

Investing in Our Future: A Survey of Support Offered to Beginning Secondary Science and Mathematics Teachers

Inducting well-trained mathematics and science teachers, who will be required to move the nation toward excellence in mathematics and science, is not obstacle-free.

Policy makers in the United States have established a national goal of educational excellence in science and mathematics (National Science Board, 1998). Two important aspects of achieving excellence in education are the training of exemplary science and mathematics teachers and supporting them within their educational system (Chaney, 1995; Monk, 1994). Providing a framework for this effort are the National Science Education Standards [NSES] (National Research Council [NRC], 1996), the Professional Standards for Teachers of Mathematics [PSTM] (National Council of Teachers of Mathematics [NCTM], 1991), and the Benchmarks for Science Literacy [BSL] (American Association for the Advancement of Science [AAAS], 1993) - products of synthesized educational research. Currently, teacher training and professional development programs are being organized around these standards.

Inducting well-trained science and mathematics teachers, who will be required to move the nation toward excellence in science and mathematics, is not obstacle-free. Newly trained science and mathematics teachers are

primed to enact the practices they have experienced in their preservice programs, practices that are consistent with the student-centered, inquiry-based learning environment espoused in the national standards documents. Unfortunately, during the first years of a teaching career, the pedagogical framework, skills, and knowledge established in the preservice training are often lost (Salish I Research Project, 1997).

In Arizona, Sowell et al. (1995) found that secondary science and mathematics teachers were inclined to use non-student-managed activities, rather than those in which students generate their own learning (p.29). In addition, they found that teachers used

textbooks and their personal beliefs as their major curriculum sources (p.18). Beginning science and mathematics educators entering this environment will most likely encounter a disparity between how they were prepared in their teacher preparation program and what is actually occurring in the classrooms of their schools.

Induction programs provide the support appropriate for resolving conflicts faced by beginning teachers (Little, 1990). In this sense, a successful induction program becomes a critical link in the entire professional development process of a teacher. The disparity between preservice training and beginning practice must be resolved in such a way that beginning teachers can both survive in the educational system *and* sustain their standards-based training.

The issues mentioned above are important and in need of study. In one state, Arizona, policy makers supported university researchers to conduct a statewide survey of school district induction programs. In addition, beginning secondary science and mathematics teachers were surveyed regarding their perceptions of their

Induction programs provide the support appropriate for resolving conflicts faced by beginning teachers.

Inducting well-trained science and mathematics teachers, who will be required to move the nation toward excellence in science and mathematics, is not obstacle-free.

teacher preparation and induction programs. This study was conducted to inform policy makers about the status of preservice education and induction programs. This paper reports and discusses the process of the study and several of the relevant findings, and how this paper informed policy at the state level. The authors hope that other policy makers interested in examining their own local or regional preservice or induction programs can draw upon the information in this paper.

Questions Addressed

This study was conducted to answer questions concerning the preservice education programs of beginning secondary science and mathematics teachers, and the induction programs in which they participated after entering the public school sector. The following general questions were utilized to guide data collection:

1. Do districts provide induction programs for their beginning secondary science and mathematics teachers? If so, how are these programs configured?
2. How do beginning secondary science and mathematics teachers rate various components of their induction programs? What strengths and weaknesses do they perceive?

3. Do the formal induction programs in which beginning secondary science and mathematics teachers participate fulfill the district expectations of those programs?
4. How do beginning secondary science and mathematics teachers rate various components of their preservice programs? What strengths and weaknesses do they perceive?

Data Collection and Analysis

This study targeted each school district and each beginning secondary science and mathematics teacher in Arizona. Secondary science and mathematics teachers were targeted because of the recent emphasis on science and mathematics education, and the shortage of qualified science and mathematics teachers in the state. "Beginning" refers to teachers in their first, second, or third year of teaching—which is also noted as the induction phase. During the spring of 1998, each school district in Arizona was contacted to obtain information about mentoring programs for their beginning science and mathematics teachers. If a formal or informal induction program existed, the contact person knowledgeable about the program was sent a questionnaire requesting information pertaining to the structure and requirements of the program, selection and training of mentors, compensation of mentors, and additional programs for beginning teachers. In addition, each district contact was asked how many induction-level science and mathematics teachers were employed. The survey for districts was composed of questions requiring a specific response (e.g., Do you have a mentoring program for beginning teachers? How do you select mentor teachers? How are your mentor teachers compensated?). Non-

responding districts were provided a follow-up questionnaire in order to increase the response rate. A total of 256 districts were contacted, and 189 provided information on their induction programs; thus, achieving a response rate of 74%.

Induction teachers identified by the initial survey of districts were sent a questionnaire either directly from the researchers of this study or via the district professional development contact person. This questionnaire asked the beginning teachers to evaluate their preservice and induction programs and to provide demographic information about themselves. The survey for beginning teachers was comprised of closed and open-ended questions that encompassed three general areas: preservice program, induction program, and background information. The questions were either specific-response (e.g., How many years have you been teaching? What is your major? How often do you meet with your mentor?), descriptive-response (e.g., Name two strengths of your preservice program; Name two areas in which your induction program could improve), or response on a Likert scale (e.g., Rate your preservice program in regard to the information you received about the planning of instruction, the *NSES* [NRC, 1996], assessment and classroom management). An estimated total of 395 beginning science and mathematics teachers were sent surveys and 186 returned them, giving a response rate of 47%. The complete district and induction teacher questionnaires and their development can be found in Luft and Cox (1998).

Data from the surveys were coded and entered into a computer by one researcher. Either descriptive, correlational, or ANOVA analysis procedures were used to analyze the data.

When significance was found, and if appropriate, follow-up pair-wise comparisons were made. SPSS 8.0 was the statistical package used to analyze and depict the data.

General Findings

During the initial contact and survey distribution phases of this study it became evident that school districts did not have a reliable mechanism in place to monitor beginning teachers. It was extremely difficult for districts to identify their beginning science and mathematics teachers. Best estimates were often given instead of actual numbers, and some induction teachers identified by district personnel were actually beyond their third year.

Of the districts that responded and provided information about their induction programs, 21% indicated that a formal mentoring program was currently in place for beginning science and mathematics teachers (as well as other new teachers), and 8% indicated that the induction programs in their schools were informal. Of the formal programs described, 68% did not extend beyond one year. Small districts (school districts with fewer than 600 students in K-8 or 9-12) were less likely to have induction programs than large districts. The analysis of data indicated 76% of beginning science and mathematics teachers in small districts not participating in induction programs as compared to 41% in large districts.

At the national level, there has been an increased emphasis on supporting beginning teachers.

At the national level, there has been an increased emphasis on supporting beginning teachers. Unfortunately, at the time of this study, Arizona did not have a mandatory requirement for induction programs; therefore, few mentoring programs existed for beginning teachers. When induction programs were offered, they rarely extended beyond a year. These findings are consistent with national data that indicate little assistance is available to most beginning science and mathematics teachers (National Commission on Teaching and America's Future, 1996). The findings also suggest that science and mathematics teachers in small districts may be sorely underserved during their induction years, a finding not reported previously in the literature.

Profile of Induction Teachers

Over half of the secondary induction science and mathematics teachers (58%) surveyed were in their first career, with 71% holding secondary certificates and 26% holding elementary certificates. Three-quarters of the responding induction teachers reported participating in an in-state certification program and most (59%) were between 20 and 30 years of age. A large proportion of the respondents were beginning their teaching careers with bachelor's degrees (83%), as opposed to master's (15%) or doctoral degrees (2%).

In mathematics, 55% of the beginning teachers reported teaching classes in which they did not have a major. In science, 40% of the beginning teachers reported teaching classes in which they did not have a major. There was no significant difference between large and small districts in the number of beginning teachers in science and mathematics who were teaching out of field.

Assigning beginning teachers out of their content field accentuates difficulties that already exist in science and mathematics.

These findings are consistent with national data in regard to the first career orientation of beginning teachers (National Center for Education Statistics, 1999), and the number of science and mathematics teachers who are teaching courses in which they do not have a major. Assigning beginning teachers out of their content field accentuates difficulties that already exist in science and mathematics (Luft & Patterson, in review). An out-of-field beginning teacher will not have experienced the discipline-specific practice that science and mathematics preservice programs emphasize. As a result, these teachers will likely rely on textbooks and personal beliefs in the classroom, and have difficulty taking advantage of the national documents of guidance and standardization such as *NSES* (NRC, 1996), *PSTM* (NCTM, 1991) and *BSL* (AAAS, 1993). An out-of-field beginning teacher assigned to science or mathematics will also have a particular need for specific in-discipline mentoring, which was a relatively low priority in formal district induction programs in Arizona, as described in the next section.

Induction Programs as Reported by School Districts

Formal induction programs are defined herein as those that are organized and conducted at the district level.

These programs are often financially supported and involve a variety of district personnel. Informal induction programs are defined as those not organized at the district level and are typically dependent upon the administration in a specific school. These programs may receive support from the school administration, or they may entail a beginning teacher seeking out the assistance of an experienced teacher without the formal knowledge of the administration.

This component of the study sought to describe the types and composition of existing induction programs. The questions asked included: Did a formal or informal mentoring program for beginning teachers exist? Did the mentoring programs for beginning teachers utilize assigned or volunteer mentors? Was training provided to mentor teachers? Did policies exist regarding the role of the mentor and/or the induction teacher? The data in Table 1 report the information obtained from the districts.

The collected data revealed that formal program requirements are more defined than informal program requirements, yet both still need guidelines that enhance the mentor and beginning teacher relationship. For example, it is well documented that mentors should be selected and prepared (Huling-Austin, 1992). Selection should be based upon the interest and capabilities of

Preparation should allow mentors to fulfill their roles as guides, advisors, and supporters, but not as evaluators.

Table 1

Mentoring Programs as Reported by School Districts

Survey Question	Formal Program Response (N = 41)	Informal Program Response (N = 16)
Mentor training required	76% yes; 22% no	13% yes; 86% no
Mentors selected or volunteered	71% selected; 22% volunteered	60% selected; 39% volunteered
Frequency of mentor meetings	22% weekly; 32% monthly; 27% mentor discretion	No requirements
Same-discipline mentor required	20% yes; 80% no	No requirements
Mentors compensated	29% extra pay; 32% career ladder credit; 27% no compensation	73% no compensation
Additional programs offered	68% yes; 32% no	32% yes; 67% no

the mentor. Selected mentors should be trained to fulfill their roles (Ackley & Gall, 1992; Little & Nelson, 1990). Preparation should allow mentors to fulfill their roles as guides, advisors, and supporters, but not as evaluators (Abell, Dillon, Hopkins, McInerney, & O'Brien, 1995). Additional guidelines that should be established concern the amount of time a mentor spends with a beginning teacher (this should not be "as needed"), the compensation a mentor receives (mentors should be compensated), and the need for same discipline mentors (a mentor should be in the same field as a beginning teacher).

Beginning Teacher Participation in Induction Programs

Beginning science and mathematics teachers were surveyed to understand the support programs in which they participate. They were asked about the strengths and weaknesses of their induction programs and how they rated various components of the programs. The results of this survey can be found in Table 2.

Beginning teachers overwhelmingly valued the opportunity to communicate with and receive feedback from another teacher.

The results of this aspect of the survey revealed areas of strengths and weaknesses in current induction programs. Generally, beginning teachers felt their induction programs were adequate and could be improved by providing better meetings and more observations with feedback. Beginning teachers overwhelmingly valued the opportunity to communicate with and receive feedback from another teacher. Not surprisingly, the topics most often discussed between the mentor and beginning teacher were consistent with previous studies that indicate beginning teachers focus on orientation issues, and curricular and instructional support (Ballantyne, Hansford, & Packer, 1995).

Table 2**Beginning Teacher Participation in Mentoring Programs**

Survey Question (N = 186)	Teacher Response
Involved in mentoring program?	53% yes; 47% no
Mentored by same-discipline teacher	53% yes; 47% no
Overall rating of mentoring programs	13% outstanding; 26% superior; 33% adequate; 13% fair; 14% poor [M = 3.10; SD = 1.23]
Strengths of mentoring programs	31% useful feedback; 26% good mentor; 26% communication with another teacher
Weaknesses of mentoring programs	57% more mentor observations and better meetings or workshops
Topics most frequently discussed with mentor	46% classroom management; 27% school and district policy; 25% classroom activities; 24% school procedures
If not in mentoring program, is there a person who takes on the role of your mentor?	52% yes; 45% no

Further analysis of the beginning teacher survey revealed several interesting findings. The number of professional activities attended within the year was higher for teachers who had either formal or informal mentors ($M = 2.68$, $SD = 1.13$; $MDN = 3.00$) than for those who did not have mentors ($M = 2.37$, $SD = 1.07$; $MDN = 2.00$). There were significant positive correlations between mentor interactions and teachers' ratings: first, the more often beginning teachers met with their mentors, the higher the teachers tended to rate their induction programs ($R = .537$, $p = 0.01$); and second, the more often beginning teachers were observed in class by their mentors, the higher they rated the induction program ($R = .448$, $p = 0.01$). Also, when beginning teachers not in an induction program sought out an informal mentor, often that mentor was in the same discipline (31% of respondents).

These findings reinforce several points. First, the concerns expressed by

the beginning science and mathematics teachers demonstrate the developmental nature of learning to teach. Huling-Austin (1992) has described the unique concerns of beginning teachers and the need for a developmentally appropriate support program. Second, the results of this component of the survey also support the need for collegial interactions during the induction period (Emmer, 1986; Huling-Austin, 1992). Beginning teachers wanted to interact with colleagues and valued the interaction they experienced with their mentors. In science and

Beginning teachers wanted to interact with colleagues and valued the interaction they experienced with their mentors.

mathematics, this interaction should exist with same discipline mentors, as there are several unique qualities about instruction in these disciplines (Adams & Krockover, 1997; Emmer, 1986; Loughran, 1994).

Comparison Between Beginning Teacher Responses on Formal and Informal Induction Programs

Two comparisons were made to determine the degree of agreement between district policy on induction programs and the induction programs that beginning science and mathematics teachers experienced. The first comparison explored the responses of beginning teachers in formal and informal or no induction programs. The second comparison was between the district program guidelines and the reported experiences of beginning teachers. Results of these comparisons are located in Table 3.

The results of the first comparison revealed, as one would expect, that informal or no induction programs provide limited support to beginning science and mathematics teachers. However, beginning teachers in informal or no induction district programs who did find mentors reported having same discipline mentors more often than did beginning teachers in districts with formal induction programs. In addition, they reported more weekly and monthly meetings with their mentor than did beginning teachers in formal district induction programs. Again, this occurred with a limited number of beginning science and mathematics teachers.

The results of the second comparison revealed a disparity between district policy and the experiences of beginning science and mathematics teachers. For example, one third of the teachers in districts with formal

Table 3
Comparison Between Beginning Teacher Responses in Formal Program (FP)
and Informal or No Program (I/NP) Districts

Comparison Question/Topic	FP Teacher Responses (N = 99)	I/NP Teacher Responses (N = 87)
Mentoring received	65% yes; 35% no	35% yes; 65% no
Reported frequency of meetings in districts that required weekly meetings	17% weekly; 14% biweekly; 17% monthly; 14% bimonthly 9% quarterly; 3% not at all	36% weekly; 23% monthly; 18% quarterly; 23% not at all
Reported frequency of meetings in districts that required monthly meetings	7% weekly; 10% biweekly; 14% monthly; 10% bimonthly 3% not at all	36% weekly; 23% monthly; 18% quarterly; 23% not at all
Reported frequency of meetings in districts that used mentor discretion as requirement	28% weekly; 12% biweekly; 16% monthly; 4% bimonthly; 4% quarterly	36% weekly; 23% monthly; 18% quarterly; 23% not at all
Programs requiring same discipline mentors	50% mentor in same discipline 50% mentor in different discipline	67% mentor in same discipline 33% mentor in different discipline
Programs assigning mentors in same discipline when possible	40% mentor in same discipline 60% mentor in different discipline	67% mentor in same discipline 33% mentor in different discipline
Programs with no requirements for same discipline mentors	36% mentor in same discipline 64% mentor in different discipline	67% mentor in same discipline 33% mentor in different discipline

examine the implementation of their induction programs—especially given the need to retain qualified science and mathematics teachers.

Beginning Science and Mathematics Teachers on Their Preservice Programs

When examining the mentoring programs of beginning science and mathematics teachers, it is also important to explore their preservice experience. Beginning teachers can be supported in an appropriate manner, but the quality of their preservice program may impede their initial success as a teacher. Thus, it is important to determine how induction teachers rate various components and the strengths and weaknesses of their preservice programs. Table 4 reports, in descending order, the ratings that beginning science and mathematics teachers gave to various aspects of their preservice programs. Frequencies below 3% are not listed.

In Arizona, beginning science and mathematics teachers report their preservice programs to be between adequate and superior. Of the topics rated by beginning teachers, training in lesson planning and providing of content knowledge received the highest scores. Training in classroom management, knowledge of the national standards, and training in technology received the lowest marks. Beginning teachers are frequently concerned with classroom management and often do not feel well prepared in this area. In regard to the other areas, beginning science and mathematics teachers in Arizona may not be adequately prepared, as advocated by the *NSES* (NRC, 1996), *BSL* (AAAS, 1993), and *PSTM* (NCTM, 1991), for the use of educational technology and an understanding of the national standards. Issues relating

programs did not receive the required district mentoring, only half of the beginning teachers in formal district programs that required same discipline mentors actually had a same-discipline mentor, and the number of required mentor meetings had low correspondence with the reported number of actual mentor meetings. Clearly, even well developed induction programs for beginning science and mathematics teachers are not achieving the standards that have been set.

The retention of beginning teachers is a highly complex issue (Gold, 1996). Beginning teachers have various psychological, sociological, pedagogical, and physical needs. While there is no guarantee that meeting these needs

will ensure teacher retention, there is evidence that a lack of appropriate support can contribute to teacher attrition (Gold, 1996). Given the shortage of qualified science and mathematics teachers in Arizona, it would seem that districts would adhere to and implement sound induction programs for beginning science and mathematics teachers. In the upcoming years, other districts and states should carefully

The retention of beginning teachers is a highly complex issue.

Table 4
Beginning Teachers on Their Preservice Programs (1 – 5 Likert scale:
Unsatisfactory, Poor, Adequate, Superior, and Outstanding, respectively)

Survey Topic	Ratings by Beginning Teachers (N = 186)	
	M	SD
Training in lesson planning.....	3.71	1.04
Content knowledge provided.....	3.70	1.01
Instruction of content courses.....	3.51	1.24
Pedagogical knowledge provided.....	3.50	1.00
Training in reflective practice.....	3.49	1.11
Instruction of education courses.....	3.48	1.14
Training in assessment.....	3.44	1.03
Content of mathematics and science courses.....	3.44	1.45
Content of education courses.....	3.32	1.06
Training in instruction of diverse populations.....	3.31	1.09
Training in classroom management.....	3.07	1.17
Knowledge of national standards.....	3.04	1.34
Training in utilizing technology in classroom.....	2.92	1.19
Overall rating of preservice program.....	3.54	1.01

If induction programs are to assist beginning teachers in achieving standards-based instruction, then a solid foundation should be set during an educator’s preservice program.

to teachers’ understanding of technology and the national standards have previously been an area of concern in preservice programs in Arizona (Luft & Ebert-May, 1999). If induction programs are to assist beginning teachers in achieving standards-based instruction, then a solid foundation should be set during an educator’s preservice program. This foundation should include an understanding of the vision advocated by the national reforms, along with the development

of beliefs that are conducive to standards-based instruction.

