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ABSTRACT

In response to the findings and recommendations of a planning conference in 1989, the Department of Energy (DOE) increased its funding of ongoing precollege programs in science and mathematics education and launched some new initiatives. To evaluate and improve its efforts, the DOE has also initiated a 4-year evaluation and technical assistance project at the National Center for Improving Science Education. This paper focuses on the strategies developed and some results emerging from the formative evaluation component of this project. The major formative evaluation strategy is the profiling of the DOE's education activities, with the development of a template for each of the five identified program types. The template for profiling the teacher-development programs of the DOE laboratories is presented as an example of the way in which a template can be used in formative evaluation. Some of the emerging results of the teacher-development research are outlined to demonstrate evaluation results. One figure illustrates an excerpt from the teacher development template. (Contains 5 references.) (SLD)

Formative Evaluation of the K-12 Education Programs of the Department of Energy

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Background

In 1989, the U.S. Department of Energy (DOE) held a planning conference in Berkeley on how it could respond effectively to the challenge presented by *The Nation at Risk*, the document that proclaimed in 1983 that "the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and as a people." The report resulting from the Berkeley conference emphasized DOE's mission of supplying the nation with the "energy resources, technologies, and information needed for economic progress and national security," and the need to build "a scientifically and technologically informed citizenry to help chart a course for public energy policy." It also concluded that DOE would have difficulty in realizing its mission because the low achievement of many students in mathematics and science kept them from advancing sufficiently to consider technical occupations. One of the major problems noted in the report was the inadequate training of teachers; other problems noted were outdated curricula, poor facilities and equipment for teaching science, and lack of student interest and motivation, particularly on part of ethnic minorities and girls. Because of its special facilities and its core of highly qualified personnel, the DOE was thought to be strategically positioned to begin addressing some of these problems.

In response to the findings and recommendation of the Berkeley conference, the DOE substantially increased its funding of ongoing precollege programs in science and mathematics education and launched several new initiatives. In 1990, over 200,000 teachers and students were affected by DOE programs; the agency's 1993 budget allocated roughly $25 million to precollege education, not counting contributions by the Laboratories. This level of effort signals considerable involvement of DOE's science and engineering community working to improve science learning in the schools. Aware of the need to evaluate and improve its efforts, the DOE also has funded a four-year evaluation and technical assistance project at the National Center for Improving Science Education. The project is designed to achieve two overarching goals:

- To develop and initiate a system for ongoing formative and summative evaluation of the Department's precollege education programs that will provide feed-back loops for future program planning in this area;

- To work collaboratively with staff from DOE Headquarter, the Laboratories, and associated facilities to share knowledge of exemplary science and mathematics education and build evaluation capacity within the Department and its internal and external program managers.

These goals are highly interrelated; they are aimed at creating the kinds of self-improvement norms and activities needed for programs to achieve their maximum impact. We at the Center are taking initial responsibility for a set of research activities that will model useful evaluation practices and begin to provide data for what works to improve science and mathematics education. These activities are being conducted collaboratively with DOE staff and the Labs, with one of the purposes being to build the capacity of program managers who have primary responsibility for formative evaluation to continue such activities in the future in order to improve their programs. Although the project as a whole is concerned with impact assessment as well as with formative evaluation and technical assistance, this paper focuses on the strategies developed and some results emerging from the formative evaluation component of the project.

First, however, we should note the challenge posed by combing in one project evaluation activities with technical assistance. For technical assistance to be effective, clients and program participants must feel free to reveal problems they are experiencing, be willing to have weaknesses uncovered through evaluative information, and have sufficient trust to ask hard questions about program elements that don't seem to be working as expected. These elements of trust and willingness to share information, even when they point up weaknesses, also are indispensable to formative evaluations which, after all, should aim for program improvement. This trust is not easy to maintain when impact assessment is involved, however, particularly if there is any threat (perceived or real) of funding decisions being linked to impact results. Our responses to this tension are as follows:

- We see our role as primarily in the technical assistance and formative evaluation modes. This allows us, even as we collect information appropriate for preliminary summative evaluations, to accompany such information with explanations of salient program and contextual factors and, more importantly, with specific recommendations (framed collaboratively with the Labs and DOE headquarters staff) for improving programs.

