform ready" faculty (the audience for which the FLAG is designed) who teach biology, chemistry, engineering, mathematics, and physics at diverse types of institutions of higher education. The Team wrote a detailed formative feedback report for the College Level One Team (see below) and will soon submit a manuscript for publication as a paper intended for a broader audience. These documents address technical aspects of participants' use of the FLAG, overall reactions to current and future value of the FLAG, experience and reactions to the individual sections of the FLAG, and suggestions for improving the FLAG. The LEAD Evaluators also met with the College Level One Team web master with a list of specific suggestions that came from the interview data for improving the FLAG design. Many of these changes have been made and have been influential in the creation of the next College Level One product, the Learning Through Technology website.

III. Staff and Collaborators

Staff: Susan B. Millar (Team Leader), Dianne C. Bowcock, Anne C. Burda, Sarah K. A. Pfatteicher, Ramona L. Gunter, Sarah Mason, and Susan Daffinrud.

Products

NISE Internal Documents

No. 1 Formative Feedback Report 1.1, Baseline Report on the Team Leaders Team and Management Team, October 1995.

No. 2 Formative Feedback Report 1.2 First Annual NISE Forum Evaluation Report, April 1996.

No. 3 Formative Feedback Report 1.3, Baseline Report on NISE "Intermediaries," April 1996.

No. 4 Formative Feedback Report 1.4, Report on Non-Team Leader Team Management Team Participants, April 1996.

No. 5 Formative Feedback Report 2.1 Report on Perspectives of the Co-Directors, Team Leaders Team, and Management Team, September 1996.

No. 6 Formative Feedback Report 2.2, Report on Perspectives of the NISE Membership, April 1997.

No. 7 Second Annual NISE Forum Evaluation Report, March 1997.

No. 8 Third Annual NISE Forum Evaluation Report, April 1998.

No. 9 Graduate Education Forum Evaluation Report, August 7, 1998.

NISE Publications of the Formative Evaluation Team

Clune, W. H., Millar, S. B., Raizen, S. A., Webb, N. L., Bowcock, D. C., Britton, E. D., Gunter, R. L., & Mesquita, R. (1997). *Research on systemic reform: What have we learned? What do we need to know? Synthesis of the Second Annual NISE Forum, Volume 1: Analysis; Volume 2: Proceedings* (Workshop Report No. 4). Madison: University of Wisconsin–Madison, National Institute for Science Education.

Daffinrud, S. M., & Herrera, O. L. (2000). *Formative feedback report: Faculty participants' experience, reactions to, and use of the Field-tested Learning Assessment Guide (FLAG) Web site.* Madison: University of Wisconsin–Madison, National Institute for Science Education.

Millar, S. B. (Ed.). (1998). *Indicators of success in postsecondary SMET education: Shapes of the future.Synthesis and proceedings of the Third Annual NISE Forum* (Workshop Report No. 6). Madison: University of Wisconsin–Madison, National Institute for Science Education.

Millar, S. B. (2000). *The role of formative evaluation in the development of an interdisciplinary academic center* (Occasional Paper No. 8). Madison: University of Wisconsin–Madison, National Institute for Science Education.

Millar, T. S., Mason, S. A., Gunter, R. L., & Millar, S. B. (1999). *Synthesis of the science, mathematics, engineering and technology Graduate Education Forum* (Workshop Report No. 7). Madison: University of Wisconsin–Madison, National Institute for Science Education.

Summary

The Institute's goals are ambitious. We attack head-on three of the most important areas for improving SMET education. At the college level, we are helping to define an emerging field of SMET education R&D; at present, most education work in higher education is focused on innovation rather than research and is scattered. In teacher education, both preservice and inservice professional development, we seek to reconceptualize the field, identifying new and more effective practices and how they can be implemented successfully across the country. In systemic reform, we seek to set the research agenda so that this reform will be pursued with increasing effectiveness through continuous improvement for decades to come. Work in each of these areas enhances work in the others, as we focus on their interconnections. A strong commitment to dissemination insures that our work comes to the attention of the NSF, professional organizations, practitioners, and other researchers.