Conclusions and Implications

Induction programs for beginning secondary science and mathematics teachers are a sound investment in the future. Unfortunately, the support offered to beginning teachers varies greatly by state and district (National Commission on Teaching & America’s Future, 1996). There are mandated induction programs that are developed and supported at the state level (Gold, 1996), and there are states in which districts determine their own support programs. This study shows, however, that even when induction programs are in place, the program experienced by the beginning teacher may differ from the program espoused.

This study examined the induction programs for science and mathematics teachers in only one state, but its conclusions and implications are important to other states and districts that have, or are developing, induction programs. First, beginning science

and mathematics teachers should participate in induction programs. The teachers in this study valued the assistance they received throughout their induction programs, such as collegiality with peers, suggestions provided by mentors, and feedback from mentors about their teaching of science or mathematics. Second, induction programs should consist of teacher/mentor meetings and mentor observations throughout the school year, with feedback to the beginning teacher. Ideally, these encounters should meet the immediate concerns of beginning teachers while fostering their implementation of the state or national science and mathematics standards. Third, induction programs for beginning teachers need to be adequately supported. Funding should be made available to compensate and train mentors, and to support the implementation of meetings. Administrators should support induction programs by selecting qualified mentors and monitoring various aspects of these programs. In this study, the varying levels of support directly affected the quality of induction program that was implemented. There is great need to retain qualified science and mathematics teachers; providing adequate support programs for beginning science and mathematics teachers is of critical importance.

The findings from this study also suggest ways to enhance induction programs. First, induction programs should be collaboratively developed and conducted by university and school district personnel. This will assist beginning teachers in retaining their standards-based pedagogical training while easing their transition into the school culture. Different areas of expertise exist between school personnel and university faculty, and

Same discipline mentors are necessary if beginning teachers are to succeed at standards-based instruction.

an induction program with only 'one' expert certainly short-changes beginning teachers (Huling-Austin, 1990; Henry, 1988; Grant & Zeichner, 1981). Second, induction programs should include an embedded assessment that ensures programs are fulfilling the expectations of district organizers, as well as the needs of beginning science and mathematics teachers. Induction programs should be evaluated to provide feedback to program directors, participants, and preservice programs (Luft, 1998). Third, beginning science and mathematics teachers should have mentor teachers from similar content fields who exemplify standards-based instruction. Beginning science and mathematics teachers face several challenges that are not found in other disciplines (Adams & Krockover, 1997; Loughran, 1994). Same discipline mentors are necessary if beginning teachers are to succeed at standards-based instruction. Fourth, induction programs should be developed to provide a seamless transition from preservice education through the first years of a teacher's career. Initial certification programs should provide information that beginning teachers desire, induction programs should extend and clarify the art and science of teaching, while professional development programs should refine and expand the teacher's professional knowledge. In the case of science

and mathematics teachers, the use of technology and the standards should be emphasized.

Final Comments

During the last few years, numerous studies have been conducted at the state level regarding the initial certification and the professional development of science and mathematics teachers (e.g., Luft & Ebert-May, 1999; Sowell et al. 1995). As a result of these studies and a general concern for education, state policy makers have focused educational funds and supported collaborative projects that addressed the needs of science and mathematics teachers. While all of the studies have provided direction locally, this study has played a unique role in its state. Specifically, this study is now part of the research base that directs grant writers in the state Eisenhower Science and Mathematics Program competition. In addition, a Department of Education grant was just awarded to four universities to create a coherent vision of science and mathematics education across the state. An important component of this proposal was the induction program, which followed the suggestions from this study. Finally, university advisory committees are using these findings to recommend collaborative induction programs. Ultimately, science and mathematics educators from across the state are learning from the self-studies and are developing programs that better meet the needs of beginning and experienced science and mathematics teachers.

References

- Abell, S. K., Dillion, D. R., Hopkins, C. J., McInerney, W. D., & O'Brien, D. C. (1995). Somebody to count on: Mentor/intern relationships in a beginning teacher internship program. *Teaching and Teacher Education, 11*(2), 172-188.
- Ackley, B., & Gall, M. D. (1992). *Skill, strategies, and outcomes of successful mentor teachers*. ERIC Document No. ED346046.
- Adams, P. E., & Krockover, G. H. (1997). Concerns and perceptions of beginning secondary science and mathematics teachers. *Science Education, 81*(1), 29-50.
- American Association for the Advancement of Science (1993). *Benchmarks for science literacy*. New York, NY: Oxford University Press.
- Ballantyne, R., Hansford, B., & Packer, J. (1995). Mentoring beginning teachers: A qualitative analysis of process and outcomes. *Educational Review, 47*(3), 297-307.
- Chaney, B. (1995). *Student outcomes and the professional preparation of eighth grade teachers in science and mathematics*. Report prepared for the National Science Foundation. Rockville, MD: Westat.
- Emmer, D. T. (1986). Academic activities and tasks in first-year teachers' classes. *Teaching & Teacher Education, 2*(3), 229-244.
- Gold, Y. (1996). Beginning teacher support: Attrition, mentoring, and induction. In J. Sikula (Ed.), *Handbook of research on teacher education*, (pp. 548-594). New York, NY: Macmillan.
- Grant, C. A., & Zeichner, K. M. (1981). Inservice support for first year teachers: The state of the scene. *Journal of Research and Development in Education, 14*(2), 99-111.
- Henry, M. A. (1988). Multiple support: A successful model for inducting first-year teachers. *Teacher Educator, 24*(2), 7-12.

- Huling-Austin, L. (1990). Teacher induction programs and internships. In W. Houston (Ed.), *Handbook of teacher education* (pp. 535-548). New York: Macmillan.
- Huling-Austin, L. (1992). Research on learning to teach: Implications for teacher induction and mentoring programs. *Journal of Teacher Education*, 43(3), 173-180.
- Little, J.W. (1990). The mentor phenomena and the social organization of teaching. In C. Cazden (Ed.), *Review of research in education: Vol. 16* (pp. 297-351). Washington, DC: American Educational Research Association.
- Little, J. W., & Nelson, C. (Eds.) (1990). *A leadership guide to mentor training*. San Francisco, CA: FarWest Laboratory for Educational Research and Development.
- Loughran, J. (1994). Bridging the gap: An analysis of the needs of second-year science teachers. *Science Education*, 78(4), 365-386.
- Luft, J. A. (1998). Alternatively assessing an in-service program. *School Science and Mathematics*, 98(1), 26-34.
- Luft, J. A., & Cox, W. E. (1998). *Final report: A report on preservice and mentoring programs in Arizona for science and mathematics teachers*. Phoenix, AZ: Arizona Board of Regents.
- Luft, J. A., & Ebert-May, D. (1999). One state's self study of initial certification programs in science and mathematics. *School Science and Mathematics*, 99(3), 124-132.
- Luft, J. A., & Patterson, N. C. (in review). Supporting beginning science teachers: An overview of need, literature, and a possible program
- Monk, D. H. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics of Education Review*, 13 (2), 125-45.
- National Center for Education Statistics (1999). *Teacher quality: A report on the preparation and qualifications of public school teachers*. Washington, D.C.: U.S. Department of Education, Office of Educational Research and Improvement.
- National Commission on Teaching & America's Future (1996). *What matters most: Teaching for America's future*. New York, NY: Teachers College, Columbia University.
- National Council of Teachers of Mathematics [NCTM] (1991). *Professional standards for the teaching of mathematics*. Reston, VA: National Council of Teachers of Mathematics.
- National Research Council [NRC] (1996). *National science education standards*. Washington, DC: National Academy Press.
- National Science Board (1998). *Science & engineering indicators – 1998*. Arlington, VA: National Science Foundation.
- Salish I Research Project (1997). *Secondary science mathematics teacher preparation programs: Influences on new teachers and their students (Final report)*. Washington DC: United States Department of Education and Office of Educational Research and Improvement.
- Sowell, E. J., Buss, R. R., Fedock, P., Johnson, G., Pryor, B., Wetzel, K., & Zambo, R. (1995). *K-12 mathematics and science education in Arizona: A status report*. Phoenix, AZ: Arizona Board of Regents.

Julie Luft is an Associate Professor of Science Education at the University of Arizona, in the Department of Teaching and Teacher Education. She is currently working to develop an induction program in Southern Arizona for secondary science teachers. Her research interests are multicultural science education, induction science teachers, and staff development programs for science teachers.

Wylie E. Cox completed his training in wildlife biology (University of Arkansas) in 1987, and science education (University of Arizona) in 1999. He is currently serving as a Field Curriculum Coordinator for Columbia University's Biosphere 2 Center in Oracle, Arizona.

Preparing Science Teachers for Diversity Through Service Learning

Service learning is described as a philosophy and methodology involving the application of academic skills to solving real-life problems.

The context for science teaching and learning in the United States has changed dramatically in recent years as classrooms become complex microcosms of cultural diversity. Demographic and social changes reflect recent increases in both fertility and migration trends (Pallas, Natriello & McDill, 1995). If these trends continue, the science classrooms of tomorrow will look distinctly different. The needs of an increasingly diverse student population will undoubtedly influence both the purposes and goals of science education.

Since its beginnings the United States, as both a concept and a country, has been a centerpiece of diversity. There is an explicit recognition that cultural diversity has been a source of

greatness for this country. Yet, at the same time, the history of schooling in the United States is one in which schools were allowed to overlook diversity or use it as an explanation for vast differences in students' academic performance. Modern educational wisdom sought to melt these differences by "making us all the same." By contrast, postmodern education cherishes difference and seeks to value excluded voices and understandings. This is a complicated task, for as Sleeter (1994) points out, students' "diverse experiences, viewpoints and frames of reference can lead to misunderstanding" (p. 109).

Challenges to Science Teacher Educators

Today there is widespread agreement that an important goal of science teacher education is to prepare teachers who have the capability to teach learners from diverse backgrounds. This poses both a challenge and an opportunity to science teacher educators. For the most part, teacher education students are women of European ancestry from rural areas, small towns, or suburban communities. They typically have little experience or knowledge of diverse cultures and prefer to teach children similar to themselves (Liston & Zeichner, 1990). McCall (1999) suggests that these prospective teachers

are likely to view the world of schools and students, and by extension the world of science teaching and learning, in an individualistic, apolitical and idiosyncratic manner which ignores the dynamics and influence of gender, race and social class. The issue is further complicated when science teacher preparation courses decontextualize knowledge through an emphasis on isolated skills and methods where "one size fits all."

Science teacher education, which seeks to meet the challenge of preparing teachers for diversity, should be contextualized in the experiences, skills and values of the community. The science education classroom, when viewed as a cultural community, can be a starting point for situating knowledge of learning to teach science within our rich individual and collective histories as science learners. Prospective teachers need to develop an understanding of the term "culture" and an awareness of their own cultural identities. Villegas (1991) suggests that a pragmatic view of culture can be particularly useful to teachers. In this sense, culture is defined as "the way life is organized in a community, including how its members interact, use language and approach learning" (p. 24). In our own experience, we have found that prospective teachers struggle with developing an aware-

Today there is widespread agreement that an important goal of science teacher education is to prepare teachers who have the capability to teach learners from diverse backgrounds.



Science teacher education, which seeks to meet the challenge of preparing teachers for diversity, should be contextualized in the experiences, skills and values of the community.

ness of culture in the classroom. In many cases, they have not yet fully explored personal beliefs, values and experiences in relation to their emerging theories of science teaching and learning.

While multicultural science educators have attempted to push the boundaries of traditional practice in preparing teachers for diversity, many challenges remain. Barton (2000) has summarized these challenges by describing four key issues in science teacher preparation. She suggests that multicultural science education ought to provide for:

1. Understanding, critiquing, and transforming *disciplinary* knowledge of science;
2. Understanding, critiquing, and transforming *pedagogical* knowledge;
3. Understanding, critiquing, and transforming teachers' understandings of histories, purposes and goals of schooling, and
4. Expanding teachers' cultural understandings and worldviews of societies, communities, schools and children (pg. 5).

How can science teacher preparation be transformed to meet these challenges? The way in which science teacher educators might accomplish this task is elusive, as different assumptions exist concerning the meaning of "science for all" and visions of multicultural teaching practice. For some, science education for all is viewed as a means of enhancing citizens' quality of life (Cobern & Loving, 1998). Other science educators view the notion of science for all as an ideological threat to cultural knowledge (Snively & Corsiglia, 1998). Similarly, some science educators emphasize that while there is a need for different teaching methods, strategies and applications of science, the underlying science concepts and principles should remain the same (Lee & Fradd, 1998). By contrast, Osborn & Barton (1998), Helms (1998) and others suggest that the underlying ideology of school science should be critiqued and challenged. With these thoughts in mind, it is important to examine science teacher preparation for diversity in light of alternative exploratory frameworks.

Service learning is one framework that offers an alternative vision of science teacher preparation for diversity. In the spirit of engaging teachers in active construction of knowledge, service learning provides an opportunity for building strong connections between community context and multicultural teaching practices among prospective science teachers. In the sections that follow, we will describe the concept and characteristics of service learning, examine its connections to multicultural science teacher education and provide an example of a specific project that illustrate the science in service learning.

Service Learning as a Context for the Professional

Development of Science Teachers

Service learning is a philosophy and methodology involving the application of academic skills to solving real-life problems in the community (Pate, 1999). A community is commonly defined as a body of people, having common organization or characteristics. In service learning, "community" can be perceived narrowly (e.g., a classroom of students, an extended family) or broadly (e.g., a neighborhood, a town). Service learning connects meaningful community service experiences with academic learning, personal growth, and civic responsibility. Service learning by nature is generally interdisciplinary and is not an add-on to the curriculum.

Four steps are generally found in service learning: preparation, service, reflection, and celebration (Wade, 1997). Preparation includes identifying community need(s) to be addressed; selecting the service activities; identifying collaborators; and researching background information necessary for the project. The action step is the service itself. Reflection in service learning, whether structured or spontaneous, provides an



Service learning is a philosophy and methodology involving the application of academic skills to solving real-life problems in the community.

opportunity for students to critically think about what they have learned academically, about a community, and about themselves. Reflection activities often occur throughout all stages of the project. Celebration is the step in which participants recognize both their learning and their contributions. Celebration provides closure to the project in the form of a party, an assembly, or through a public awareness campaign. As in any learning activity, motivation is enhanced when there is student ownership in all phases of the service learning project.

At our respective institutions, prospective science teachers have the opportunity to engage in service learning projects in three ways:

1. In service learning and community-based research opportunities on a self selected basis,
2. In designated courses as a requirement, and
3. In a stand-alone service learning course.

The stand-alone course, taught annually each spring, is open to any major in the university, as an elective in their program of study or as a course requirement. The course centers on students' understanding of and experience with service learning.

In the section that follows, we will share an example of a service learning project from the stand-alone course that illustrates the science in service learning. We will also provide portfolio data from the preparation, service, reflection, and celebration stages of the service learning project *Science Supplies* (Bothma & Brown, 2000). Italics indicate student voice.

Science Supplies: A Service Learning Project

In this service learning project, two prospective secondary science teach-

As in any learning activity, motivation is enhanced when there is student ownership in all phases of the service learning project.

ers developed in-depth knowledge about a particular science curriculum while helping practicing teachers collect needed science materials and supplies. After several lessons on the history, research, and components of service learning, Chessa and Trudi began conceptualizing their project.

During the preparation/reflection stages of *Science Supplies*, as juniors just beginning their education courses, Chessa and Trudi decided they wanted and needed to be in science classes in schools as much as possible. With this in mind, they began their efforts to identify a school-community need. *After visiting a local middle school and interviewing science teachers, we determined there was a need for science supplies. The science teachers were using a program involving many hands-on activities in which students worked in small groups of two to four. The experiments in the curriculum were designed to ensure that students obtain a better grasp of the concepts presented to them.* Chessa and Trudi soon found, however, that the move from a traditional lecture format had the middle school teachers desperately seeking consumable materials. After determining a genuine need, Chessa and Trudi contacted the district science coordinator to find out precisely what supplies were essential to enacting the middle school science curriculum.

Chessa "Reflection One" February 14, 2000

We have accomplished many of the preparations for our project by getting a list of the supplies the teachers need and typing them up in an attempt to find out which items they need the most. Trudi and I have also obtained a list of businesses and contact people. The next major step that we need to take is to contact these individuals with a list of items that we wish for them to donate.

However, with all this success also comes failure. We have not learned anything about the science program other than the fact that it is a type of integrated science, which means that it brings all fields of science together. We did obtain a copy of the Quality Core Curriculum (QCC) from the resource room so we now know what the teachers in the class are referring to when they say QCC. I think the QCC provides a very basic guideline for what science teachers need to go over in the classroom during the school year and leaves a wide margin for interpretation. It will be interesting to see how the teachers that we will observe interpret what the QCC is looking for.

Thus far in my project I have learned many things. Being pretty computer illiterate, Dr. P. had to teach me how to put a table into a word document so that when we write our letters to local businesses we will be able to include a table of the supplies that we are asking for.

The most important thing that I have learned is that you have to tell people exactly what you want from them if you want to get what you want. While the teachers were quick to provide us with a list of their needs, we have been unable to pin them down to get into the classroom to talk about how they use

their science program. I hope that we will see different interpretations of the curriculum that the state has identified to be taught.

Another important thing I have learned is that you need connections! Dr. P. has played a vital role in our project by giving us the names of individuals we can get in touch with. Now that we know that we need to be explicit with our need to learn about the curriculum, we will tell the teachers that we get in touch with exactly what we expect to learn from them about the curriculum and the science program they are using at the middle school. With names of specific people to ask for we hope to track down a few teachers to observe and discuss with them the ways in which they use the curriculum.

**Trudi “Reflection One”
Feb. 22, 2000**

Chessa and I went to the middle school today to speak with Mrs. K. Unfortunately, we left the school with less enthusiasm than we entered. During the brief meeting, Mrs. K. gave us a list for each grade (6-8). Each list had several items the teachers wanted for their classrooms. Eight[h] grade alone was 8 pages long! I don't think that getting the supplies will be too difficult. The most daunting part will be to get organized.

On our way to the car Chessa and I agreed that our project is not really what we wanted. We do want to help with supply gathering, but we would also like to be at the school. I think we both need to work on communicating our needs better. We went into the school looking for guidance from Mrs. K., but we really need to determine what we want to do on our own before we contact her again.

The lists have given us a little more insight into integrated science. From the eight[h] grade lists we can see how many hands-on activities are done and what kinds of materials they need. I am a little confused though – is there any instruction before? Almost everyday is an activity day.

Chessa and I ended our outing by deciding to ask Dr. P. how to turn our project into something we can learn more from.