- Through collaborative activities that we are sponsoring, the Labs are sharing information with each other which we believe will serve to make each Lab's individual programs more effective. At the same time, we are working with DOE headquarters staff to use evaluative information constructively for program improvement.

- We are encouraging DOE to construct a long-range time schedule for the phasing of formative and summative evaluations. At any given time, we see both as necessary, but in different mixes. In the current initial period, much more energy and resources should be devoted to efforts that will improve programs (formative evaluation and technical assistance); over the long range (five to ten years, depending on the nature of the program), as programs become well defined and established, evaluation efforts should concentrate on summative evaluation.

- Lastly, through a series of seminars with evaluation experts, we are reviewing the hallmarks of good evaluations with the DOE participants and engaging them in developing criteria for assessing the evaluation information being generated by themselves and by outside evaluators, so that they will become informed evaluation sponsors and consumers.

Formative Evaluation Strategies

In concert with the priorities set by the Federal Council for Science, Engineering, and Technology (FCCSET), the Department of Energy is pursuing two overarching long-term goals in its efforts to improve mathematics and science education:

- Arming teachers with a better grasp of subject matter and more effective strategies for teaching science and mathematics through teacher enhancement programs; and

- Improving student outcomes, particularly their achievement and persistence in pursuing technical fields.

In order to achieve these goals, DOE emphasizes the following elements in its programs: maximizing the use of the unique resources of the DOE's Laboratories, including the science and engineering expertise of their staff, their advanced facilities and equipment, and their involvement in cutting-edge research; forming partnerships with other federal agencies, states, businesses, higher education institutions, and community organizations; focusing on minorities and other groups underrepresented in the science and engineering professions; supporting systemic reform, i.e., impact on whole schools, districts, or states; and promoting the best in science education research and practice, including emphasis on hands-on, experiential learning.

In the first phase of our work with DOE, we jointly identified five program types: (1) intensive experiences for students; (2) systemic change efforts generally involving whole districts; (3) research opportunities for teachers; (4) teacher enhancement through workshops or institute-like experiences; and (5) interventions involving students and teachers simultaneously. The existence of programs focused on five different areas increases the challenge of understanding what is occurring with DOE support. During the four years of the project's life, we will be concerned with piloting evaluation approaches and instruments for each of these different program types.
Our formative evaluation strategies are designed to find out:

- what the primary components of a program are, and which of these the program operators believe to be critical;

- to what extent the design of each program being offered nationally or by individual DOE Laboratories matches what we know from research and best practice to be effective science and/or mathematics education;

- to what extent the design matches research findings and best practice in student enhancement and motivation, teacher enhancement, or systemic change (depending on the type of program);

- to what extent what is actually happening in the program matches the program design, and what facilitating or impeding factors are being encountered; and

- what needs to be done to improve, stabilize, and institutionalize programs, once judgments on effectiveness have been made.

Not only is it helpful to ask these kinds of questions early in the development of promising new education initiatives, but it is also important to build into all parts of such programs the capacity and expectations for ongoing reflection and evaluation. In our view, the early, formative stages of program development and implementation -- which characterize many of the current DOE programs -- are opportune for such reflective activity.

Our major formative evaluation strategy is the *profiling* of DOE education activities, i.e., carefully gathering information about what is happening when the program is going on. This process, developed by the NETWORK over ten years ago (see references), generates detailed descriptions and facilitates understanding of how each program works and to what extent the programs are actually doing what they are expected to be doing -- by DOE headquarters, Lab program developers, and participants. It thus enables program managers and evaluators alike to address both implementation and impact issues.

We are developing a template for each of the five different program types, based on research and exemplary practice where they exist, and enhanced by the experiences of program developers as to what makes a particular type of program effective. The use of templates facilitates communication, assessment of variation, and understanding of why different outcomes occur in different settings. Each template is a description of the components of an idealized program model, with possible variations. The template allow us to profile each program that within a program type in a standardized way, so that similar programs can be compared to the idealized model and within and across settings. To date, three templates have been completed: for teacher research participation, for teacher enhancement, and for student programs. The template for systemic development is nearing completion.