At the end of five years, we have launched a whole new approach for the continuous improvement of SMET education. The goal of high levels of SMET literacy for all segments of our population is better understood and more broadly accepted. New communities of scholarship and practice have been established, where scientists, education researchers, and education practitioners work collaboratively to address the enduring problems of SMET education, problems that have resisted solutions from more narrow approaches.

Appendix A
NISE Staff and Collaborators by Team

Systemic Reform

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College Level One

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[1] The National Partnership in Advanced Computational Infrastructure Supercomputer Project was active in Year 4

[2] The Graduate Science, Mathematics, Engineering, and Technology Education was active in Years 3 and 4

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Appendix B
NISE Conferences, Forums, and Workshops

Year One

Conference Title	Team	Location	Date
College Level One Planning Workshop: *Articulation, Equity, and Literacy Issues*	CL-1	Madison, WI	June 23-24, 1995
Systemic Evaluation Conference	SESR	Madison, WI	January 4-5, 1996
First Annual Forum *Professional Development for Science and Mathematics Education: Putting Knowledge into Action*	PD/IPA	Arlington, VA	March 18-19, 1996

Year Two

Policy Analysis of Systemic Reform Conference	PASR	Madison, WI	July 25-26, 1996
Understanding Interdisciplinary Teamwork Symposium	CSIC	Madison, WI	Nov. 15-16, 1996
Systemic Reform Seminar I	PASR	Madison, WI	January 15, 1997
Systemic Reform Seminar II	PASR	Madison, WI	January 17, 1997
Systemic Reform Seminar III	PASR	Madison, WI	February 4, 1997
Systemic Reform Seminar IV	PASR	Madison, WI	February 14, 1997
Second Annual Forum *Research on Systemic Reform: What Have We Learned? What Do We Need to Know?*	PASR/ SESR/ IPA/FE	Washington, DC	February 24-25, 1997
Evaluating Systemic Initiatives Conference	SESR	Madison, WI	March 13-14, 1997
Cooperative Learning in Higher Education	CL-1	Madison, WI	May 16-17, 1997

Year Three

National Education, Outreach, and Training Planning/Evaluation Workshop	NPACI	Madison, WI	September 11-13, 1997
Team Leader Team Retreat	TLT	Madison, WI	September 15, 1997
Special Emphasis Panel Meeting	SR	Arlington, VA	October 6-7, 1997
NISE National Advisory Board Meeting	NAB	Madison, WI	October 14, 1997
Professional Development Team Conference	PD	Washington, DC	November 14-15, 1997
Graduate Education Planning Conference	GE	Madison, WI	December 8-9, 1997
Third Annual Forum *Effective Practices and Their Indicators in Reforming Postsecondary SMET Courses: Shapes of the Future*	CL-1/ IPA/FE	Washington, DC	February 23-24, 1998
Professional Development Miniforum	PD	Las Vegas, NV	April 17, 1998
Special Emphasis Panel Meeting	SR	Arlington, VA	June 8-9, 1998
Graduate Education Forum	GE	Arlington, VA	June 29-30, 1998

Year Four

NISE National Advisory Board Meeting	NAB	Madison, WI	October 26, 1998
Fourth Annual Forum *Evaluation of Systemic Reform in Mathematics and Science*	SR	Arlington, VA	February 1-2, 1999
College Level One Institute for Technology Planning Retreat	CL-1	Madison, WI	April 1-3, 1999

Year Five

Team Leader Team Retreat	TLT	Madison, WI	August 23-24, 1999

NISE National Advisory Board Meeting	NAB	Madison, WI	October 18, 1999
National Science Teachers Association Conference *Reforming Professional Development*	PD	Orlando, FL	April 7, 1999
Fifth Annual Forum *Diversity and Equity Issues in Mathematics and Science Reform:* *What Do We Know?* *What Do We Need to Know?*	SR	Detroit, MI	May 22-23, 2000