Chessa and Trudi experienced at this point what many novices to service learning experience. Their project was getting too big and focusing too much on the service. They felt they had lost or had never even had a focus on science teaching and learning. Even so, they were already in the process of understanding, critiquing, and transforming disciplinary and pedagogical knowledge of science. They had already begun to expand their understanding of schools.

**Trudi “Reflection Two”
April 11, 2000**

We finally had the chance to see a teacher in action! All our previous observation times the teacher was either giving a test or playing a review game, so we've not really seen a whole lot of science taught.

We observed a 7th grade science teacher. The topic was DNA and genetics. While I could see that the teacher was good at explaining the concepts to her students, I am really appalled at the videos that students have to watch to go along with their hand-outs. The video gives no background into the subject matter and skips around a lot! The worst part is the person in the video; an old professor-looking man who spoke too fast. I got the distinct impression that the students weren't really absorbing any material from

the video; they were just listening for key words they had to define.

After the class, Mrs. L. mentioned that she has to spend a large part of every Sunday looking over the material to make sure that the students will understand. So far I don't see why this program was chosen as the curriculum. I understand that hands-on activities improve learning, but any curriculum without proper background is no good. I also don't like the little handbooks they use. Chessa and I looked through the eight[h] grade Block 3 book, and we both thought there was not enough introduction into a concept. I almost felt like I was reading an article in Time – where they have little charts and pictures to help readers out.

So far, I really do not like the integrated science program.

**Trudi “Reflection Three”
April 15, 2000**

Today has been the most exciting day of the entire project! Chessa and I observed in Mrs. M's sixth grade science class for one class period. We thought we were only going to observe, but Mrs. M. involved us in the class procedures. She had us introduce ourselves and later we helped the students with the flower dissections. I thought that it was really neat that the teacher introduced us to make the students feel at ease. No other teacher had done that before, and it almost made me feel like I was part of the class.

The other exciting aspect of today is that I realized that I chose the right profession! Interacting with the students was wonderful and they even showed me their work like I was the teacher! Talk about a natural high!

This observation also made me realize that hands-on activities are crucial in science to make new concepts understandable. For example,

in the class period, Mrs. M. put up an overhead of a flower diagram that looked nothing like an actual flower. When the students started pulling the flowers apart, they could not relate the pieces on the paper to the pieces in their hands. I think an exciting challenge for me will be to look for new ways to contextualize as many activities as possible.

Finally, Chessa and Trudi were able to investigate the district-adopted science curriculum and see science teaching in action. They questioned different teaching methods, strategies, and applications of science. Chessa and Trudi were actively engaged in the construction of knowledge related to science curriculum and instruction.

In the next reflections, Chessa and Trudi think back on their celebration experiences, for them, public speaking engagements about their service learning project.

Chessa “Reflection Four” April 28, 2000

The presentation at Leadership Athens, while informal, was still a cause of a lot of stress. Trudi and I did not realize that we had so much to talk about with our project, but once we began there were more aspects to our project than I realized. The interest of the group also encouraged us to speak up. They asked us a few really good questions and we were able to answer most of them completely. Although we were given false hope when one of the members requested a copy of our supplies list, maybe he will still get back to us.

The presentation to our class was really easy for us. We know most of the people in our class and we knew what we had to talk about. We have also gained quite a bit of self-confidence. I attribute this to the fact that

we had to be rough and tough with the businesses and be up front with the teachers. I think that this has also led to us being better able to express our wants and needs to individuals. This will help us express our wants to our future students and our needs to the local businesses.

The third presentation that I participated in was to the College of Education. I was a little more nervous at this one, but I think that it was because I did not know very many of the people there and because of the prestige of the people that were there.

While looking at my Academic connections page I could not believe the number of things that I learned while doing a project that interested me. I can hardly wait to begin teaching so that I can try service learning in my classroom. I think this is a great motivator and yet it teaches so much. I can hardly believe that it has taken me this long to learn about this way of teaching.

Now that the end of the semester has come Trudi and I have decided that we enjoyed this project so much that we want to work on another one. We have really learned a lot about the science curriculum, so in order to learn about social studies, reading, and math curriculum we want to work on a curriculum integration program.

As part of their portfolio requirement, Chessa and Trudi were asked to reflect on learning connections they had made as a result of their *Science Supplies* project. The connections are divided into science teaching, other skills, and regarding myself (See Figure 1).

It is clear when reading Chessa’s and Trudi’s reflections and connections that they realized the power of their service learning activities for themselves as prospective science

teachers. According to Chessa and Trudi, *the school was the benefactor of our service because they received the donated goods; we benefited by learning invaluable curriculum [insights].* They viewed their experience as one that enabled them to learn about science curriculum, the needs of teachers, student learning, and their own beliefs and assumptions. What Chessa and Trudi experienced is consistent with research on college students’ involvement with service learning. Their participation had a strong effect on their personal development, career awareness, choice of a service-oriented career, and self-efficacy regarding the ability to help solve societal problems (Eyler & Giles, 1993; Salz & Turbowitz, 1992). Their involvement in the school and the community, together with reflection on their experiences, was a more powerful experience than simply reading a science curriculum guide in a classroom setting.

Chessa and Trudi were true to their words. Their service learning project was such a meaningful experience that they expressed the desire to participate in another project. They subsequently enrolled in an independent study focusing on service learning and science, even though the course was not a graduation requirement. The project they are now collaborating on was initiated by a non-profit environmental education group. Chessa and Trudi are creating middle and high school units and service learning project ideas for the use of alternative pesticides. They are also participating in an internship program at the Center for Disease Control (CDC). According to Wade and Anderson (1996), “... service involvement is likely to contribute to their [prospective teachers] being more effective in the classroom, particularly with children of diverse or

Figure 1

TRUDI'S CONNECTIONS	CHESSA'S CONNECTIONS
<p>Science Teaching:</p> <ul style="list-style-type: none"> • What integrated science is, how it is used in the classroom, and how teachers adapt the materials they are given to better suit their students • That teachers do not have to follow the ... Science program exactly • What materials are used in the program: supplies, handbook, videos, teacher's handbook • What "curriculum in a can" is • The importance in having a good background in the subject matter you teach 	<p>Science Teaching:</p> <ul style="list-style-type: none"> • What integrated science is • The lack of materials available to teachers • The lack of funding at the middle school • How poorly the ...Science program was planned out • What curriculum in a can is • How often there are misleading or outdated facts in the ...science book • How loud seventh graders can be • How many hours some new teachers spend preparing for the week • A little bit on how to use the integrated science program and yet also teach something to the students • The thoughts and feelings of the teachers about the... Science Program
<p>Other skills:</p> <ul style="list-style-type: none"> • How to insert a table in a Microsoft Word document • How a rubric works • What a democratic classroom is and how it is run • What service learning is • How to use a digital camera • Which businesses are most willing to donate [science supplies] • What a portfolio is and how to put it together [level] • How funding works at the middle school • What Quality Core Curriculum (state curriculum objectives) is and where to obtain a copy of it [science QCC's] • How to properly write a business letter • Where to find information on local businesses 	<p>Other skills:</p> <ul style="list-style-type: none"> • How to write business letters • Where to get information about local businesses • How to make a table on Word • What QCC is • Where to find the QCC • How to promote our project • How to communicate with others what we want • What service learning is • How to get in touch with the middle school [science] teachers • How to get information together in a single file to be put on the Internet • How to get pictures inserted into a file on the Internet • How to use Help on Word • What a rubric is • What a democratic classroom is • How to put together a portfolio (can you believe I have never had to do this before?) • What context is [means] • What a needs statement is • How to cut back a huge project to make it manageable, but still get something done
<p>Regarding Myself:</p> <ul style="list-style-type: none"> • How to approach someone without sounding too demanding • How to be assertive when approaching managers • That I would like to teach Middle School [science] • That I like sixth graders more than I thought I would • How to work with a partner in a long-term project • To be less domineering 	<p>Regarding Myself:</p> <ul style="list-style-type: none"> • How to be aggressive • How to present informally to a group • How to be forceful yet polite with managers • How to work with Trudi • How to work with other people in general • How to decide whose idea to use • How to make my idea sound more attractive (be persuasive)

troubled backgrounds" (p. 62). The authors further state that because of service learning activities, "teacher education students have learned about the importance of being aware of community service agencies (Anderson & Guest, 1993), increased their knowledge of and commitment to working with culturally diverse student populations (Tellez & Hlebowitsh, 1993), and developed an awareness of how children's home lives affect their learning in school (Wade, 1993)" (p. 62). Chessa and Trudi fit the bill perfectly!

Connecting Service Learning to Multicultural Science Teacher Education

Using service learning as an approach to multicultural science teacher education moves beyond stereotypical notions of culture. It enables prospective teachers to gain an understanding of culture as the way groups of people socially negotiate their everyday living circumstances in local settings. Through service learning projects, such as "Science Supplies" prospective teachers can examine cultural diversity in light of forces that shape human dynamics such as racial relationships, economic status, and political power. The contextual nature of service learning brings a real world perspective to learning about cultural diversity as it is lived by local citizens experiencing the consequences of these sorts of community dynamics. Furthermore, by involving prospective science teachers in action-based projects service learning promotes thinking about the ways in which teachers and science education play a responsible role in contributing to the lives of students and parents in the school community. Accordingly, through examples such as the "Science Supplies" project, we

Using service learning as an approach to multicultural science teacher education moves beyond stereotypical notions of culture.

see service learning as posing important avenues for multicultural science teacher education, as it holds the potential to:

- Provide a more authentic representation of the nature of science
- Promote critical reflection about culture as it relates to science teaching and learning, and
- Develop sensitivity toward students' cultural backgrounds and how these influence science learning.

Science educators are encouraged to more authentically represent the nature of science by engaging prospective teachers in solving real-world problems that do not have pre-determined solutions (American Association for the Advancement of Science, 1989; National Research Council, 1996). Furthermore, prospective teachers should experience science by—generating their own questions for inquiry, engaging in tasks to collectively work on problems, and negotiating solutions to solve problems (Aikenhead, 1985, 1994; AAAS 1989; NRC, 1996). According to Helms (1998), community-based science inquiry more authentically represents the nature of science as a practice having a contextual basis and serving particular goals. Unlike

traditional representations of science typically framed as classroom texts or laboratory exercises serving no particular purpose or persons, service learning embeds science in real-world problems involving members of local communities. The science learning that takes place holds the potential to generate knowledge about unique situations that can contribute important insights to the scientific community. The approach to service learning highlighted in this article follows the recommendations of Helms (1998) for ensuring that prospective science teachers will see the connections of service learning projects to science and the local community by: “facilitating action-taking, beginning with awareness, moving through genuine care and the recognition of the value of service, and ending with action” (p. 649). The responsibilities and actions involved in Trudi and Chessa’s initial service learning experience helped them understand the power of learning about a problem they believed was important and enabled them to work collaboratively in developing solutions to the problem.

Rodriquez’ (1996) criticism of the rhetoric calling for science teachers to address equity and cultural diversity in the classroom accentuates the need for more practical approaches that can substantively help prepare science teachers to deal with these issues. Science teacher educators,

Service learning embeds science in real-world problems involving members of local communities.

however, have found it challenging to translate theoretical notions of multicultural science education to curriculum practice (Atwater, 1994). In the case of Chessa and Trudi, their service learning project engaged them in critical reflection on purposes and approaches underlying science teaching in classrooms.

Through their interactions at the school, they explored what it felt like to become a member of the professional culture of science teaching. They examined the resources teachers use to guide their curricular ideas and activities and experienced the power and joy of sharing ideas with other teacher colleagues. These prospective teachers also experienced how it feels to cross a cultural border—sometimes feeling devalued, as teachers merely regarded them as “service providers” instead of granting them a more professional and collegial status. This is the sort of example of experience needed to help prospective teachers develop a practical understanding of cultural diversity in a community and the dynamics of inequity.

Finally, service learning helps develop sensitivity toward the cultural backgrounds of students. Aikenhead’s (1996) notion of cultural border-crossing emphasizes the need for science teachers to consider the life worlds students bring to the science classroom. Some students experience little difficulty participating in science class as they have strong support from family and friends who motivate and encourage their academic performance. Other students are ridiculed by peers when they participate in classroom activities, and may have parents who did not experience academic success in school. These students may risk feeling alienation if they negotiate crossing cultural boundaries of their

home life and school. As Chessa and Trudi found meaning in their service learning project they were able to adopt new strategies and goals for teaching science to diverse learners. They developed a new perspective on what makes learning meaningful. They came to understand the importance of being a valued part of a learning community, and recognized that their own questions could serve as legitimate and important beginning points for learning.

Service learning can provide an exciting avenue for multicultural science teacher education. Through engagement in real-world problems in actual community contexts, prospective science teachers can practically develop understandings of cultural dynamics and the implications of cultural diversity to science teaching and learning. In this process, critical reflection grounded in service learning experiences can lead prospective science teachers to new insights about science education—with a personal sense of care and responsibility to promote meaningful science education.

References

- Aikenhead, G.S. (1985). Collective decision making in the social context of science. *Science Education*, 69(4), 453-75.
- Aikenhead, G.S. (1994). What is STS teaching? In J. Solomon and G. Aikenhead (eds.). *STS education: International perspectives on reform*, 47-59. New York: Teachers College Press.
- Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education*, 27, 1-52.
- American Association for the Advancement of Science. (1989). *Science for all Americans: a project 2061 report on literacy goals in science, mathematics, and technology*. Washington, DC: AAAS.
- Anderson, J. & Guest, K. (1993, April). *Linking campus and community: Seattle University's community service internship for pre-service teachers*. Paper presented at the National Service Learning Conference, Minneapolis, MN.
- Atwater, M. (1996). Social constructivism: Infusion into the multicultural science education research agenda. *Journal of Research in Science Teaching*, 33(8), 821-838.
- Barton, A. C. (2000). Crafting multicultural science education with preservice teachers through service learning. *Journal of Curriculum Studies*, 1-24.
- Bothma, T. & Brown, C. (2000). *Science Supplies*. Unpublished document.
- Coburn, W. W., & Loving, C. C. (1998, April). *Defining "science" in a multicultural world; Implications for science education*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Diego, CA.
- Eyler, J. & Giles, D. E. (1993, April). *What we know and need to know about education in field settings*. Paper presented at the American Educational Research Association Annual Meeting, Atlanta, GA.
- Helms, J. (1998). Science in the community: Context and goals in practical work. *International Journal of Science Education*, 20(6), 643-653.
- Lee, O., & Fradd, S. (1998). Science for all, including students from non-English language backgrounds. *Educational researcher*, 27(4), 12-21.
- Liston, D. P., & Zeichner, K. M. (1990). *Teacher education and the social conditions of schooling*. New York: Routledge.
- McCall, A. L. (1999). We were cheated! Students' responses to a multicultural, social reconstructionist teacher education course. *Equity and Excellence in Education*, 28(1), 15-24.
- National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.
- Osborn, M., & Barton, A. C. (1998). Constructing a liberatory pedagogy in science: Dilemmas and contradictions. *Journal of Curriculum Studies*, 30(3), 251-260.
- Pate, P. E. (1999). *Foundations of service learning*. [Online]. Available: <http://www.coe.uga.edu/~epate/>
- Pallas, A. M., Natriello, G. & McDill, E. L. (1995). Changing students/changing needs. In E. Flaxman & H. Passow (Eds.). *Changing populations, changing schools: Ninety-fourth yearbook of the national society for the study of education*, 30-58. Chicago: University of Chicago Press.
- Rodriguez, A.J. (1997). The dangerous discourse of invisibility: A critique of the national research council's national science education standards. *Journal of Research in Science Teaching*, 34(1), 19-37.
- Salz, A. & Turbowitz, J. (1992). You can see the sky from here: The Queens College Big Buddy program. *Phi Delta Kappan*, 73, 551-556.
- Sleeter, C. E. (1994). The value of a multicultural education for all students. In B. McLeod (ed.). *Language and learning: Educating linguistically diverse students* (pp. 107-128). Albany, N.Y.: State University of New York Press.
- Snively, G., & Corsiglia, J. (1998, April). *Rediscovering indigenous science: Implications for science education*. Paper presented at the annual meeting of the National Association of Research in Science Teaching, San Diego, CA.
- Tellez, K. & Hlebowitsh, P. S. (1993). Being there: Social service and teacher education at the University of Houston. *Innovative Higher Education*, 18(1), 87-95.
- Villegas, A. M. (1991). *Culturally responsive pedagogy for the 1990s and beyond* (Trends and Issues Paper, No. 6). Washington, D.C.: Eric Clearinghouse on Teacher Education.
- Wade, R. C. (1997). Community service learning: An overview. In R. C. Wade (Ed.). *Community service-learning: A guide to including service in the public*

school curriculum (pp. 19-34). New York: State University of New York.

Wade, R. C. (1993). Social action: Expanding the role of citizenship in the social studies curriculum. *Inquiry in social studies: Curriculum, research, and instruction*, 29(1), 2-18.

Wade, R. C. & Anderson, J. B. (1996). Community service-learning: A strategy for preparing human service-oriented teachers. *Teacher Education Quarterly*, 23(4) 59-74.

P. Elizabeth Pate is an Associate Professor of Middle School Education at the University of Georgia. She is involved in school/university partnerships and teaches courses on service learning and contextual teaching and learning. She was recently named the 2001 recipient of the Walter Hill Award for distinguished service by the University of Georgia.

Sharon E. Nichols is an Associate Professor of Science Education at East Carolina University where she currently serves as graduate coordinator. Sharon is involved in elementary science school/university partnerships and an international science education research collaboration with science teacher educators in the Philippines.

Deborah J. Tippins is a Professor of Science and Elementary Education at the University of Georgia, where she serves as program head for elementary science. She recently received the D. Keith Osborn Faculty Senate Award for Teaching Excellence and the University of Georgia Faculty Fellow Award. Address all inquires to The University of Georgia, Department of Science Education, 212 Aderhold hall, Athens, GA 30602-7126.

New Literacy for Leadership: Engaging the Information Services of ENC and

A profile of online resources from ENC, ERIC, and ERIC/CSMEE points to a wealth of information and resources for science educators that can be obtained instantly.

The purpose of this article is to inform and to invite. We want to inform science education leaders about the wealth of information and services available from the Eisenhower National Clearinghouse (ENC), the ERIC (Educational Resources Information Center) system, and the ERIC Clearinghouse for Science, Mathematics, and Environmental Education (ERIC/CSMEE). We will also discuss how desired information can be located and used, and what skills are needed to search successfully for information. At the same time, we will invite your suggestions and collaboration in exploring and clarifying the informational needs of leaders in science education. First, we begin with a pair of virtual visits. On a recent foray through cyberspace looking for information about TIMSS-R, we stumbled upon some intriguing Web sites that distracted us from our quest:

Visit 1: The first stop, Estuary-Net, states that it was “developed by the National Estuarine Research Reserve System in response to water quality issues arising in coastal areas” and “strives to develop collaborations ... to solve non-point source pollution problems in

estuaries and their watersheds.” As we read, we learned that 425,000 acres of estuary are now protected by the NERRS and a “healthy, undisturbed estuary produces from four to ten times the weight of organic matter produced by a cultivated corn field of the same size.” (National Estuarine Research Reserves, 1997) If we were teaching a class about estuaries, this could be a tremendous resource. But we are not. So this was simply a fun and educational detour.