Practice profiles and the templates on which they are based typically are developed by evaluators in collaboration with program developers. They are piloted in the field to check whether any components are missing and whether the full range of variation has been anticipated by the developers. The distinction between "ideal", "acceptable", and "unacceptable" variations is based largely on the principles of effective practice, the tested or theory-based concepts underlying the program's design, identified by the program's developers. The use of profiles in evaluation can yield quantitative data about the extent of implementation of program components. The variations within each component can be scaled from ideal implementation to non-implementation; components can be weighted by their developers as to their importance; and summary implementation scores can be derived from individual program participants. The degree of implementation can be considered when examining impact data so that questions about why impact seems to be particularly high or low can be addressed.

Following this methodology, we have worked closely with Lab program and evaluation staff and DOE headquarters staff to identify the key components of the programs for which we have constructed templates; we have piloted the templates in a limited number of settings and revised them on the basis of the pilots; and we have the trained Lab staff to use revised templates to profile their programs. We supplement the descriptive information about program components gathered through use of the template with data on the various structural and cultural elements existing in each setting that serve to constrain or support the program. This information begins to address questions of how different settings contribute to the way a program is designed and implemented, and ultimately to its success. We hope that for those programs not included in the five clusters noted above, Lab staff will be able to develop their own templates as a result of our work with them.

Profiling of the Labs' Teacher Development Programs

The template for this cluster of programs was developed in early 1992 and piloted in five Labs between mid 1992 and early 1993. The remaining Labs then profiled their own programs; the information summarized below is based on data gathered by the National Center and the Laboratories.

One of the seven components of the teacher development template is displayed in detail in Figure 1; the other components--spelled out in equal detail-- are: Program Administration, Vision for the Classroom, Unique Contribution of the Laboratory, Follow-up, Teacher Leadership and Responsibility, and Program Evaluation. The complete template, operational definitions, and other information is available from the National Center in "Profiling Teacher Development Programs: An Approach to Formative Evaluation". The template was used to address questions such as:

- What is best practice for teacher development programs?
- To what extent is a program in a specific Lab designed to reflect what is most effective?
- To what extent does the program in place reflect best practice?
- To what extent is the program's design actually carried out?
- Where are the gaps? What can be improved? What is beyond the program operators' control?

Five teacher development programs were selected for piloting, which ran from July, 1992 to April, 1993. They were chosen to vary across such dimensions as grade level of

Figure 1: Excerpt from Template for Teacher Development Programs, November 1993

Components of Effective Practice	Intended Program	Actual Program
3. Teacher Development Program Activities		
a. are appropriately designed for adult learners[8,9] • focus on growth rather than defects • relevant and practical • focus on teachers' interests and concerns • link teachers to resources and support		
b. model teaching principles and strategies that can be transferred to the classroom[6,12,13]		
c. allow teachers to actively construct knowledge through hands-on activities[12,13]		
d. include the use of tools, methods, and processes of scientists[12,13]		
e. immerse teachers in the scientific process[12,13]		
f. include actual or simulated problems or challenges of "real world" science[12,13]		
g. are designed so teachers learn cooperatively in small groups[6,12,13]		
h. include opportunities to practice new classroom behaviors or strategies[6,12,13]		

teachers, format, types of target populations, and the scientific discipline focused on. The programs and sponsoring Labs were: the Topics in Modern Physics (TMP) program of Fermilab; the Science Alive program of Pacific Northwest Laboratory; the Science Advisors (SCIAD) program of Sandia National Laboratories, New Mexico; the Teacher Opportunities to Promote Science (TOPS) program of Los Alamos National Laboratory; and the Chicago Science Explorers program of Argonne National Laboratory.

The data used for profiling were collected through examination of program materials, a two-day site visit by at least two National Center staff and associates, and comments on the draft profile by the Lab program staff. The site visit involved interviews with program managers, participating teachers, scientists, and in some cases, teachers from past years, students, principals of participating teachers, program evaluators, and partners such as school district and museum personnel. In addition, site visitors observed the teacher development activities whenever possible. These activities took place in the Laboratories, schools and classrooms, hotel meeting rooms, and in the field (e.g., on a farm where waste dumping was occurring).

After the pilot visits were complete, National Center staff developed a profile of the programs, identifying issues that cut across the five programs as well as corresponding recommendations for program improvement. The resulting report, "Profiling Teacher Development Programs: A Pilot Report," was drafted for review by the Labs and DOE in October, 1993, and completed in December, 1993.