Appendix C
NISE Publications

Research Monographs

Item Code	Author	Title
RM1	Knapp, M.	Between systemic reforms and the mathematics and science classroom: The dynamics of innovation, implementation, and professional learning
RM2	Kirst, M., & Bird, R.	The politics of developing and maintaining mathematics and science curriculum standards
RM3	Rodriguez, A.	Counting the runners who don't have shoes: Trends in student achievement in science by socioeconomic status and gender within ethnic groups
RM4	Tate, W.	Race, SES, gender, and language proficiency trends in mathematics achievement: An update
RM5	O'Donnell, A., DuRussel, L., & Derry, S.	Cognitive processes in interdisciplinary groups: Problems and possibilities
RM6	Webb, N.	Criteria for alignment of expectations and assessments in mathematics and science education (in collaboration with the Council of Chief State School Officers)
RM7	Derry, S., DuRussel, L., & O'Donnell, A.	Individual and distributed cognitions in interdisciplinary teamwork: A developing case study and emerging theory
RM8	Ridgway, J.	The modeling of systems and macro-systemic change: Lessons for evaluation from epidemiology and ecology
RM9	Kahle, J. B.	Reaching equity in systemic reform: How do we assess progress and problems?
RM10	Kennedy, M.	Defining optimal knowledge for teaching science and mathematics
RM11	Springer, L., Stanne, M. E., & Donovan, S.	Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis

RM12	Lee, O.	Current conceptions of science achievement in major reform documents and implications for equity and assessment
RM13	Kennedy, M.	Form and substance in inservice teacher education
RM14	Rodriguez, A.	Equity through systemic reform: The case of whole-school mathematics and science restructuring in Puerto Rico
RM15	Eveland, W. P., & Dunwoody, S.	A review of educational hypermedia uses and effects with application to the study of learning via the World Wide Web
RM16	Clune, W.	Toward a theory of systemic reform: The case of nine NSF Statewide Systemic Initiatives
RM17	Mundry, S., Spector, B., Stiles, K., & Loucks-Horsley, S.	Working toward a continuum of professional learning experiences for teachers of science and mathematics
RM18	Webb, N. L.	Alignment of science and mathematics standards and assessments in four states
RM19	Ohana, C.	Preservice teacher cohorts and their implications for mathematics and science education
RM20	Heck, D. J., & Webb, N. L.	Purposes and issues of systemic evaluation in education
RM21	Rodriguez, A. J.	A Cross-case analysis of the Puerto Rico Statewide and the Miami-Dade Urban Systemic Initiatives: Promising examples of equity in systemic reform

Occasional Papers

Item Code	Author	Title
OP1	Raizen, S.	Standards for science education
OP2	House, E. R.	Implementing evaluation findings in government agencies
OP3	Clune, W. (Ed.)	Commentaries on mathematics and science standards
OP4	Tobias, S.	Some recent developments in teacher education in mathematics and science. A review and commentary

OP5	Kirst, M., Bird, R., & Raizen, S. A.	Tensions between mathematics and science content standards and local politics
OP6	Cooper, J. & Robinson, P.	Small-group instruction: An annotated bibliography of science, mathematics, engineering and technology resources in higher education
OP7	White, P. A. (Ed.)	NISE Fellows program: Feedback from past Fellows
OP8	Millar, S. B.	The role of formative evaluation in the development of an interdisciplinary academic center