Visit 2: Then it was snowflakes. Wow. A beautiful Web site called *Snow-crystals* has “tons” of information with highlights on the engineering of snowflake designs, natural snowflakes, and snow crystal physics (both for beginners and advanced) (Libbrecht, 1999). If we were students doing a report on precipitation, this would be the jackpot.

These sites (both listed in the December, 2000 ENC Digital Dozen) and thousands like them are filled with fascinating pieces of information. Careful examination of their content might reveal information valuable to our profession, but more often the professional is faced with compiling

just the right information within a very limited period of time. Browsing or selecting something from an interesting menu can certainly result in wonderful “finds” and lead in directions never before considered; it’s not much different from wandering through a grocery store without a shopping list. Still, undirected browsing is not the most efficient strategy for locating needed information. Browsing in a section that you are confident holds answers to your needs can be much more worthwhile, but, using a well-designed search tool can speed your efforts and greatly improve the quality of your results.

Pulling together the worlds of Information and Action

Despite what one may think about the rapid emergence of the Internet and World Wide Web in daily life, one thing is certain: there is a lot of information available at our virtual fingertips. From libraries and government agencies to e-businesses and fanatics, anyone who has a personal computer, server software, and access to the Internet is capable of setting up shop and sharing his or her opinions, publications, knowledge, or misinfor-

mation with anyone in the world who is interested or curious. The storehouses of information are being opened, all the conventional information filters and gatekeepers have been displaced, and the emancipation of information dissemination from external control has created a global free market of ideas. Within this milieu of electronic resources, instant access to information, dot-com business, and mental distractions there is a renewed opportunity to form a nexus between information providers and leaders in science education. Just as the patterns of access to information are rapidly changing, our notions of leadership and informed decision-making in science education are evolving. Leadership has become less defined by hierarchical roles and managerial styles than by taking decisive action within one's sphere of influence to change the common course of events. We believe this confluence of circumstances—the worldwide, instant availability of information and the changing conceptions of leadership—presents us with an opportunity to pull information and action closer together through knowledgeable decision-making by leaders in science education.

For leaders in science education information is essential, and the information being sought at any given moment generally is pertinent to a particular issue or question requiring efficient strategies that lead to reliable information. Skills, skepticism, and the ability to determine the accuracy of the information found become critical to successful searching. The World Wide Web is littered with information, with gems among the trash. Whether the information is gem-like or trash depends on the context as well as the accuracy. One of the most important questions to ask is, "What do we hope

to do with the information we find?" With that answer we are better prepared to ask, "What information do we need to accomplish our goals? Do we need data that can be used to help make decisions? Do we want expert advice based on summaries of many studies and long experience? Are we looking for ways of presenting our understandings and decisions? Or do we seek new perspectives on a persistent problem? A successful search is one that leads to high quality information that is consistent and appropriate for your needs.

Information can be obtained, but knowledge must be created. Information by itself generally has limited value. But *from* information one can create knowledge that broadens understanding and guides decision-making. Facts remain just information until you act upon them. When you compare new information with the knowledge you already have, it may challenge or reinforce your current understandings. It may enrich your knowledge by pushing you to revise what you thought you understood, or it may lead you to see new applications or relationships within what you already know. The information may help fill gaps in understanding or challenge the accuracy and value of what you have previously thought.

This is where ENC, ERIC, and ERIC/CSMEE excel. They provide *sources of information* (a reasonable number of reliable sources, organized in ways that make them relatively easy to use), *tools* that enable searchers to find the particular sources of information best for them (menus, hierarchical trees, site searches, database searches), *information* consistent with the K-12 mathematics and science education leaders' needs and interests, and a level of *reliability* that instills confidence.

Who Are The Leaders?

As Pellicer and Anderson (2001) have described, American schools have long been organized according to an outmoded industrial model, with some employees cast as managers (administrators) and others cast as laborers (teachers). Leaders have traditionally been cultivated among the managers. In recent years, however, teacher roles have expanded along with the spreading realization that teachers must participate in decision-making and join in partnership with administrators in leading the way to more effective schools. So our view of leadership is not one of position, but of informed action. The leaders in science education are those who join in creating visions, making decisions, and taking action to improve teaching and learning, whatever their professional appointments might be.

More Than Access

Given our view of leadership, we believe that well-developed skills in finding, evaluating, and interpreting information are essential to the leaders in science education. Mere access to information has become much less of a concern; access to relevant informa-

The leaders in science education are those who join in creating visions, making decisions, and taking action to improve teaching and learning, whatever their professional appointments might be.

tion is readily available to all who are online and care to search for it, and who have the necessary perseverance. But how does one systematically search for information; how does one differentiate useful or credible information from misinformation, and how does one transform information into knowledge and action? Answering these questions may help clarify the potential synergy between information providers and leaders in science education. Following are two simple cases where instructional leaders had access to information, but needed help in finding and applying information. They sought help through the AskERIC service (ericir.syr.edu/Qa/).

Case 1: High School Committee Member

What happens to student learning when science teachers are reassigned to teach subjects outside their area of expertise?

This is the question of a high school teacher from New Jersey who was serving at the time on a school committee charged with the task of establishing policy regarding teacher assignments. Jean had tried searching the Web using general search engines, but had found little of relevance. She submitted her question to the AskERIC service, and within 48 hours she had a response. She received information relevant to the question asked, as well as help in learning how to structure searches of the Internet and the ERIC database to find useful information. Jean was provided guidelines for using an online search engine (Google (www.google.com)) to locate Web resources, along with several recommended Web sites. Suggestions for searching the ERIC database were also provided, along with the results of a

search that focused on science teachers and teacher qualifications. In addition to providing data about the incidence of out-of-field teaching, the AskERIC specialist provided references to research on a range of issues related to teaching, learning, and equity that result from such practices.

Case 2: School Improvement Assignment

In another case, a teacher designated as a “Distinguished Educator” was assigned to a low-performing middle school to develop a school improvement plan that included objectives and activities reflecting research-based strategies. In particular, Susan was searching for research about the effectiveness of “active learning teaching strategies” with regard to improving student achievement. She had a particular interest in higher-order thinking skills, cooperative learning, and graphic organizers, as she explained:

I am in a very low performing middle school. Therefore, we are attempting to raise student achievement. We have many computers that are not being used effectively. Our school has a weak discipline policy. Most of our teachers are using the “sit and get” method for teaching—too much lecture, worksheets, etc.—that is the reason for the active learning research.

In response, an AskERIC specialist provided guidance in finding the needed information. In addition to identifying useful Web resources and records from the ERIC database, he showed Susan how to use Descriptors from the online ERIC Thesaurus to construct the following search strategy:

((active learning in de) or (study skills in de) or (cooperative learning in de) or (advance organizers in de))

and (academic achievement in de) and (middle schools in de) (25 records; Note: “de” indicates “descriptors”)

In both of these cases, someone in a situation calling for leadership wanted to make informed decisions and had access to information, but they needed help in formulating questions and conducting fruitful searches. The information provider in these cases offered the following: (a) gateways to relevant information, (b) help in translating questions into fruitful search strategies, (c) instructions in how to use search tools, and (d) sample results from searches. Clearly, information providers cannot give this much individual attention to leaders in science education every time they have questions, but the two cases serve to illustrate the typical informational needs of leaders, as well as some dimensions of potential interaction between leaders and information providers in science education.

Within the most recent decade, while access to information has spread globally, there has been essentially

Within the most recent decade, while access to information has spread globally, there has been essentially no research or scholarly attention to the informational needs, information skills, information seeking behavior, or information services of science educators.

While ERIC focuses more on published research and scholarly articles, ENC handles the curriculum and instruction side of information resources.

no research or scholarly attention to the informational needs, information skills, information seeking behavior, or information services of science educators. Beyond discussions of specialized courses or learning modules, such as that of McNalley and Kuhlthau (1994), there has been no systematic exploration of the role of information literacy skills or the role of information providers in leadership development or science education reform. With this report of resources and services provided by ERIC/CSMEE and ENC, we hope to begin a larger dialogue about the informational needs and information skills of science educators, the role of information providers, and the possible dimensions of collaboration among science educators and information providers. We begin here with a description of current resources and services.

Inside ENC

While ERIC focuses more on published research and scholarly articles, ENC handles the curriculum and instruction side of information resources. ENC’s goal is to link K-12 mathematics and science educators with the resources they need to help each student learn (See Figure 1). Perhaps the most powerful way to obtain such information from ENC is online

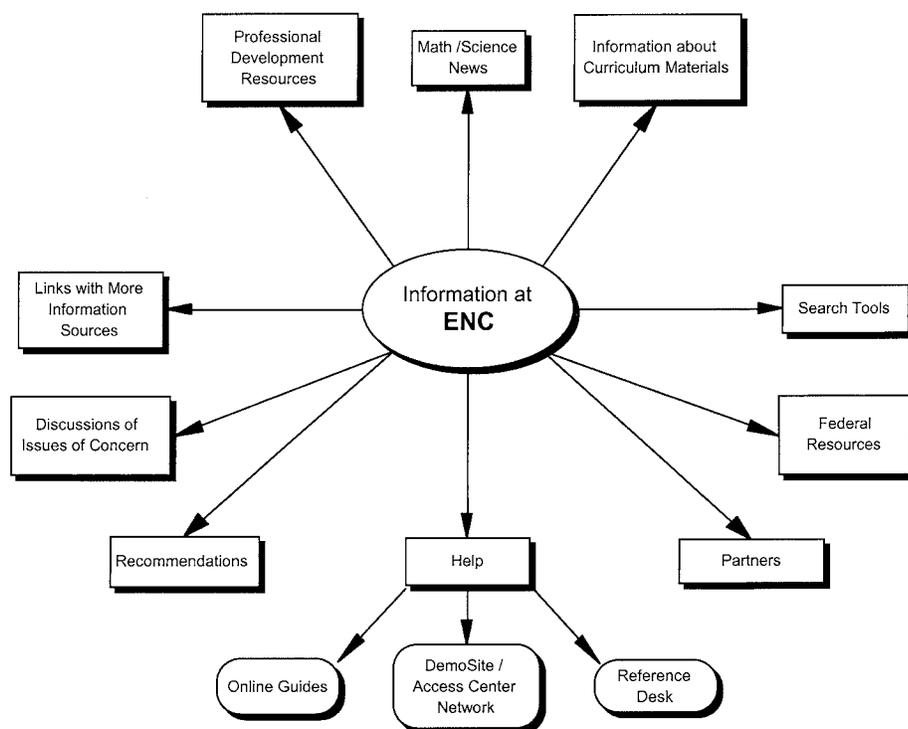
at the *ENC Online* web site. When a teacher or a leader of teachers comes to www.enc.org they will find instructional materials, standards, web sites for learning, new ideas, professional development activities and packages, science content background, personal help, recommendations and advice from successful teachers, news—all for K-12 mathematics and science – laid out in ways that make sense.

The education leader looking for *Information about Curriculum Materials* should visit the “Curriculum Resources” section of the ENC Web site, the gateway to ENC’s search tools and access to the largest databank of information on mathematics and science instructional resources in the nation. Over 18,000 mathematics and science curriculum resources, real stuff and virtual, web sites, kits, text-

books, professional readings, videos, software, CD-ROMs, etc. have been reviewed and abstracted by professional abstractors and specialists in mathematics and science education. Their objective descriptions along with extensive information like grade level, subject area, specific topics, cost range, media type, type of resource, table of contents, evaluation information, title, data, author, publisher, funding agency, and other information comprise the catalog records for each item. (www.enc.org/resources/)

A variety of *Search Tools* are designed to suit the varied and specific needs of science educators. The Simple Search tool provides a quick word search that can be limited by using criteria like grade level bands, cost, and one of four major categories of intended use. ([Figure 1](http://www.enc.org/re-</p>
</div>
<div data-bbox=)

Information Available at ENC



sources/search/) The Advanced Search tool enables the user to refine their search by specifying grade, media type, resource type, subject, funding agency, and more. (www.enc.org/resources/search/advanced/) A search could even be limited to just Web sites that have won recognition as one of ENC's Digital Dozen. The Browse tool provides three levels of subject terms organized in a hierarchical tree around mathematics, science, integrated approaches, general education, and educational technology. Beginning with these very general subject areas you follow the "tree" to specific topics like motion or photosynthesis. This may be the ideal approach when you are not sure where to begin or you want to identify pertinent search terms that you might have overlooked. (www.enc.org/resources/browse/)

The huge breadth of potential search criteria encourages fine-tuning each search to obtain optimum results. For example, through an ENC search a teacher may locate lessons that involve 3rd grade students in learning about rainforests. (www.enc.org/resources/) A teacher educator might find examples of using the Action Reflection Process to ensure that all students including those with special needs succeed in inquiry based science learning. (www.enc.org/resources/) A district science supervisor may identify information that will help convince a reluctant teacher to buy into important changes. (www.enc.org/topics/change/) Careful searches may locate materials perfect for a particular student or classroom, or for the professional growth of a school or district or even state.

Online Guides for both the novice and the more advanced aid in searching ENC and the Web in general. "Search Help" provides extra guidance in using the ENC database search

tools and includes: "Elements of an Advanced Search, Limiting and broadening searches, and Resource type definitions." (www.enc.org/resources/search/help/) ENC Pathfinders offer pre-selected searches on certain important topics including: Higher Education Scholarships, Grants, and Fellowships; Integrating Technology into the Classroom; Professional Development Grants; Technology and Equipment Grants; and Technology Plans. Pathfinders are easy to print and contain full titles of the suggested web resources, complete URLs, and contact information. ENC will continue to create Pathfinders on additional topics. (www.enc.org/professional/timesavers/reference/paths/) The "ENC Site Search" includes a Help with quick tips and advanced strategies for using InfoSeek to locate desired information on the ENC web site. (carson.enc.org:8765/help/)

In "Timesavers" (Professional Resources) educators will find a "Searching the Web Tutorial" that includes Internet Basics like "What is the Internet" and "Why Search the Web?" The tutorial for more advanced searching includes refining the question, planning the search strategy, advanced keyword searches, etc. Finally an excellent glossary removes the mystery of related jargon. (www.enc.org/professional/timesavers/web-searching/)

Even more help is available from the *ENC/ERIC Reference Desk* (also in Professional Resources). Research librarians respond to online requests, e-mails, phone calls, letters, and personal visits to help educators find the information desired. They will help clarify specific questions and find answers in both the ENC and ERIC systems. If a question is beyond their expertise, they identify

others who can answer the questions. (www.enc.org/professional/timesavers/reference/).

Closer to home, you can find help from real people located at ENC's network of twelve regional *Demonstration Sites* and over 150 volunteer local *Access Centers*. Contact information for Demonstration Site and Access Center coordinators can be found among the ENC *Partners* lists along with the Eisenhower Regional Consortia, professional organizations, and others who work closely with ENC. (www.enc.org/partners/)

Every publication of the Eisenhower National Clearinghouse is available at ENC Online in full text and graphics and can be printed as needed. But they are also available for free in print and in some cases, CD-ROM. Each issue of the free quarterly magazine, *ENC Focus: A Magazine for Classroom Innovators*, features *Discussions of Issues of Concern* in mathematics and science education. They contain essays by noted experts, stories by classroom teachers that illustrate outstanding teaching and learning related to the topic, and descriptions of exemplary instructional resources that support good practice. Recent titles have included: *Partnerships with Business and the Community*, *Making Schools Work for Every Child*, *Mathematics and Science in the Real World*, *Assessment That Informs Practice*, *The Reality of Change*, *Integrating Technology in the Classroom*, *Inquiry and Problem Solving*, *Family Involvement*, *Informal Math and Science Education*, *TIMSS*, and more. A list of issues along with all related resources at ENC can be found in the "Topics" section. (www.enc.org/topics/)

Many may not be aware that ENC produces materials especially for use by professional develop-

Every publication of the Eisenhower National Clearinghouse is available at ENC Online in full text and graphics and can be printed as needed.

ers as they work with teachers and schools in mathematics and science reform efforts. For example, currently available online are *Teacher Change: Improving K-12 Mathematics*, *Ideas that Work: Science Professional Development*, and *Ideas that Work: Mathematics Professional Development* (publications by Susan Loucks-Horsely), and *Equity*. These *Professional Development Resources* along with many other outstanding web sites useful for professional development can be found in the “Web Links” section of ENC Online. While supplies last ENC’s professional development packages are also available in print and/or on CD-ROM. Coming soon will be a package designed to assist educators in using the Authentic Task Approach to professional development, a facilitated system that leads teams of educators to develop solutions to real problems they currently face. (www.enc.org/weblinks/pd/) The annual *Guidebook to Federal Resources* (now published exclusively online as a searchable database in the “Professional Resources” section) helps leaders locate *Federal Resources* available in their own state as well as describing each agency’s national programs for students and educators. For example, a search for resources available from the U.S. Department of

Education in the State of Virginia will give the names and phone numbers of key staff at the Eisenhower Regional Math/Science Consortium at AEL and the services they can provide leaders. The same search gives the contact information for the coordinators of the state’s Eisenhower Professional Development Program. Links to the web sites of each Federal agency as well as a special search tool to locate only materials created or supported by a specific Federal agency (NSF or NASA, for example) adds even more value. (www.enc.org/professional/federalresources/guidebook/)

Of course, ENC also has hundreds of *Links* to other outstanding Web sites for students, teachers, and leaders of teachers. The links are organized into menus that make sense, like lesson plans and activities categorized by mathematics and science subject areas, or “Student/Classroom” sites that can be used by or with students both within and beyond the context of the teaching day, things like projects, simulations, virtual field trips, games, and even online courses. Within “Reference Sources” one finds “Ask-An-Expert Sites,” “Real Data Sources,” “Math and Science Background Information,” and “Biography Sites.” And of course, there’s the “Professional Resources” section with national and state “Standards and Frameworks” and “Funding Opportunities.” (www.enc.org/weblinks/)

What more is at ENC Online?

Here are some additional treasures to look for:

- *News* –Daily Education Headlines and Education Bulletins assembled from 75 U.S. newspapers every day with links to the full stories in the newspapers cited. In addition to

articles about teaching and learning there are articles concerning advances in scientific knowledge. (www.enc.org/thisweek/news/)

- *Recommendations* for high quality k-12 mathematics and science Web Sites known as the monthly “Digital Dozen;” (www.enc.org/weblinks/dd/) evaluative information and learned opinions about resources in the collection like “Exemplary and Promising Programs;” (www.enc.org/professional/federalresources/exemplary/) and advice for using the Web effectively in the classroom – in articles like “Getting What You Want from the Web,” “Becoming a Critical Consumer of the Web,” “Taming the World Wide Web,” “School and Home Connect Through the World Wide Web,” and “Designing a Classroom Web Page.” (www.enc.org/professional/timesavers/classroom/)
- *ENC Content Calendar* – A brand new online feature with lessons and activities designed to celebrate each day of the year, highlighting birthdays of outstanding scientists and mathematicians, historical events, and notable applications of mathematics and science.