After the pilot, other Laboratories profiled one of their teacher development programs. The eight programs profiled were: the Teachers' Supercomputing Workshop, Lawrence Livermore National Laboratory; Fossil Energy Teacher Institutes, Oak Ridge Institute for Science and Education; BEAMS (Becoming Enthusiastic About Math and Science), Continuous Electron Beam Accelerator Facility; Oak Ridge Materials Science Summer Institute, Oak Ridge National Laboratory; Inservice Course in Environmental Science, Brookhaven National Laboratory; Partners for Terrific Science and Chemical Education for Community Understanding Program (CEPUP), Fernald Environmental Management Project; and the National Teacher Institute in Materials Science and Technology, Pacific Northwest Laboratory.

Each Laboratory was to complete a template on its selected program, send it to the National Center for feedback, and then submit a revised template and set of issues and recommendations to the National Center staff, who in turn would write a summary report. In addition to the five pilot sites, only two of the remaining eight programs sent in both a revised template and set of issues and recommendations. Others completed parts (e.g., a template but no discussion of issues and recommendations). Factors that may have contributed to this lack of completion are: (1) insufficient time and attention given to building the skills and knowledge base necessary for engaging in this type of self-evaluation, (2) the format of the template which constrains in-depth responses, and (3) the lack of good examples of template and profiling completions to serve as models. Our current work with the Laboratories is addressing these issues.

Some Emerging Results

1. Viewing Teacher Development as a Long-Term Proposition

The research literature on teacher development points out the need for sustained engagement with teachers; "one-shot" efforts have limited usefulness (Fullan, 1991; Loucks-Horsley et al., 1987). For teachers to make meaningful change in their practice, a development effort must be both intensive and extensive. Indeed, the majority of the Lab programs that were profiled provided participants with intense experiences: a three week residential program, often with some follow up, was typical. The most intensive was the program that worked with the same teachers over a three-year period during the summer and academic year. There were exceptions, however. One was a program that included one-day inservices for teachers to learn to use activities developed by other teachers to accompany field trips and videos. The shortest program -- designed to train participants in the use of a kit of materials from Lawrence Hall of Science -- was five hours.

When Laboratories consider alternative designs that allow their teacher development activities to extend over time, they are faced with some difficult issues. First is one of resources. Having one-week sessions spread out over the year rather than one three-week session raises travel costs. Another issue is teacher time: Labs have learned that summer sessions are preferable to those that take teachers out of class during the school year. Finally, related to the first issue of resources, is the number of teachers that can be involved. If more time is taken per teacher, necessarily the number of teachers reached will need to decrease.

2. Helping Teachers Make Explicit Links with Their Own Curriculum

The majority of programs that were profiled provided teachers with materials or the opportunity develop lessons, units, or activities to use back home; yet only two made any attempt to make explicit links between the activities and the curriculum frameworks of the state and/or city where teachers worked. With the current emphasis on standards and frameworks, teachers are nearly all pressured to teach within some parameters; and if they are to use what they learn in Laboratory programs, Labs need to pay attention to these frameworks in their sessions.

Good frameworks define not only content, but they have a teaching/learning model that is based on research (see reports from the National Center for Improving Science Education). Most frameworks that are emerging at this time (as opposed to some written in the '70s and '80s) are similar in their focus on major concepts (such as change, systems, cause and effect), skills and dispositions toward science; and their learning models resemble the inquiry or investigative process, with attention to presenting content in a context appropriate to students' development levels. Helping teachers think about their instruction within such a framework is very helpful, particularly if it is one that guides their district's or state's science curriculum. Casting new material within an existing context makes it seem more integrated than something completely different that has been added on. For programs interested in having teachers transfer their Lab experience to the classroom, this is an important point to keep in mind. The more integrated the change, the more easily can it be implemented.

3. Making Links to the Community and Cultural Context

To the extent that DOE is serious about its commitment to reaching students from underrepresented populations, Labs need to consider how they work with teachers who themselves are from these populations and/or who teach students from these populations. This issue cuts two ways. First is the hope that communities can become advocates for science and technology education, supporting their teachers in efforts to improve as well as becoming actively involved in helping students learn. Second is the need for teachers to understand the cultural context of the students they teach along with differences in their learning style preferences and, more relevant to Lab programs, to understand the way the students' culture views Western science and the implications that has for student learning.