Workshop Reports

Item Code	Author	Title
WR1	Bisgaard, S., et al.	College Level One: Articulation, equity, and literacy issues. The report of a workshop organized by the College Level One Team
WR2	Webb, N. L., & Heck, D. J.	Evaluation Strategies Project: A report of the Evaluation Questions Conference of the Evaluation Strategies Project
WR3	Hewson, P., & Loucks-Horsley, S.	Professional development for science and mathematics education: Putting knowledge into action. A synopsis of the First Annual Forum
WR4	Clune, W. H., Millar, S. B., Raizen, S. A. Webb, N. L., Britton, E. D., Bowcock, D. C., Gunter, R. L., & Mesquita, R.	Research on systemic reform: What have we learned? What do we need to know? Synthesis of the Second Annual NISE Forum. Volume 1: Analysis and Volume 2: Proceedings
WR5	Gance, L. L.	Understanding interdisciplinary teamwork: Challenges for research and practice
WR6	Millar, S. B. (Ed.)	Indicators of success in postsecondary SMET education: Shapes of the future. Synthesis and proceedings of the Third Annual NISE Forum
WR7	Millar, T. S., et al.	Synthesis of the science, mathematics, engineering and technology Graduate Education Forum

WR8	Webb, N. L.	Evaluation of systemic reform in mathematics and science: Synthesis and proceedings of the Fourth Annual NISE Forum

Briefs

Vol. 1, No. 1	Loucks-Horsley, S., Stiles, K., & Hewson, P.	Principles of effective professional development for mathematics and science education: A synthesis of standards
Vol. 1, No. 2	Webb, N.	Determining alignment of expectations and assessments in mathematics and science education (in collaboration with the Council of Chief State School Officers)
Vol. 1, No. 3	Weiss, I.	The status of science and mathematics teaching in the United States. Comparing teacher views and classroom practice to national standards
Vol. 2, No. 1	Ridgway, J.	From barrier to lever: Revising roles for assessment in mathematics education
Vol. 2, No. 2	Eveland, W., & Dunwoody, S.	Surfing the Web for science: Early data on the users and uses of *The Why Files*
Vol. 2, No. 3	Kahle, J. B.	Measuring progress toward equity in science and mathematics education
Vol. 3, No. 1	Mundry, S., & Loucks-Horsley, S	Designing professional development for science and mathematics teachers: Decision points and dilemmas
Vol.3, No. 2	Kennedy, M. M.	Form and substance in mathematics and science professional development
Vol. 3, No. 3	Meyer, R. H.	Value-added indicators: A powerful tool for evaluating science and mathematics programs and policies

Internal Documents
These confidential reports are part of the NISE's Internal Document series.

Item Code	Author	Title
ID1	Millar, S. B., Team Bowcock, D. C., & Burda, A. C.	Baseline report on the Team Leaders Team and Management
ID2	Millar, S. B., Bowcock, D. C., & Burda, A. C.	First Annual NISE Forum
ID3	Millar, S. B., Bowcock, D.C., & Burda, A. C.	Baseline report on NISE "intermediaries"
ID4	Millar, S. B., participants Burda, A. C., & Bowcock, D. C.	Report on non-Team Leader Team/Management Team
ID5	Bowcock, D. C., Team, and Pfatteicher, S. K. A., & Millar, S. B.	Report on perspectives of the co-directors, Team Leaders Management Team
ID6	Bowcock, D. C., Gunter, R. L., Millar, S. B., & Pfatteicher, S. K. A.	Report on perspectives of the NISE membership
ID7	Gunter, R. L., Mesquita, R., Bowcock, D. C., Pfatteicher, S. K. A., & Millar, S. B.	Second Annual NISE Forum evaluation report
ID8	Mason, S., & Millar, S. B.	Third Annual NISE Forum evaluation report
ID9	Gunter, R., & Mason, S.	Strengthening graduate education in science and engineering: Promising practices and strategies for implementation

ID10	White, P. A.	Fourth Annual NISE Forum evaluation report
ID11	White, P. A.	Fifth Annual NISE Forum evaluation report

NISE Books

Clune, W. H., Osthoff, E. J., & White, P. A. (2000). *Theory and practice of systemic reform of mathematics and science education*. Manuscript in preparation.

Derry, S. (2000). *Toward a cognitive science of interdisciplinary collaboration*. Manuscript in preparation.