Whether a reform effort has to do with implementing effective science learning strategies using information technologies, using community resources in learning mathematics and science, or rebuilding the science curriculum around inquiry learning and the National Science Education Standards, helpful resources are abundant at ENC Online and the tools are available to help you locate all that you need.

ERIC and ERIC/CSMEE from the inside

You might say ERIC has an identity problem; it has been a part of academic life for so long that it has something akin to brand-name recognition. Unfortunately, the acronym is so familiar that most educators never stop to wonder if they really know what ERIC is or does. Surprisingly, most are less familiar with ERIC than they realize. The one ERIC resource that is most familiar is the database; ERIC maintains the world's largest bibliographic database of education-related resources with over one million records. Because ERIC has regularly acquired and archived "ephemeral" publications, ERIC is also the only viable source for many influential documents in the ongoing evolution of science education. We'll talk more about the database shortly.

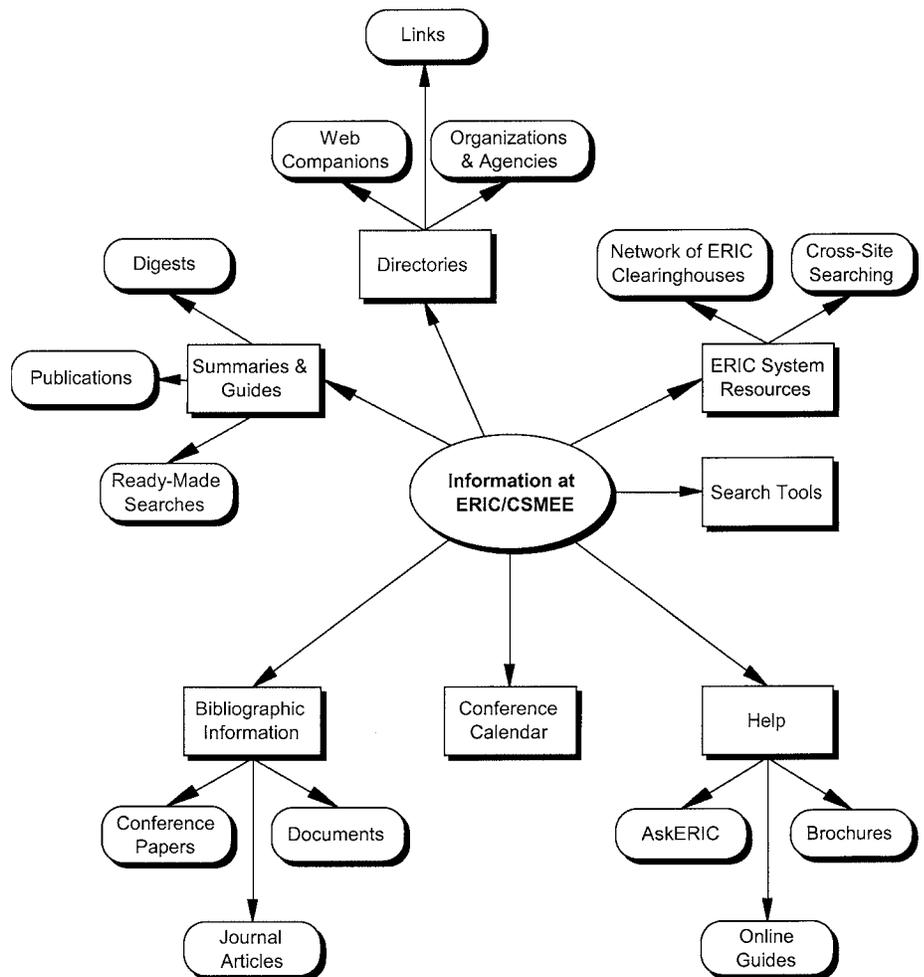
What most people do not realize is that ERIC is a misnomer; the Educational Resources Information Center has no center. ERIC is a decentralized information system comprising 16 clearinghouses, a processing facility, a public relations component, and ever-changing numbers of adjunct clearinghouses. Of particular relevance to science educators is the ERIC Clearinghouse for Science, Mathematics, and Environmental Education (ERIC/CSMEE), which is located at the same address as ENC. In addition to sharing hallways, meeting rooms, a resource room, and restrooms, we share responsibility for keeping science educators informed of practices, research findings, resources, and policies related to science teaching and learning (See Figure 2). So, when you say "ERIC" you could be referring to any one of the many components in the system. Here we will try to differentiate the

ERIC maintains the world's largest bibliographic database of education-related resources with over one million records.

resources of ERIC the system from those of ERIC/CSMEE.

ERIC the system is large and multifaceted, but its services can be roughly divided into four functional pieces: (a) the database, (b) an array of Web servers, (c) publications, and (d) teams of specialists to answer questions and provide services. First we will consider the database, since it is the aspect of ERIC that is most familiar to educators. Each of the 16 ERIC clearinghouses acquires documents from around the world and reviews magazines and journals for relevant articles to index. Those long familiar with ERIC will remember, and pos-

Figure 2
Information Available at ERIC/CSMEE



sibly still use, the *RIE (Resources in Education)* and *CIJE (Current Index to Journals in Education)* indices that used to be available in most research libraries and many public libraries. *CIJE* was the red one, remember? Within its database, ERIC has records of scholarly publications, conference papers, journal articles, and other documents having to do with teaching and learning all subjects at all age levels. One of the few types of printed material not found in ERIC, textbooks, happens to be one of the specialties of ENC. Since ENC also collects kits and other non-print media, one of the unique features of the ERIC-ENC team is that between the two of them you have access to nearly every type of resource available for education in science. Users can access the ERIC database a number of ways, and your preferred mode of access may reflect your academic heritage. Those familiar with the paper indices in the reference sections of libraries probably became familiar with ERIC sometime prior to the 1980s. From the 1980s until recently, most ERIC users came to rely on searching the database by using CD-ROMS. With the new millennium has come widespread access to the ERIC database through the World Wide Web of the Internet. There is an array of search engines, from those developed by universities to commercial search engines. Fortunately, ERIC now has its own search engines that can be accessed through a gateway at www.accesseric.org:81/searchdb/searchdb.html. The most popular search engine is hosted by AskERIC at ericir.syr.edu/Eric/, but the wizard at searcheric.org/ is also becoming very popular. It allows very rapid searches using ERIC Descriptors and includes an online *ERIC Thesaurus*. Tutorials and help using the search engines are also avail-



Within its database, ERIC has records of scholarly publications, conference papers, journal articles, and other documents having to do with teaching and learning all subjects at all age levels.

able at both locations mentioned.

The number of ERIC Web sites continues to grow, but they are all interconnected. The official home page of the ERIC system is located at www.accesseric.org/home.html, but ERIC/CSMEE also maintains a directory at www.ericse.org/ericsys.html. We will say more about the ERIC/CSMEE Web site shortly, but if it all seems too amorphous, you can search the contents of all ERIC clearinghouses with a single search engine at search.ed.gov/csi/eric.html. Each clearinghouse and other ERIC components have their own Web sites with online publications, links, and services, so it would be valuable for leaders in education to take the grand tour of the individual Web sites to become familiar with the abundance of resources available.

Each ERIC clearinghouse also publishes a number of documents each year, from two-page Digests to research monographs. The best way to learn of these publications is to visit the Web sites of the individual clearinghouses, but there is a central search engine to locate ERIC Digests

at www.ed.gov/databases/ERIC_Digests/index/. You can also browse a listing of science-related Digests published by ERIC/CSMEE at www.ericse.org/digests.html. Digests are very popular with teachers, teacher educators, and parents because they present very succinct overviews of specific topics, either providing an overview of findings related to a topic, or pointing the way to the array of resources available on a particular topic. The ERIC system as a whole also produces an annual guide to education-related conferences, and the guide can be searched online at webprod.aspensys.com/education/ericconf/ericcal/introduction.asp.

In addition to all the electronic services available from ERIC, you can also still talk to people in the ERIC system. Each clearinghouse has a toll-free telephone number, and all have user services specialists who will try to answer your questions. For an overview of the ERIC system and contact information for all the clearinghouses, download the guide, *All About ERIC*, at www.accesseric.org/resources/allabout/index.html. The most popular personal service of the ERIC system, by far, is the AskERIC service. Anyone “interested” in education is invited to submit questions by e-mail through ericir.syr.edu/Qa/. Someone in the ERIC system will respond to you within 48 hours, usually providing a sample search of the ERIC database as well as a listing of other Internet resources pertaining to your question. Most of the science-related questions are answered by staff members at ERIC/CSMEE.

Being part of the ERIC system, ERIC/CSMEE offers all the resources typical of ERIC clearinghouses, so here we will focus on resources that will be of particular interest to

science educators. We do publish a variety of ERIC Digests and other documents that are described on our Web site (www.ericse.org), and our newest book is, *Developing Teacher Leaders: Professional Development in Science and Mathematics* (Nesbit, 2001). ERIC/CSMEE also has an outreach office that provides packets of Digests, sample searches, brochures, and bookmarks for conferences or meetings upon request. Packets can be requested through e-mail (ericse@

Anyone “interested” in education is invited to submit questions by e-mail through ericir.syr.edu/Qa/

[osu.edu](mailto:ericse@osu.edu)) or telephone (1-800-276-0462). Of special interest to teachers and others wishing to find Web-based resources for particular topics or situations, we are in the process of developing directories that we call “companions.” The Web companions currently online are listed at www.ericse.org/companion.html and include the following: Homework Companion; African Americans in Science; Women in Science, Math, and Technology; Earthday Everyday Companion; Space Science Companion; Science Fair Companion; and Evolution Companion.

The ERIC/CSMEE Web site also includes an array of links to organizations, lesson plans, online publications of special interest, announcements, and journals. Our hope is to support ongoing improvement

in science teaching, learning, and scholarship by facilitating an active exchange of ideas and resources, so there are guidelines at our Web site for you and others to contribute to our ongoing development of resources.

Summing Up

This discussion of the link between useful information and taking action reminds David of a serious mistake he made several years ago in his role as a workshop leader. The two-day workshop was to be held some distance from where the participants lived, in an area where most of us had never traveled. David decided that it would be good to give everyone a map to the site, so he called the lodge we were using and asked for directions. As the person described each road, turn, intersection, and landmark, David dutifully drew a map. It looked good; he took special care to label all the roads and include distances and significant landmarks. When we made copies, many commented on how well the map turned out and how helpful it was to have the map. Only later, when David tried to follow the map, himself, did he learn that the person on the telephone had forgotten a critical turn. After being lost for some time, David finally found the lodge and stayed by the telephone to take the many calls that he knew would be coming from other lost drivers. Though embarrassing, David learned a valuable lesson through this experience: be sure to check your sources and carefully assess the reliability of your information. Everyone in a leadership role will occasionally have to make decisions or take actions in situations where he or she has no personal experience or little personal knowledge. In those situations, reliance will have to be placed on the knowledge, skills, or

experiences of others, whether direct reliance on a colleague, or indirect reliance through research findings, project reports, or Web resources. It is at this nexus that the resources of ENC and ERIC/CSMEE come into focus. Our hope is that we can be the sources of pertinent and reliable information when you are searching, but we need help in determining how best to tailor and refine our information services to be of greatest assistance to science educators who are taking the lead in our ongoing efforts to reform science teaching and learning.

Invitation to a Dialogue

Both ENC and ERIC are committed to providing high quality products and services, and to continuous response to the K-12 science community. So we invite you to join us in a dialogue to refine the processes of seeking and using information. Please consider with us questions like the following:

- *What are the informational needs and issues facing science education leaders?*
- *How best can ENC and ERIC contribute to addressing those needs?*
- *What information seeking behaviors and resources are currently most used by leaders in science education?*
- *How can we (ENC and ERIC) obtain the continuous feedback we need to adjust our services in response to the changing needs and priorities of K-12 science leaders?*
- *What resources and services at ENC and ERIC work best for you now? How can we make them better?*

- *What gaps or roadblocks have you faced in using the resources and services of ENC and ERIC?*
- *What research is needed to inform efforts to provide, locate, share, and use information effectively to improve science teaching and learning?*
- *What are (and what should be) the roles of information literacy skills and the roles of information providers in leadership development or science education reform?*
- *What can leaders of K-12 science education do to move along our investigation of the best roles for ERIC and ENC?*

If there are other important questions to add to this list, please let us know. To join us in this dialogue send e-mail to haury.2@osu.edu or to tgadsden@enc.org. We invite your suggestions and collaboration in exploring and clarifying the informational needs of leaders in science education.

References

- Libbrecht, Kenneth G. 1999. *Snowcrystals*. [WWW document, December 2000] Available WWW: www.its.caltech.edu/~atomic/snowcrystals.
- McNalley, M.J., & Kuhlthau, C.C. (1994). Information search process in science education. *Reference Librarian*, 44, 53-60.
- National Estuarine Research Reserves. 1997. *Information on Estuaries* [WWW document, December 2000] Available WWW: inlet.geol.sc.edu/nerrsintro/nerrsintro.html.
- Nesbit, C.R., Wallace, J.D., Pugalee, D.K., Miller, A-C., & DiBiase, W.J. (Eds.) (2001). *Developing teacher leaders: Professional development in science and mathematics*. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Pellicer, L., & Anderson, L. (1995). *A handbook for teacher leaders*. Thousand Oaks, CA: Corwin Press.

Tom Gadsden, Jr. is Associate Director for Collaboration, Eisenhower National Clearinghouse, College of Education, The Ohio State University, Columbus, Ohio 43210.

David L. Haury is an associate professor of science education at The Ohio State University, director of the ERIC Clearinghouse for Science, Mathematics, and Environmental Education, and Executive Secretary of the National Association for Research in Science Teaching.

Inquiry-Based Field Studies involving Teacher-Scientist Collaboration

Collaboration is seen as an important ingredient in designing teacher professional development programs.

Introduction

High quality science education must include major efforts by both university schools of education and colleges of arts and sciences before we can realize the national goal of producing scientifically literate citizens. In addition to science teaching methods courses, prospective and practicing teachers must take science courses in which they learn science through inquiry, having the same opportunities as their students will have to develop understanding (NRC, 1996). To design an effective curriculum that will give teachers opportunities to learn science by inquiry will take a concerted, integrated, and cooperative interaction of exponents from education and all the disciplines of science at the university level (Crosby, 1997). The challenge to universities is to create optimal collaborative learning situations in which the best sources of science and education expertise are linked with the experiences and needs of the teachers. This will require substantive changes in science teaching at the university level.

Scientists and educators have long argued that the best way for majors and nonmajors to learn science is for them to model what scientists do (Halpern, 2000). There is general agreement that inquiry into authentic questions generated from students'

Teacher research also supports lifelong learning and the intellectual rigor required to lead students through investigation and inquiry.

experiences is the key to effective science teaching. A good way to introduce teachers to inquiry is through participation in scientific research with scientists. When teachers have the opportunity to conduct scientific research, they understand the nature of science and learning by enhancing their own skills through exploring, constructing, and discovering new ideas and knowledge. Teacher research also supports lifelong learning and the intellectual rigor required to lead students through investigation and inquiry. Although successful teacher-scientist partnerships have been established, they are challenging to achieve; little is known about the effects of such collaborations on participants and students (Caton, Brewer, & Brown, 2000).

A project, entitled the Teacher Scientist Network (TSN), teamed scientists with teachers in elementary classrooms. The teacher-scientist partnerships were created to enhance and support science education. The two goals of TSN were that (1) the scientist would address the school's science curriculum, so that children were helped along the existing curriculum and (2) the teachers would ensure the scientist's skills were used appropriately. It was reported that the TSN enhanced classroom science by bringing fresh, up-to-date information. Teachers were provided contact with professional science information and advice, and scientists were provided insight into educational processes and purposes. Students were able to view science role models, and teachers were given opportunities for professional development in science and science education (Chennell, 1999).

Educators at North Carolina State University developed SCI-LINK to link research scientists with grades 6-12 science teachers to assist in developing skills, classroom strategies, and instructional materials needed to include recent advances in science in their teaching. It was reported that SCI-LINK provided teachers with a better understanding of scientific environmental research and recent findings, and allowed the development

of activities and other instructional materials for classroom use. Leadership skills also were developed, as evidenced by the master teachers who evolved and the many professional activities in which they have been engaged (Anderson, 1993).

Caton, Brewer, & Brown (2000) reported on a project that linked energy science engineers with middle and high school science teachers in research partnerships. A two-day summer institute allowed teams of 4-5 teachers and a scientist to explore wind-energy by building working windmills, using kits of everyday supplies and equipment. They found teachers had an increased appreciation of inquiry, greater confidence in teaching using inquiry, and greater use of inquiry in the classroom.

This article describes a collaborative effort between a School of Education and College of Arts and Sciences at a Midwestern university to design a teacher professional development program, using teacher-scientist teams to improve teachers understandings of methods of scientific inquiry with field-based environmental research activities. It specifically presents an overview of the inquiry based inservice program, describes the program's

Teachers were provided contact with professional science information and advice, and scientists were provided insight into educational processes and purposes.

development, its content and goals, activities, results, and subsequent changes as the program evolved.

Teacher-Scientist Collaboration

A project entitled "Inquiry-Based Field Studies involving Teacher-Scientist Collaboration" was undertaken as a result of collaborative meetings between the School of Education and the College of Arts and Sciences, initiated by a request from teachers and administrators from an urban school district in a large Midwestern city to identify and implement a model of inquiry learning for middle and high school mathematics and science teachers. Three consecutive cycles (1998-99, 1999-00, 2000-01) were funded with Dwight D. Eisenhower Professional Development Program grants. The project explored ways to establish productive, collaborative relationships between teachers and scientists and to give teachers the opportunity to ask authentic scientific research questions of scientists. The project was initially based on the 21 Questions to Conclusions model for teacher enhancement (Calabi, 1997). The 21 Questions to Conclusions model was selected because it was reported to be an effective way to team teachers and scientists in research, and it was consistent with the pedagogy and content stipulated by the Missouri Show-Me Standards (Missouri Department of Elementary and Secondary Education, 1996) and National Science Education Standards (NRC, 1996) as requested by the urban school district.

Prior to seeking Eisenhower funding, university professors and school district teachers and administrators were provided training on 21 Questions to Conclusions by Dr. P. Calabi, who developed the model. Continued

communication between university and school district personnel resulted in numerous planning meetings, from which we developed a basic framework for a professional development program that teamed teachers and scientists.

A science educator from the university volunteered to be the project director and wrote the initial and all subsequent Eisenhower grants. He facilitated communication between the university and school district, insured teacher involvement in the planning of the project, and administered details of the grant. A university research geologist, with a long record of studying shale throughout the world, volunteered to be co-PI and lead scientist. He recruited scientists at the university and in the local community colleges to work as collaborators with the science teachers, and he also identified field research sites. A university organic chemist volunteered to be co-PI and worked as the staff development specialist. She had extensive experience with the 21 Questions to Conclusions model and led university staff development and training during subsequent years. The curriculum coordinator for the urban school district helped recruit teachers to participate in the program. In addition, two high school teachers from the Houston, Texas area, who had previously participated in the original institute, acted as facilitators during the projects first cycle.