To their credit, the Laboratories exert considerable effort to recruit teachers serving minority student populations. With some exceptions, however, the profiling data indicate that most programs are not specifically addressing the issue of cultural relevance of science for the particular populations the teachers were teaching, including high concentrations of African American, Hispanic, and Native American students. A random classroom observation made in one program showed that boys were actively involved in the lessons but girls were not. No program specifically mentioned addressing the needs and interests of girls. Descriptions focused largely on the presence of role models (females and minorities) rather than the content and/or presentation of the material. One program indicated that a session on multicultural education was part of their institute but did not say what specific content was covered. A few programs said that their program accounted for diversity but provided no details as to how that was occurring.

4. Involving Schools or Districts to Support Teachers and Extend Their Reach

Teachers need support back home to do new things, including a relationship with the principal or department chair that creates realistic expectations, encourages specific kinds of help after the institute, and, expresses the administrator's commitment to the teacher's success in implementing changes. Support is even more important when Lab programs hope for change beyond the individual teacher, as was the case for most of the programs profiled. In eight of the programs there was an expectation that the teachers would share the information and experience gained during the Lab program with their colleagues.

Attending a DOE Lab workshop or some form of teacher inservice requires administrator approval, but more than that is needed to help the teachers work with their colleagues. Spreading their new knowledge and skills requires time, making science a priority in the school, supplies, and understanding that all won't be changed effectively overnight. Moreover, the teacher presenting a workshop for their colleagues may need assistance in the design of the workshop, presentation and group dynamics skills, audiovisual materials, evaluation, follow-up, and other aspects of planning and conducting staff development. The Labs might play a useful role in communicating with their teacher participants via electronic mail in support of teachers' dissemination activities.

5. Advocating a New Model of Pedagogy

DOE Laboratories have a clear contribution to make in terms of science content: they are places where scientific knowledge is not only used day-to-day but refined and created. Thus a logical goal for teacher development programs is updating teachers' science content knowledge. Less clear, however, is the Lab's role in promoting new ways of teaching science.

Laboratories' programs varied widely in their approach to pedagogy. One program purposely did not model particular teaching principles or strategies, instead taking the approach of a university seminar enriched by tours and demonstrations. Other programs were also more traditional in that the typical format was lecture/discussion/ demonstration/lab. Field trips and tours were common components of these programs. Other programs tried using more activity-based approaches with varying degrees of success. Participants in one program said of their hands-on, inquiry based approach that they used the tools and processes of scientists and were immersed in the scientific process, having designed and conducted experiments to which they did not know the answers at the outset. Other programs used activity-based approaches with apparently insufficient understanding of the specifics of such approaches, especially how to ensure that teachers were increasing their science knowledge as well as process skills.

6. The Role of Labs in Teacher Development

The Department of Energy is a relatively new player in teacher development, and it is continuously searching for its optimal role. The profiled teacher development programs were taking different approaches to a given Lab's role. Some of the Labs clearly lead from the strength of the Lab in linking their teacher development program to their ongoing research. Others use scientists to demonstrate that science can be relevant, fun, and a career pursuit of "real people." Still others engage teachers with scientists in investigations like those done at the Lab, in an effort to model how science learning can be holistic, real-world, engaging, and relevant. Some attempt to demonstrate how science, technology, and mathematics are integrated -- rather than separated into distinct areas -- in real-life problems.

All these are critically important roles for scientists -- to connect teachers to the real world and knowledge base of science, and to help them develop a deep understanding of how scientific knowledge is created. This increases the potential that students will not think of science as a dry body of facts to be mastered, a field they would never want to enter.

Having Lab staff demonstrate science teaching approaches, whether with teachers in their institutes, or with students in their classrooms, is another role altogether. Acknowledging that teaching, as a profession, has its own knowledge base and technical skills suggests that scientists should not be expected to be excellent teachers (just as teachers shouldn't expected to be excellent scientists). This issue for the Labs is whether they believe that their institutes should exemplify cutting-edge teaching strategies as well as cutting-edge science and, if so, how they can do that.

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