Loucks-Horsley, S., Hewson, P., Love, N., & Stiles, K. (1997). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

Lynch, S. (2000). *Equity and science education reform*. Mahway, NJ: Erlbaum.

Mintzes, J. J., Wandersee, J. H., & Novak, J. D. (Eds.). (1998). *Teaching science for understanding: A human constructivist view*. San Diego, CA: Academic Press.

Mintzes, J. J., Wandersee, J. H., & Novak, J. D. (Eds.). (2000). *Assessing science understanding: A human constructivist view*. San Diego, CA: Academic Press.

Mundry, S., Britton, E., Raizen, S., & Loucks-Horsley, S. (2000). *Designing successful professional meetings and conferences in education: Planning, implementation, and evaluation*. Thousand Oaks, CA: Corwin Press.

Mundry, S., & Loucks-Horsley, S. (2000). *Challenges in designing effective professional development programs*. Manuscript in preparation.

Mundry, S., Loucks-Horsley, S., et al. (2000). *Learning to design: A field book for designing professional development for teachers of science and mathematics*. Manuscript in preparation.

Stiles, K., Loucks-Horsley, S., et al. (2000). *Learning by design*. Manuscript in preparation.

Webb, N. L. (Ed.). (2000). *Evaluating systemic reform in mathematics and science*. Manuscript in preparation.

Joint Publications

Adelman, C. (1997). *Leading, concurrent, or lagging? The knowledge content of computer science in higher education and the labor market* (ED Publication No. PLLI 97-8046). Washington, DC: U.S. Department of Education.

Adelman, C. (1998). *Women and men of the engineering path: A model for analysis of undergraduate careers* (ED Publication No. PLLI 98-8055). Washington, DC: U.S. Department of Education.

Britton, E., Raizen, S., Kaser, J., & Porter, A. (2000). *Beyond description of the problems: Directions for research on diversity and equity issues in K-12 mathematics and science education*. Washington, DC: National Center for Improving Science Education.

NISE Web Sites

Collaborative Learning: *http://www.wcer.wisc.edu/nise/cl1/CL/default.asp*

College Level One: *http://www.wcer.wisc.edu/nise/CL1*

Field-tested Learning Assessment Guide (FLAG):
http://www.wcer.wisc.edu/nise/cl1/flag/default.asp

Graduate Education Forum: *http://nise.wcer.wisc.edu/gradforum/*

Learning Through Technology: *http://www.wcer.wisc.edu/nise/CL1/ilt/default.asp*

NISE home page: *http://www.nise.org*

NPACI Supercomputer Project: *http://www.npaci.edu/Online*

NSF TechEd99 Workshop: *http://www.wcer.wisc.edu/teched99/*

Student Assessment of their Learning Gains (SALG): *http://www.wcer.wisc.edu/salgains/instructor/*

Secondary Teacher Education Project: *http://www.wcer.wisc.edu/step/*

The Why Files: *http://whyfiles.news.wisc.edu*

Appendix D
NISE-Related Publications

Adelman, C. (1997). *Leading, concurrent, or lagging? The knowledge content of computer science in higher education and the labor market* (ED Publication No. PLLI 97-8046). Washington, DC: U.S. Department of Education.

Adelman, C. (1998). *Women and men of the engineering path: A model for analysis of undergraduate careers* (ED Publication No. PLLI 98-8055). Washington, DC: U.S. Department of Education.

Boone, W. J., & Kahle, J. B. (1998). Student perceptions of instruction, peer interest, and adult support for middle school science: Differences by race and gender. *Journal of Women and Minorities in Science and Engineering, 4*(4), 333-340.

Bowen, C. W. (2000). A quantitative literature review of cooperative learning effects on high-school and college chemistry achievement. *Journal of Chemical Education, 77*(1), 116-119.

Clune, W. H. (1998). The national standards in math and science: Developing consensus, unresolved issues, and unfinished business. *Teachers College Record, 100*(1), 6-7.

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