Summary of Subject Content and Goals

The project was designed to help teachers develop a better understanding of scientific inquiry. Reflection on how these skills could be integrated in the classroom was not formally addressed, although informal discussions occurred throughout the project.

The primary goal was to establish productive, collaborative relationships between teachers and scientists and give teachers the opportunity to ask authentic scientific research questions of scientists. This goal was subsumed by the following objectives: to model the skills of asking and answering research questions; to encourage teachers to ask questions and to formulate hypotheses; to increase teachers' self confidence in doing scientific research; to make instruction more student-centered; to model and encourage analytical thinking in science or any subject; and to awaken learner curiosity. In addition, we planned to include the following content and pedagogical skills but maintained open lines of communication about content to enable teachers "...to have a significant voice in decisions about content..." as stipulated by National Science Education Standards Teaching Standard E (NRC: 1996, page 46).

Subject Content:

1. Science as Inquiry
 - a. Identify questions and concepts that guide scientific investigation.
 - b. Design and conduct scientific investigations.
 - c. Use technology and mathematics to improve investigations.
 - d. Formulate and revise scientific explanations and models, using logic and evidence.
 - e. Recognize and analyze alternative explanations and models.
 - f. Communicate and defend a scientific argument.
2. Characteristics and interactions of living organisms.
3. Changes in ecosystems and interactions of organisms with their environments.

4. Processes (such as water cycle, airflow) and interactions of earth's biosphere, atmosphere, lithosphere and hydrosphere.
5. Impact of science, technology and human activity on resources and the environment.

Pedagogy Skills:

1. Model the planning of an inquiry based science program for their students.
2. Guide teachers in active and extended scientific inquiry.
3. Design and manage learning environments that provide teachers with time, space, and resources needed for scientific inquiry.
4. Model the intellectual rigor and standards of evidence of scientific processes.

21 Questions-to-Conclusions

Twenty-one Questions-to-Conclusions was used to introduce teachers and scientists to approach scientific research in simplistic terms. It provided a platform to develop a scientific research project (Calabi, 1997). This method contained four steps: asking questions, discussing the questions, utilizing "triage," and developing a research project. The process was led by a facilitator assigned to the research site.

The first step, asking questions, introduced the study area by helping participants focus on the details of the field site. Study sites selected were: a woodland, a grassland, a creek, and an urban site in a field adjacent to a local high school. Participants were asked list questions until they had reached 21 in total or the time limit had been reached (30 minutes). During this stage, the participants immersed

themselves in the assigned area. They were asked to work alone while keeping in sight of another person, and write down the first 21 questions that came to mind. Once they were finished with 21 questions, or the time limit had been reached, participants came back into a group.

During step two the participants' questions were discussed. They were requested to choose one question for which they were really interested in knowing the answer; this was called a "burning question." Other questions were prioritized during this process, in case two people had the same "burning question." Then, facilitators and participants were arranged in a circle, and participants shared their questions. Facilitators led a discussion of the questions by asking additional questions such as, "How would you go about studying this question?" and "What do you think is going on with the phenomenon?"

Step three, the "triage" portion of this technique, was to used re-evaluate the questions as possible research questions. Each "burning question" was written on a portable tablet carried into the field for all to see and discuss. Each topic was dissected into sections: what is the question, how would you answer the question, and what methods would you use? During this stage, questions were focused and clarified.

Step four, developing the research project, involved choosing a question. The participants decided which question they wished to pursue during a specified timeframe. They worked in groups limited to four members, to plan and conduct their respective research projects with the aid of a facilitator.

Project Activities during the 1998-99 Cycle

The project had three specific phases, designed to facilitate development of specific skills and knowledge. Phase 1 involved introduction to field research sites using 21 Questions to Conclusions and introduction to research methodology with a facilitator. Phase 2 focused the development of scientific processes through field study, data collection, and communication of research findings with 3-day research projects, culminating in a poster session of findings. Phase 3 involved an extensive long-term field based research project by teacher-scientist teams, culminating in a poster session which university and school district faculty and administration were invited to attend.

Phases 1 and 2 occurred during a two-week summer institute in June 1998, for a total of 80 contact hours. During phase 3, teacher-scientist teams conducted long-term research for a total of 80 hours of independent study, including 4 follow-up meetings during Fall 1998 and Winter 1999. In addition, teachers attended a half-day preliminary meeting May 1998, to provide an overview of the project, and discuss equipment, procedures, and safety concerns of scientific fieldwork.

Most of the research activities were focused at J.A. Reed Wildlife area, a 2500+ acre site located a half-hour drive from the university campus. The project specifically included some work in an urban setting close to campus, to demonstrate that scientific research was not the exclusive domain of exotic wilderness settings, but worthwhile field projects can be done in any setting.

During the first four days of the summer institute, teachers were introduced to the four different study areas.

Teams of teachers rotated among the four study areas each day and were introduced to field based research by facilitators, using the Twenty-one Questions to Conclusions model. The facilitators were 2 high school teachers who had completed a similar program. During the four one-day mini-projects, teachers asked questions, selected questions of interest for research, designed experiments to answer questions, collected data, and drew conclusions. At the end of each day all of the teacher teams returned to a central location to share research findings.

On the fifth day of the summer institute, teacher teams began three-day research projects, which were self-designed research projects culminating in a formal poster session. A half-day was spent on campus in the computer lab organizing research and constructing posters. At the poster session, scientists were introduced to the teacher teams. Subsequently, each of the scientists made a formal presentation of his/her personal research efforts. Informal discussions followed the presentations, serving as a mechanism for teachers and scientists to discover common interests that led to the formation of teacher-scientist research teams. Teacher-scientist teams then jointly designed long-term research projects, with teachers taking the lead and participating scientists providing guidance. The remaining two days of the summer institute were used to identify and chose research questions for the long-term research projects, plan how the 80 hours of independent study would be used to conduct the research, and begin data collection.

Phase 3 began after the summer institute was completed. Some teacher-scientist teams immediately took advantage and conducted much of their

research during the summer. Other teams had previous commitments and did not begin long-term research projects until the fall. During the fall and winter, teacher-scientist teams attended three half day and 1 full day follow-up meetings. Teams provided progress reports; continued planning; shared ideas and techniques; trouble-shot problems, and began working on posters. The final follow-up meeting was used to complete and present research in a poster session which university and school district faculty and administration were invited to attend.

Results

The urban school district provided each middle and high school mathematics and science teacher a written description of the project and instructions for enrolling. Having received release time from their schools, sixteen prospective science-teacher participants attended a May preliminary meeting to learn about the project. On learning that such participation would involve a commitment to two consecutive weeks of full-time field work in June and considerable team-based research during the subsequent school year, accompanied by four additional, mandatory, follow-up meetings, several individuals indicated that they would be unable to participate in the project. Twelve urban middle and high school mathematics and science teachers enrolled. Each teacher received a daily stipend for participating, compensation for mileage to travel to research sites, meals during the sessions, materials for use in the field and for the poster sessions, and 9 hours of graduate credit in a course entitled "Field-Based Inquiry and Problem Solving."

All of the participants successfully completed the 2-week summer institute and formed teacher-scientist research teams for long-term research projects. Three teachers dropped out before completing their independent research projects. Teacher attitudes and impressions about the course were collected and pre and post assessment data were collected, using a performance based assessment tool. Long-term research projects of the teacher-scientist teams are summarized below.

Long-term research teams

Three of the four teacher-scientist teams successfully completed long-term research projects that were presented as poster sessions. Many of long-term projects began in mid-June, and all were completed by March of the next year. Research included:

(Team One) A team of three teachers and a biologist from a state agency conducted a study of the relationship between macroinvertebrates and various sorts of plant debris in the Blue River, a tributary of the Missouri, which flows throughout Kansas City. The stated object was to determine whether there was any one-to-one correspondence between the types and numbers of invertebrates. Specifically, did gastropods, crustacea, etc. display any affinities with particular types of leaf litter?

(Team Two) A team of three teachers and an EPA scientist, conducted a comparative study of the CO₂ contents of air within classrooms in three buildings to which the participating three teachers were assigned. The stated objective was to determine the source of carbon dioxide in the buildings and whether the type of heating or cooling sys-

tem (or lack thereof) had a major effect on the CO₂ content of the ambient air.

(Team Three) A team of three teachers and a mineralogy professor conducted a study of the relative amount of deterioration occurring on building stones exposed on the exterior of a middle school to which two participating teachers were assigned. The stated objective was to determine whether or not textural features or the mineralogy of the rocks as determined by X-ray diffraction, could be used to predict their vulnerability to the weather.

(Team Four) A team of two participants, who ultimately dropped from the program, attempted to conduct a study of the deer population of rural acreage, but they lost interest.

Performance Assessment

The performance assessment was a written test administered prior to and after the summer institute. The goal of the assessment was to provide additional objective evidence, in addition to the three-day and long-term research projects, on the effectiveness of the summer institute for introducing the following skills: stating a problem as a cause and effect question, hypothesizing, designing an experiment to test the hypothesis, and drawing conclusions.

The test had two parts, which began with a description of a hypothetical study area of 1000 acre woodland with a creek running through it, surrounded by businesses and residences. In the first part, the description was followed by instructions to identify suitable research questions, variable identification, hypothesizing, experimental design. During part 2, possible errors were identified, conclusions

were drawn, and additional questions were asked, based on a pre-defined question, hypothesis, experimental design and data set. The following is a general description of the performance assessment.

Teachers were asked to brainstorm 5-10 possible research questions about the hypothetical study area and select one question for development into a research project. High quality questions were defined as completely describing the cause (independent variable) and effect (dependent variable). After identifying a question for development into a research project, teachers were asked to identify the independent and dependent variables, constants, and controls followed by a hypothesis. Hypotheses were assessed on which essential elements were present and whether or not they fit the question. Hypothesis was defined by five essential elements: (1) incorporates independent variable, (2) incorporates dependent variable, (3) shows directional effect or possible outcome, (4) testable, (5) explains an outcome.

In next section, teachers developed an experimental design to test the hypothesis. The item was open-ended, without guidelines. In addition to assessing whether the procedure offered a test of the hypothesis, we assessed the completeness of design, classified on five different levels according to the essential elements. Five essential elements defined a complete experimental design: (1) materials, (2) control procedure clearly stated and appropriate, (3) logical sequence of procedures, (4) clearly stated test situation, and (5) adequate test of hypothesis.

After designing an experiment, teachers were asked to draw conclusions, based on an abbreviated version of a hypothetical research project from the study area in which informa-

tion about the project was provided, including the question, independent and dependent variables, control, constant, hypothesis, and data collected during an experiment. Teachers were asked to suppose the data were collected many different times with similar results, to eliminate the need for statistical analysis, and were asked to write possible conclusions from the experiment regarding the hypothesis. Three essential elements defined a conclusion: (1) conclusion is based on all the data, (2) statement of support or lack of support of the hypothesis, and (3) conclusion is reasonable.

A scoring guide was developed, based on the essential elements of each item described above. Teachers' responses were transcribed from original assessment papers to individual sheets, to simplify handling and hide the identity of the teacher. Researchers, using the same scoring guide, assessed each item on the performance assessment and compared results. Disagreement between researchers was negotiated until a score were agreed upon. Modifications of the scoring guide were made as we assessed the small practice set. The modifications continued until the researchers were satisfied the scoring guide would provide meaningful analysis. Scoring was then applied to the entire set of 12 pre- and post-tests.

With an $n=12$, statistical analysis has very little power to determine significance between tests (Ferguson & Takane, 1989). These data alone would be insufficient for describing the outcome of the project, but add they to the overall picture previously described with the long-term projects and course evaluations. With this in mind, data were reported below. There was a greater average score on the post-test than pre-test in all categories.

Teachers gained most on the question and drawing conclusions. There were gains for experimental design fit to hypothesis and completeness of design, respectively. The least gain was 0.1 for formulating a hypothesis. T-tests indicated there was a significant difference between pre- and post-mean test scores for formulating a question, designing an experiment to fit the hypothesis ($p<0.05$), and no significant difference between mean scores for formulating a hypothesis, completeness of experimental design, and drawing conclusions ($p>0.05$).

Course Evaluation 1998-1999

The course evaluation consisted of 18 free response items about the project. The wide variety of items included questions about the study areas, the 21 Questions to Conclusions model, food, facilitators and scientists, scientific equipment, time in field, assessment, and overall impressions.

Generally, participants were satisfied with the study area. Some commented they wished it were closer to campus, but most agreed that a wide variety of environments were available for research. The 21 Questions to Conclusions model was well

received by most participants. Many commented it was "excellent" or "a very good idea." Another teacher commented that the model was good for introducing one-day projects but did not lead to good research projects. Another said "it was hard to do some days, and in some areas, but a good teaching (model) for all areas."

A wide variety of comments were made about the facilitators and scientists. Responses included "great groups of people, who quickly learned how to work together," "facilitators made everything stay on track," and "the diversity (scientists and science educators) was wonderful." Others responded that "the scientists dominate too much," "specific questions were in some cases not answered," and "too many times I felt that I had to fight or demand information before it would be given and sometimes it was flatly refused," referring to designing their own research projects. In general, interaction among facilitators, teachers and scientists was viewed as positive.

Scientific equipment available for use was viewed as sufficient, and all thought the food was great. Many felt more time was needed in the field, and some felt "overwhelmed" and "rushed" at first, and thought more time was also needed to prepare poster sessions. One commented that they would have preferred 2 three day projects instead of 4 one day and 1 three-day project, to reduce the feeling of being rushed.

Participants were asked if the performance assessment was representative of the program. The pre-assessment was given during the preliminary meeting before the summer institute and the post assessment was given the Saturday following the summer institute. Many commented it was

As evidenced by the three-day and long-term research projects, and the performance assessment, teachers continued to have difficulty writing high quality research questions.

excellent, or it was representative. Others felt the assessment was very long, very difficult, and said they were not mentally prepared. Asked to comment about the overall experience, responses included fun, hard work, exhausting, scary, overwhelming, excellent, just right, uncomfortably general, pretty good, I liked the freedom, I felt restricted, and it was fine.

Modifications in Project Activities for 1999-2000 and 2000-2001

The Teacher-Scientist Collaboration project was funded for two additional Eisenhower cycles. We have also been invited to submit a full NSF proposal based on the project, and will be submitting another Eisenhower proposal for the 2001-2002 cycle. Some major and minor changes have been made in the project since the 1998-99 cycle, based on performance assessments, course evaluations, and comments from the scientists. Major changes included research content, additional detailed focus on questioning, and modeling causal questions. During the first cycle, teachers researched any topic of interest. There were unlimited possibilities. Although the scientists felt secure in their scientific abilities, many felt uncomfortable collaborating on questions outside their primary specialty. Subsequently, during the following years, field sites were selected with collaborating scientists in mind. If a scientist specialized in local fossils, we selected study sites with fossils, or if a scientist specialized on aquatic biology, we selected an aquatic site. Because a limited number of scientists were participating in the project, if teachers posed a question beyond the expertise of our scientists, we would re-direct them or ask them to pose a new question.

The 21 Questions to Conclusions model was a good way to introduce a new field site, but it was limited for developing questions appropriate for hypothesizing. As evidenced by the three-day and long-term research projects, and the performance assessment, teachers continued to have difficulty writing high quality research questions. Many of the questions that resulted from the 21 Questions to Conclusions model were factual, descriptive, or correlative. Few, if any, causal questions were asked that lent themselves to hypothesizing. As a result, we continued to use 21 Questions to Conclusions model to introduce field sites. However, more time was included for reflection and discussion of the types of questions appropriate for research. If teachers posed a causal question appropriate for research within the time and equipment constraints, it was used. However, if an appropriate research question did not arise, we introduced a causal question developed during research site selection process prior to the two-week institute. By selecting a causal question in advance good questioning practices could be modeled along with making connections between questions, hypothesizing, experimental design, and drawing conclusions, which was a challenge for the 1998-99 cycle teachers. Also by introducing a question, it was easier to model scientific reasoning skills with a high quality research project within a short period of time. With a longer time frame it may be possible for teachers to discover the characteristics of good questions, but the two-week summer institute did not provide enough time. The 4 one-day research projects have been reduced to 3, and the main focus is on developing good scientific questions and reasoning skills. The fourth

If teachers posed a causal question appropriate for research within the time and equipment constraints, it was used.

day is now used to introduce additional field sampling techniques.

Minor changes were made in assessment procedures, poster sessions, transportation to field sites and project advertisement. Initially, the post-assessment was administered on the Saturday after the summer institute. Some teachers were exhausted and many commented that it was difficult to focus on the assessment. The post-assessment has been moved to one of the fall follow-up meetings, allowing recovery and reflection upon the two-week summer institute.

Almost all of the teachers commented that there was too little time to prepare posters after the three-day research projects. One entire day is now scheduled, rather than a half-day, to construct posters. Transportation to research sites was a problem during the 1998-99 cycle. At times, teachers would arrive late or request to leave early. It was difficult to maintain coherence during research with arrival and departure traffic. Further, we were limited to research sites with sufficient parking. Subsequently, vans are now rented to transport facilitators, teachers, scientists, and equipment to research sites. The vans have eliminated late arrivals and early departures, and have increased camaraderie and team spirit. With fewer limitations in select-

ing research sites, the time driving can be used to discuss content, point out interesting phenomena, reflect, and discuss the days work.

For the first cycle, a project description was developed to advertise the project. Our partner school district made every effort to provide teachers with the description; 16 teachers inquired and 11 urban school district teachers participated in the project. We sent the description and letters to other Kansas City school districts superintendents and principals advertising the project, and one additional teacher applied. Enrollment was limited to 24 teachers. After the first cycle, we discovered that a number of teachers never heard of our project. The next cycle (1999-2000) brochures were directly mailed to schools in the urban school district and other area schools. A web site also advertised the project. Eleven teachers participated in the second cycle. For the third cycle (2000-2001) copies of the brochures were sent to the districts in early spring. Inquiries about the project were low. Finally, a classified ad about our project was run in the local newspaper. Within a week 30 inquiries were received. Twenty-four applied for the program. Twenty attended the first meeting, and eighteen completed the program. In the future, we are considering over-enrolling to allow for attrition. A series of newspaper ads will also be run as early as possible during the spring. Many teachers indicated they were interested, but found out too late or already had plans.

Final Thoughts

The primary goal was to establish productive collaborative relationships between teachers and scientists and give teachers the opportunity to inquire into authentic scientific re-

search questions with scientists. Not only did the project allow teachers to conduct research with scientists, it provided them opportunities to develop a deeper understanding of the nature and processes of science. Teacher and scientist left the project with a greater understanding of the problems that each faces in science and science education.

Feedback from teachers was a key factor in modifying the project from year to year. Course evaluations were examined carefully, and comments were taken seriously. Many of the scientists were impressed with the teachers' enthusiasm and knowledge.



Teacher and scientist left the project with a greater understanding of the problems that each faces in science and science education.

One scientist commented that many of the teachers were capable to doing research equal to graduate level science majors.

Professional development projects like this one requires a tremendous commitment from both teachers and scientists. Especially during independent study, both must be willing to spend their free time and weekends conducting research. Each year there has been attrition during the independent study. Both teachers and scientists have commented on the tremendous amount of work required. It is important that all be briefed about the major time and energy commitments required to successfully complete such a project before enrolling.

Nothing worth having is easy. The hard work among the teachers, scientists and educators has resulted in strong working relationships between the School of Education, the College of Arts and Sciences, and the urban school district. Scientists are beginning to recognize their important role in teacher education, and have found a new respect for science education as a discipline; teachers and educators have found a greater understanding of the nature and processes of science. Clearly, more research is necessary to explore relationships among teachers, scientists and educators. However, the efforts and the results in this project are encouraging for universities who struggle to provide a comprehensive professional development program for teachers that is dependent upon both schools of education and colleges of arts and science.

References

- Anderson, N.D. (1993). SCI-LINK: An innovative project linking research scientists and science teachers. *Journal of Science Teacher Education*, 4(2), 44-50.
- Calabi, P. (1997). *Teacher change through collaboration with scientists*. Cambridge, MA: TERC.
- Caton, E., Brewer, C. & Brown, F. (2000). Building teacher-scientist partnerships: Teaching about energy through inquiry. *School Science and Mathematics*, 100(1), 7-15.
- Chennell, F. (1999). The Teacher Scientist Network. *Education in Science*, 184, 20-21.
- Crosby, G.A. (1997). The necessary role of scientists in the education of elementary teachers. *Journal of Chemical Education*, 74(3), 271-72.
- Ferguson, G.A., & Takane, Y. (1989). *Statistical Analysis in Psychology and Education*. New York: McGraw-Hill Book Company.

Halpern, E.A. (2000). Modeling the whole scientific process for nonmajors. *American Biology Teacher*, 62(4), 242

National Research Council (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

Show-Me Standards (1996). Missouri Department of Elementary and Secondary Education.

Arthur Louis Odom, Associate Professor, Science Education, School of Education, University of Missouri-Kansas City, 5100 Rockhill Road, Kansas City, MO 64110

A Cultural and Linguistic Approach to Teaching Science and Mathematics to Native American Students

An argument is made that traditional approaches to teaching science and mathematics to Native American students have not been successful, perhaps because the students do not find meaning in the curriculum.

Introduction

Traditionally, educators claim that science and mathematics are “culture free,” that earthly objects are classified as living or non-living, or that $2 + 2 = 4$, and that these truths exist independently of any reality. Such statements ignore the way these sciences developed from attempts to solve real-world problems, and they overlook the rather substantial thrusts of the past decade to relate school curricula in mathematics and science to the real world (NCTM, 1989; NRC, 1996).

One issue to consider is whether the “real world” is the same for all students. The “real world” on an Indian reservation is quite different from the “real world” of inner-city Detroit, suburban Denver, or rural Minnesota. Judging by the relatively lower performance of ethnic minorities (especially African Americans, Mexican Americans, and Native Americans) on normed mathematics and science tests, it appears there may be other reasons why these students perform less well in mathematics and science (Bourque, Champaigne, & Chrissman, 1997; Reece, Miller, Mazzeo, & Dossey, 1997).

A number of studies have focused on the growing problem of Native Americans and people with non-western world views transforming their resurgent cultures to a Euro-western understanding of mathematics and science (Anderson, 1988). In Montana, for example, standardized test results indicate significant differences in native students on the reservations when compared with other ethnic cultures (Montana Office of Public Instruction, 1998). Though questions concerning the validity of norm-referenced testing as base-line data exist, these tests still serve as indicators of achievement (or lack thereof) and such data are cause for alarm. Test scores are, in effect, snapshots of student achievement generalizable only to the specific moment the test was given.

Historically, attempts to assimilate Native American students into the structure of American schools have proven ineffective, notwithstanding the substantial financial investment that has been made. For example, during the decades of the 60s and 70s, many of the children were forbidden to speak their native language and forced to speak English only. The effects were profound because language is

the primary method by which meaning is constructed (Freire, 1982; Shapiro, 1994). Simply stated, since language is such a central component in any culture for the construction of existing schema, a whole generation of native students become adults with little understanding of the language base of their own culture.

Above all, it has been shown that the learning of Native American students is affected by their understanding of the English language as well as by their understanding of native language and culture (Atwater, 1994; Crawford,

Historically, attempts to assimilate Native American students into the structure of American schools have proven ineffective, notwithstanding the substantial financial investment that has been made.

1997: Indian Nations at Risk, 1991; Reyhner & Tennant, 1995). This intercultural and bilingual understanding helps to develop a prior knowledge so important as a foundational knowledge base. Yet, so many native children are Limited English Proficient (LEP) and also limited in their understanding of their own native language. Consequently, this creates some serious gaps in the foundational schema in native children. Without a language to interpret and describe concepts, new knowledge does not have individual or prescribed meaning.

Native Understanding of Science and Mathematics

The purpose of this article is to consider factors affecting the learning of mathematics and science and to explore strategies for improving the performance in mathematics and science of students living on the Crow Indian Reservation in Montana. On the Crow Indian reservation, a course for Native American teachers and aides was designed specifically to enhance the learning of science and mathematics by native students. The coursework focused on integration of mathematics and science, constructivist techniques, and the development of culturally relevant curricula. There is little argument that most curriculum materials, textbooks and other resources, used with Native American students provide little information that is relevant to their interests. Further, how much of these materials are relevant to their cultural background? For example, many native cultures emphasize a juxtaposition with nature rather than dominance over it (Caduto & Bruchac, 1989). Native peoples view soil, water, or trees as brother or sister (Robbins, 1983). Hence, the course focused on strategies to enrich the students' math and science curricula with culturally

There is little argument that most curriculum materials, textbooks and other resources, used with Native American students provide little information that is relevant to their interests.

appropriate illustrations.

The results of these classes offered on the Crow Indian Reservation have stimulated several questions that need to be addressed. First, how authentic are culturally relevant materials? For example, can a member of one culture develop a curriculum that is relevant to another culture, or can an activity that is relevant in one culture be relevant in another culture? This article focuses on successful strategies for developing and using culturally relevant curricula with Native American students.

Curricular Relevant Materials

The new generation of Native American students know very little about their cultural heritage. Indian grandmothers express concern that today's children are losing both their native language and their knowledge of cultural traditions. This, from an educational standpoint, is serious; unless the children value their heritage, their self-esteem will be affected. It becomes the educator's responsibility to help these students to value who they are. Denigrating their heritage and trying to assimilate them into the "anglo" way of thinking must cease.

One duty of a teacher on "native soil" is to promote a generous understanding of the heritage. Can this occur if the teacher is not a member of that culture? For example, can an anglo teacher develop *culturally* relevant understandings of Euro-centric scientific concepts and mathematical ideas which are integrated with traditional cultural beliefs? The answer could be yes, but only if adequate cultural understanding is incorporated in the lessons. This, however, is not the norm in the inter-racial classrooms we have visited. Through no fault of their own, few anglo teachers have the cultural background to create culturally relevant materials. At best, they have taken one or two undergraduate courses in Native American studies that focus more on social issues involving Native American cultures, than on important pedagogical concerns and appropriate curriculum development.

Textbook Presentations and Culture

As indicated in the introduction, there is a strong belief among curriculum specialists that mathematics and science curricula are culture-free. In a typical textbook presentation in geometry, many of the activities are artifacts of the anglo culture. Nevertheless, regardless of the ethnicity of the students, the problems are generalizable to most school settings. Texts typically continue with illustrations that are not culturally embedded.

Studies indicate that Native American students are holistic learners (More, 1989; Walker, Dodd, & Bigelow, 1989). Though this may not be a generalizable statement about Native American learning, learning in a holistic manner is more consistent with constructivist philosophies. Many constructivists would state that learning in this way would be best for

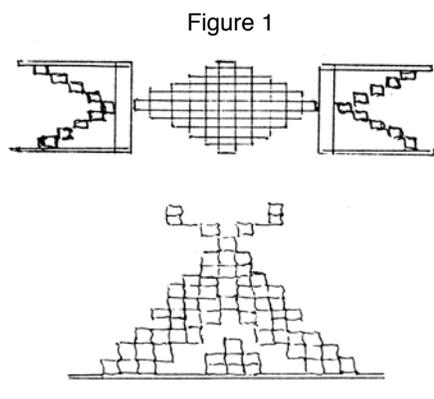
As educators it is essential for us to use culturally sensitive curricula to enhance learning.

students (Brooks & Brooks, 1993; Shapiro, 1994; Yager, 1991). Science educators have known for decades the value of inquiry and discovery. Emerging from the National Science Education Standards (NRC, 1996) and the Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989) is a strong emphasis on constructivist approaches for all Americans. To add to that, the standards in both science and mathematics suggest a strong emphasis on pedagogy that is inquiry based and more closely parallels constructivist ideology.

A lesson in symmetry, closely linking the mathematics standards and traditional native culture, is consistent with constructivist beliefs. Figure 1 shows how the same topic of symmetry can be developed using culturally rich examples. In this manner, symmetry can be explored in ways that respond to the culture of the students. As educators it is essential for us to use culturally sensitive curricula to enhance learning. In fact, one of the strategies recommended for use in classrooms of Native American students is to replace the conventional material that introduces a lesson with information that is culturally sensitive and will appeal specifically to the particular audience. This approach can be generalized to curriculum illustrations that are relevant to students of other cultures.

Other culturally relevant examples in symmetry include star quilts, loom beadwork, and native art. A substantial amount of informal geometry is used by practitioners of these crafts. Thus, within the tribal culture there is much informal mathematics that is inherent in the culture; as educators we have failed to acknowledge their scientific efforts.

The amount of mathematics and science that is traditional to the Native American is indeed significant. Consider the scientific achievements of the Mayans, the Aztecs and the Incas. Historically, mathematics and science books written even by the more enlightened authors overlook the



contributions of non-western mathematicians and scientists. The typical American approach to the history of science and mathematics is Eurocentric and should move away from this emphasis if the thinking of all non-European Americans is to be treated justly.

Is it possible to develop culturally sensitive materials by using textbooks? The answer is no. Specifically, western and non-western worldviews do not match. For example, in a sample lesson in science, the textbook handles the topic of classification in a typical manner. The lesson is representative in that it begins with the major kingdom

classifications as determined by Euro-western science. It continues with the breakdown of kingdom classifications into phyla, class, order, family, genus, and species. These diagrams on classification can be found in almost any life science textbook.

Native culture has little need to classify living things in this manner. These attributes used to classify plants, for example, are of little relevance to the Native culture. In fact, living things do not hold the same attributes. Further, classifying plants first as vascular or non-vascular has very little meaning. Instead, in the Native American culture, the classification of plants is based solely on the specific use and value within the society. In changing a typical activity of plant classification to a more culturally sensitive one, it would be more appropriate to classify the regional or local plants based upon their use within the culture. For example, the teacher would take a plant like the Choke Cherry and provide the Crow name (Baachua) and its uses within the culture, that is, to dye clothes, make jams and jellies, and pemmican. Plant classifications are based on uses within the culture, thus the activity is much more culturally relevant than classification based upon how western scientists define, identify, and classify plants.

This is not to suggest that all-typical presentations of science and

The amount of mathematics and science that is traditional to the Native American is indeed significant.

mathematics are inappropriate. But it is inappropriate that, in most cases, textbook activities are the only presentations used in the typical classroom. Unless teachers are culturally sensitive, they cannot prepare lessons that are culturally relevant.

Cultural teaching strategies present a curricular problem, in that teaching specific concepts in a cultural manner require more time. The activities are more in-depth, with less emphasis on curricular coverage. Cultural teaching strategies involve teaching philosophies more in line with inquiry, discovery, and active learning. This philosophy is more holistic and provides opportunities for a more constructivist approach to teaching. To effect this change, several teaching strategies must be employed, including the integration of mathematics and science.



Cultural teaching strategies involve teaching philosophies more in line with inquiry, discovery, and active learning.

Integrating Science and Mathematics

Several methods of integration can be used to provide for a more relevant curriculum. Content specific, process and thematic integration (Davison, Miller, & Metheny, 1995) are some of these methods. Of these types, thematic integration techniques are most common in today's schools. The design of culturally sensitive thematic unit should include ideas that embed

culture into the theme. Miller and Davison (1998) show how to represent a culturally sensitive thematic unit. Notice that the understandings presented are common to the specific culture in the audience. Such a web should include native artwork, indigenous social uses, and common understandings specific to that culture as well as traditional western beliefs and understandings.

Of course, there are some basic problems specific to techniques used in thematic integration. Many times in our schools, thematic integration develops from work in language arts, with the content of mathematics and science held at a minimum. Content in these two disciplines is relevant only in the context of completing the unit and rarely matches specific math or science content scope and sequence. In fact, many thematic units suggest that simply reading about whales, for example, is the "doing" of science. This is cause for some concern. Thematic integration has a tendency to gloss over the important concepts needed in mathematics and science. Yet, with care, it is possible to create very appropriate learning activities for students using a thematic integration model (Miller & Davison, 1998).

Native Americans commonly are taught as though you isolate instead of integrate the native approaches to culture with the different content areas. If concepts are presented more holistically, embedding a cultural focus in thematic integration, content and cultural learning would be enhanced. This is different from what is commonly called multicultural education. To most educators, multicultural education reflects the diverse cultures that make up our United States and includes references to all cultural traditions as part of the ever-changing American

curriculum. To cultural minorities in America, however, the focus of a "multicultural" approach is the inclusion of perspectives from their culture as an integral part of the curriculum. Curriculum development along these lines uses illustrations and activities that are appropriate and sensitive to the classroom audience.

Questions still remain regarding the abilities of different cultural members to provide culturally relevant activities. At the very least, white, Mexican American, and African American students need to be culturally aware of the generalized Native American culture. An articulated goal of bilingual education is that a Native American teacher be an effective role model for Native American students. This means that Native American teachers from outside the specific tribe also need to be culturally sensitive and appropriate role models.

Certainly it is not productive to continue to teach white cultural values on Indian reservations. Many of the available supplemental resources are stereotypical. We should not, for example, observe a reservation classroom at Thanksgiving and find children coloring picture of pilgrims, teaching children that the faces in the pictures do not match the faces in the classrooms. Instead, the classroom of the Native American student should hold rich examples of culturally relevant activities specific to Native American culture. But more important, it should provide a multicultural perspective that will enable native students to be successful outside their tribal culture (Van Hamme, 1996). However, teachers who are themselves Native Americans use some of the most culturally insensitive materials. Consequently, plans to increase the number of native teachers to any culture have

to be with the understanding that they need to be sensitive to enhancing the academic standards and the cultural mores of their own people.

Conclusion

This article has examined strategies for enhancing the learning of science and mathematics by Native American students. Traditional approaches to teaching these subjects to Native American students have not been successful, and a relevant approach that would help the students find meaning in the curriculum has been suggested.

The use of constructivist learning techniques, wherein the student draws on prior experiences to facilitate the acquisition of new learning, is consistent with the use of curricular illustrations from the students' culture. Accordingly, the inclusion of such examples from the Native American culture as beadwork and star quilts in geometry and plant classification in science, will help students find more relevance in their science and mathematics curricula.

Finally, a curricular approach that integrates mathematics, science, and culture will also enhance learning opportunities for Native American students. Thematic integration, focusing on a central theme, promotes a holistic view of the curriculum that can help students make connections between different views of the curriculum and their lives. The challenge for educators is to continue to explore such connections and to continue to look for ways that science and mathematics can be integrated with each other and within the native culture.

References

- Anderson, J. A. (1988). Cognitive styles and multicultural populations. *Journal of Teacher Education*, 39(1), 2-9.
- Atwater, M. M. (1994). Research on cultural diversity in the classroom. In Gabel, D. L. (ed.), *Handbook of research on science teaching and learning* (pp. 558-576). New York: Macmillan.
- Bourque, M. L., Champaigne, A. B., & Chrissman, S. (1997). *1996 science performance standards: Achievement results for the nation and the states*. Washington, DC: National Assessment Governing Board.
- Brooks, J., & Brooks, M. (1993). *The case for constructivist classrooms*. Association for Supervision and Curriculum Development: Alexandria, Virginia.
- Caduto, M. J., & Bruchac, J. (1989). *Keepers of the earth: Native American stories and environmental activities for children*. Golden, CO: Fulcrum, Inc.
- Crawford, J. (1997). *Best evidence: Research foundations of the Bilingual Education Act* (ED408858). Washington, DC: National Clearinghouse for Bilingual Education.
- Davison, D. M., Miller, K. W., & Metheny, D. L. (1995). What does integration of science and mathematics really mean? *School Science and Mathematics*, 95(5), 226-230.
- Freire, P. (1982). *Pedagogy of the oppressed*. New York: Continuum.
- Indian Nations at Risk Task Force. (1991). *Indian Nations at risk: An educational strategy for action*. Washington, DC: US Department of Education.
- Miller, K., & Davison, D. (1998). Is thematic integration the best way to reform science and mathematics education? *Science Educator*, 7(1), 7-12.
- Montana Office of Public Instruction. (1998, October). *Montana standardized test scores*. Helena, MT: OPU, Nancy Keenan, Superintendent.
- More, A. J. (1989, August). Native Indian learning styles: A review for researchers and teachers. *Journal of American Indian Education*, 28, 15-28.
- National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.
- National Research Council. (1996). *National science education standards*. Washington, DC: Author.
- Reese, C. M., Miller, K. E., Mazzeo, J., & Dossey, J. A. (1997). *NAEP 1996 report card for the nation and the states*. Washington, DC: National Center for Education Statistics.
- Reyhner, J., & Tennant, E. (1995). Maintaining and renewing native languages. *The Bilingual Research Journal*, 19(2), 279-304.
- Robbins, R. (1983). John Dewey's philosophy and American Indian: A brief discussion of how it could work. *Journal of American Indian Education*, 22(3), 1-9.
- Shapiro, B. (1994). *What children bring to light: A constructivist perspective on children's learning in science*. New York: Teachers College Press.
- Van Hamme, L. (1996). American Indian cultures and the classroom. *Journal of American Indian Education*, 35(2), 21-36.
- Walker, B. J., Dodd, J., & Bigelow, R. (1989, August). Learning preferences of capable American Indians of two tribes. *Journal of American Indian Education*, 28, 63-71.
- Yager, R. (1991). The constructivist teaching model. *Science Teacher*, 58(6), 52-57.

Kenneth W. Miller, Professor of Science Education, Department of Curriculum and Instruction, Montana State University-Billings, Billings, Montana 59101

David M. Davison, Professor of Mathematics Education, Department of Curriculum and Instruction, Montana State University-Billings, Billings, Montana 59101

Self-Efficacy and Outcome Expectancy of Selected Upper Elementary and Middle School Science Teachers – Surprises and Lessons

A study of teachers' self-efficacy and outcome expectancy, as the result of a professional development outreach program, provides information concerning selected characteristics of teachers and their students.

Introduction

Research is widespread in the field of self-efficacy and outcome expectancy of teachers. Many researchers have previously investigated self-efficacy and outcome expectancy for those who teach in a variety of settings. However, previous work does not seem to have considered teachers involved in local outreach programs; researchers do not seem to have taken into consideration how teachers might be similar or dissimilar as a function of school setting and student demographics. This study provides important details regarding the self-efficacy and outcome expectancy of grade 5-7 teachers involved in local outreach workshops.

During the last five years, the National Aquarium in Baltimore and researchers from Indiana University conducted an extensive data collection in an effort to (a) investigate the mechanism by which master science teachers instruct peers, (b) explore ways to optimize sustained professional development for science teach-

ers, and (c) evaluate data collection techniques carried out with practicing elementary and middle school science teachers. This work was a component of a three-year teacher enhancement project funded by the National Science Foundation. Part of the grant involved preparing a national pool of master teachers to utilize a grades 5-7 curriculum entitled "Living in Water." Each summer, a new cadre of master teachers discussed and practiced with hands-on activities associated with the curriculum. During the last week of the summer institute, the master teachers, with the guidance of the aquarium staff, discussed and planned outreach programs. Each master teacher received three university credits for participating in the summer institute and a stipend for completing both the institute and outreach with teachers near their own district.

This study concentrated on evaluating one aspect of the grant's data collection: the evaluation of "local" teachers who attended outreach pro-

vided by master teachers throughout the United States. Local teachers were asked to complete two self-efficacy surveys, one distributed during the outreach (on-site survey) and the other survey mailed approximately one year later to the local teachers (follow-up survey). The local teachers also provided data concerning their own ethnicity. In the follow-up survey, the local teachers provided an approximation of their own students' social economic status, geography, and ethnicity.

The results of this study provide a unique snapshot of local teachers' self-efficacy, more specifically the self-efficacy of teachers who did not participate in a multiple week summer institute, but did attend a local workshop presented by a master teacher in their district (or a local district). The data collected for this study provide guidance for those developing summer institutes and inservices to encourage science teaching. The results may help science educators and supervisors bet-

ter understand elementary and middle school science teachers who commonly attend local outreach provided by master science teachers, but do not (for whatever reason) attend multiple week summer institutes. The data analysis presented in this paper focuses on two aspects of the local teachers' self-efficacy: (1) self-efficacy as a function of teacher-reported student demographics, and (2) self-efficacy as a function of the teacher-response-rate to a follow-up survey. These data are important for all those interacting with science teachers; particularly those involved in planning, structuring, and evaluating professional development programs and outreach.

Literature Review

Teacher Self-Efficacy

The construct of self-efficacy used for the foundation of this survey originated from Bandura's (1977) social cognitive theory. Later, Gibson and Dembo (1984) applied a two-part construct (self-efficacy and outcome expectancy) to the teaching profession by defining teacher efficacy to involve confidence in one's own teaching ability and expectation of student learning based upon his or her own teaching strategies. Initially, much of the research in this field considered the issue of teacher efficacy possibly correlating with student achievement. Various studies suggested a relation-

It is important to note, however, that the relationship of self-efficacy and achievement is an indirect relationship.

ship between teacher efficacy and student achievement (Ashton, 1984; Gibson and Dembo, 1984). In 1984 Ashton commented, "no other teacher characteristic has demonstrated such a consistent relationship to student achievement" (p. 28). It is important to note, however, that the relationship of self-efficacy and achievement is an indirect relationship. Teacher efficacy influences teacher behavior, that in turn correlates with student achievement. Gibson and Dembo (1984) reported that teachers with high self-efficacy had better organized classrooms, coherent instruction, and more feedback for students experiencing learning difficulties than teachers with low self-efficacy. More importantly, teachers with high self-efficacy took more responsibility for their students' learning. When students were struggling, teachers blamed their own actions before blaming their students' actions (Ashton and Webb, 1986; Gibson and Dembo, 1984).

Self-Efficacy Instruments

Instruments used to measure teacher self-efficacy in recent years have evolved from non-subject specific scales to subject-specific scales (Gibson and Dembo, 1984; Guskey, 1987; Riggs and Enochs, 1990). Riggs and Enochs (1990) created one commonly utilized subject specific scale, the Science Teacher Efficacy Belief Instrument (STEBI), which measures the self-efficacy of science teachers. The instrument measures two specific constructs: (1) teacher self-efficacy, defined as a teacher's confidence in teaching science, and (2) outcome expectancy, defined as a teacher's belief in what science a student can do. When this scale is used, one set of items is used to determine a respondent's self-efficacy measure, and a different set of

More importantly, teachers with high self-efficacy took more responsibility for their students' learning.

items are used to calculate a respondent's outcome expectancy measure. A higher outcome expectancy measure of one group (e.g., group 1) compared to that of another group (e.g., group 2) indicates that the group 1 respondents have a stronger belief in what their students can do. A higher self-efficacy measure of one group (again group 1) compared to another group (group 2) indicates that group 1 respondents have a stronger belief in themselves as science teachers. The original Riggs and Enochs survey can be reviewed for the text of each item. A sample outcome item is the following: When a student does better than usual in science, it is often because the teacher exerted a little extra effort. A sample self-efficacy item is the following: I am continually finding better ways to teach science.

In general, the majority of research presented in the literature concerning self-efficacy involves investigations of teachers in classrooms or pre-service teachers training for future teaching. However, little specific attention has been paid to classroom teachers choosing to attend local workshops, many of whom choose not to attend national institutes. This study of local teachers attending workshops is particularly important, for in the last decade, many science education initiatives have been characterized by: (1) professional development sustained over time, and (2) the goal of wide scale and suc-

successful dissemination of knowledge by using master teachers who work with teachers local to their school. Some examples of recent programs emphasizing these issues are NSF funded programs, such as the Ohio's State Systemic Initiative and Purdue University's Epicenter program.

Data Collection

Local teachers attending outreach institutes in four different states presented by one of seven different master teachers provided the data reported in this study. Local teachers in most instances taught in either the same school district as the master teacher or a neighboring district. Prior to the start of each one-day outreach institute implemented by master teachers, every attending local teacher completed the self-efficacy survey of Riggs and Enochs (1990). When completing the initial survey, local teachers supplied their names and mailing addresses for a one-year follow-up survey. In the follow-up administration of the Riggs and Enochs (1990) survey, local teachers were also asked to supply the following information: percentage of their students as a function of ethnicity (Asian, African-American, Hispanic, Pacific Islander, Native American, White); percentage of their students according to approximate economic level (poverty, low income, middle income, upper income), percentage of their students based upon geography (rural, rural/suburban, suburban, urban). Over 450 local teachers completed surveys at the initial workshop, 225 completed the follow-up survey (50% response rate). Not all of the 225 teachers who responded to both the follow-up survey and the initial survey furnished complete surveys. This issue is reflected in the N values presented in the tables.

Data Analysis

Two measures of self-efficacy (self-efficacy and outcome expectancy), as outlined by Riggs and Enochs (1990), were computed for each local teacher who completed either the on-site survey or both surveys. Attitudes of respondents' self-efficacy and outcome expectancy were computed by first taking the response categories selected by respondents and converting these selections to attitudinal measures utilizing the Rasch model (Wright and Masters, 1982) which helps one correct for the possible non-linearity of rating scales. Rasch analysis provides linear measures that can then be used in analyses that utilize parametric equations. Immediately using numbers used for the coding of responses ignores that fact that such numbers are only labels which indicate which part of the scale was selected by a respondent. For instance the number 1 might be used to indicate the selection of "strongly agree" in the rating scale, and the number 2 used to indicate the selection of "agree" by a respondent. See Wright and Masters (1982) for a full discussion of these issues. In the analysis, the Rasch log odds units (logits) are used for evaluation and are presented in the data tables.

To organize the data, respondents' demographic information was tallied using the following procedure. A local teacher who would classify the majority of his/her students as Asian would be a teacher of Asian students. A local teacher who would classify the majority of his/her students as African-American would be a teacher of African-American students. Similar procedures were used with all student ethnic categories. The same strategy was used to classify teachers as a function of students' geography and social economic status (SES) levels.

This strategy (which limited or eliminated empty cells and cells containing low frequency counts) allowed the researchers to avoid violating the underlying assumptions of ANOVA tests. For example, when utilizing all of the ethnicity categories, one category may only have one member and another category may have 40 members. When an attempt was made to perform a two-way ANOVA test with these cells, it was discovered that some cells were missing. As a result, combination and stratification of the data were necessary to eliminate missing cells and avoid cells with low frequency counts. This strategy resulted in a definition of two levels for each variable; ethnicity (white, minority); geography (suburban, urban); SES (poverty/low income, middle income/upper income).

To evaluate the data, t-tests and ANOVAs were utilized. T-tests compared the self-efficacy and/or the outcome expectancy of the local teachers who completed only the on-site survey with the local teachers who completed both surveys. Using the local teachers who completed both surveys, a t-test was used to evaluate the difference between the on-site survey data and the follow-up data for self-efficacy and outcome expectancy. A fourth evaluation utilized a two-way ANOVA, investigating the changes in self-efficacy and outcome expectancy of local teachers who completed both surveys. Finally, an ANOVA was used to specifically investigate teachers' self-efficacy and outcome expectancy as a function of students' ethnicity, geography, and SES.

Results

Results of the analysis provide a unique view of local teachers' (1) self-efficacy as a function of teacher-reported student demographics and (2) self-efficacy as a function of the

teacher-response-rate to the follow-up survey. It is also important to point out that these local teachers, in reality, refer to teachers who are predominately white, but do teach a range of students in terms of ethnicity, SES, and geographic setting of student residence.

As a result of the distinction with respect to self-efficacy made by Riggs and Enochs (1990), these results are presented in the following manner: (1) self-efficacy as a function of demographics, (2) outcome expectancy as a function of demographics, (3) self-efficacy as a function of teacher-response-rate, and (4) outcome expectancy as a function of teacher-response-rate.

Self-Efficacy/Demographics

The self-efficacy (confidence) of teachers was found to be no different when analyzed with regard to their students' ethnicity and geography. However, the difference between the mean self-efficacy of teachers who taught students classified as being of poverty or very low economic status, averaged across the two levels of geography (suburban and urban), and the mean self-efficacy of teachers who taught students classified as being middle or upper income, also averaged across the two levels of geography, was too great to attribute to sampling fluctuation, $F(1, 166) = 7.15, p = .01$

(See Table 1). Simply stated, teachers classifying their students as middle/upper income had a statistically higher self-efficacy when compared with teachers classifying their students as poverty/low income. Thus, teachers responding to this survey who taught students predominantly of middle or high income had a stronger belief in themselves as teachers. However, when local teachers are compared in terms of student ethnicity and geographic location there was no difference in teacher self-efficacy.

Outcome Expectancy/Demographics

Analysis of variance of the local teachers' outcome expectancy on the reporting of the percentage of students living at different economic levels, different geographic locations, and different SES, showed no significant difference. In other words, local teachers were found to have the same beliefs in what their students could do, regardless of their students' ethnicity, geography, and SES.

Self-Efficacy/Teacher-Response-Rate

The mean score for the self-efficacy of local teachers who completed both surveys ($M = 1.79, SD = 1.64$) was significantly different from that of local teachers who only completed the

on-site survey ($M = 1.33, SD = 1.45$), $p = 0.001$ (See Table 2.). Teachers who completed both surveys had significantly higher self-efficacy measures (greater confidence in their ability to teach) than local teachers who only completed the on-site survey.

A related evaluation of teachers who completed both surveys compared the self-efficacy of teachers who completed the survey at the master teacher workshop with their own self-efficacy approximately one year later. Interestingly, no statistical differences in self-efficacy among these teachers were found (See Table 3); their self-efficacy (as a group) did not change.

Outcome Expectancy/Teacher-Response-Rate

Mean scores regarding the outcome expectancy of local teachers who completed both surveys ($M = 0.99, SD = 0.90$) were found to be significantly different from those of local teachers who only completed the on-site survey ($M = 0.87, SD = 0.83$), $p = 0.04$ (See Table 4.). Teachers who completed both surveys had significantly higher outcome expectancy measures (greater belief in what their students could do) than local teachers who only completed the on-site survey. Mean measures (for outcome expectancy) were compared for local teachers who

Table 1.
Self-efficacy of Local Teachers as a Function of Student SES.

SES	N	Mean (logits)	Standard Deviation (logits)
Middle income/upper/income	97	2.19	1.62
Poverty/low Income	73	1.60	1.53

p= .01

Table 2
T-test results comparing the mean self-efficacy data of teachers who completed only the on-site survey with those teachers who completed the on-site survey and the one year follow-up survey.

Local teachers	N	Mean (logits)	SD (logits)
Completed On-site Survey Only	228	1.33	1.45
Completed On-site and Follow-up Survey	225	1.79	1.64

p=.001.

Table 3
T-test results comparing the mean self-efficacy data of local teachers who completed both surveys.

Surveys	N	Mean (logits)	SD (logits)
Completed On-site Survey Only	225	1.79	1.64
Completed On-site and Follow-up Survey	225	1.94	1.65
No significant difference			

Table 5.
T-test comparing the self-efficacy of local teachers who completed both surveys.

Surveys	N	Mean (logits)	SD (logits)
On-site	225	0.99	0.90
Follow-up	225	0.85	0.90
No significant difference			

Table 4.
T-test results comparing the mean outcome expectancy data of teachers who completed only the on-site survey with those teachers who completed both surveys. Comparison is made using only on-site data.

Local teachers	N	Mean (logits)	SD (logits)
Completed On-site Survey Only	228	0.87	0.83
Completed On-site and Follow-up Survey	225	0.99	0.90
p=.04			

completed both the initial survey and the follow-up survey. No differences were found (See Table 5); thus teachers who completed both surveys did not change over the course of a year with regard to self-efficacy or outcome expectancy.

Discussion

Researchers often collect data from master teachers. Rarely are the attitudes of local teachers involved in the dissemination effort evaluated. One goal of this data analysis was to better describe and understand some characteristics of local teachers attending the one-day outreach offered by master teachers. Results of analyzing these data provide a snapshot of these local teachers, based upon their self-efficacy and outcome expectancy according to demographic information and teacher-response-rate. Results suggest that the outcome expectancy of teachers did not depend upon their students' economic level, geography, or ethnicity. Thus, what teachers felt a student could achieve did not differ as a function of economic level,

geography, or ethnicity of students. Also, the teachers' self-efficacy was not dependent upon their students' geography or ethnicity. Thus, how these teachers felt about their own teaching ability did not differ as a function of students' geography or ethnicity.

Bandura (1977, 1982, 1986) suggests that the construct of self-efficacy, including self-efficacy and outcome expectancy, affects teachers' thoughts, actions, and emotions. Following Bandura's (1977, 1982, 1986) suggestion that self-efficacy affects teachers' actions, Gibson and Dembo (1984) found that teachers with high self-

Thus, what teachers felt a student could achieve did not differ as a function of economic level, geography, or ethnicity of students.

efficacy had organized classrooms, coherent instruction, and provided relevant feedback to students experiencing difficulty. Finson (2000) reports that teachers' with high self-efficacy "tend to teach in ways characterized by the use of inquiry approaches, more student-centered thought, beliefs that they can help any student overcome learning problems and succeed, and are more knowledgeable of their students' developmental levels" (p. 1). These and other studies have suggested that teachers' self-efficacy tends to affect teachers' actions in the classroom. Since researchers report that high self-efficacy ratings are linked with best-practice teaching strategies, it is certainly a positive result that the local teachers (99% of whom were white) reported no difference in self-efficacy or outcome expectancy as a function of their students' geographic location (suburban, urban) or ethnicity (white, minority).

However, results from this study indicate a significant difference between SES factors in relation to the self-efficacy of local teachers. Other studies have also suggested that teachers' positive actions directed toward students such as recognition, praise, and intellectual expectation correlate to students' SES (Jackson and Cosca, 1974; Sadker and Sadker, 1981). Analysis of this data set suggests that

local teachers who classified their students as coming from a middle/upper income background had a higher self-efficacy when compared to local teachers who classified their students as poverty/low income. This result might suggest that these two groups of teachers may differ in the classroom. However, analysis of this data set revealed no difference between these same groups of teachers concerning their outcome expectancy (the teacher's belief in what the students can do). In other words, the teachers of the middle/upper income students may have a higher self-efficacy (more confidence in what they—the teacher can do) than do the teachers of poverty/low income students. However, these two groups of teachers do not differ in what they feel their students can do. This is certainly a positive result that mirrors results found by other self-efficacy researchers.

Science workshop developers should note the differences found when both self-efficacy and outcome expectancy are considered on a function of student SES. It is important for educators, involved in summer workshops, professional development, or research focusing on outcome expectancy to analyze self-efficacy and outcome expectancy. Analyzing just one aspect of self-efficacy and not both could provide an incomplete picture regarding the whole self-efficacy of the teachers. Furthermore, it is useful to collect added information on students of teachers, to more fully explore differences and similarities of teachers.

As another part of this study, two added analyses were made: (1) a comparison of local teachers who completed only the on-site survey with those who completed both on-site and follow-up surveys and (2) a comparison of teachers' responses

to the on-site and follow-up surveys (for those teachers who completed the instrument both times it was administered). The analysis suggests that local teachers who responded to both surveys had a higher self-efficacy and outcome expectancy than those local teachers who only responded to the on-site survey. Teachers who responded to both surveys reported their self-efficacy and outcome expectancy no differently from the on-site survey to the one-year follow-up survey. This finding suggests that the outreach experience (and anything else during the year) did not change the self-efficacy or outcome expectancy of the local teachers. In many ways this should not be surprising, for one shot inservices can help teachers, but it is perhaps too ambitious to claim such a short intervention will make a great difference in a teacher's life.

Workshop developers and researchers need to pay much greater attention to the significant difference of self-efficacy and outcome expectancy between the teachers who only completed the on-site survey and those that completed both surveys. Educators will always find it difficult to retrieve responses from research subjects (especially after one year). However, the difference between those who responded after a year and those who did not indicate that it is necessary to

Teachers who are now teaching at a new school may no longer feel a need to report on a curriculum that was introduced at a previous school.

pay very close attention to those who are and those who are not responding to data collection requests. If there is a difference in those who do and do not respond to data collection requests in any study, and any reform effort, then how different is "reality" from that which is presented in a report or paper? It seems it should be an immediate goal of science supervisors and science educators to draw in teachers who may not wish to provide feedback in initial or follow-up surveys. In any school district there are teachers who would gladly become master teachers, there are those who will attend local workshops without hesitation, there are those who will not provide follow-up data, and of course there are those who do not want to attend any workshops nor do they wish to provide any data to those involved in workshops, inservices, and dissemination. It seems that each of these groups must be more often considered when designing and evaluating efforts to improve elementary and middle school science classrooms.

What might be some reasons for the lack of response from some of the surveyed teachers? Those teachers who did not respond might simply not answer the survey. However, it could be that those not answering have been transferred to another school, or have moved their residence (the researchers did not ask that teachers specify the "type" of address they were supplying). Teachers who are now teaching at a new school may no longer feel a need to report on a curriculum that was introduced at a previous school. Also, perhaps there is something important about those teachers who either willingly or unwillingly are now teaching at another school. These teachers may have asked for a transfer and/or the district may have transferred them without their consent.

It is suggested that those interested in collecting similar data pay careful attention to steps that may be used to collect data from as large a sample as possible. Such steps may include “freebies” for the completion of a survey, funds to find missing teachers, or withholding some portion of a stipend for those conducting outreach and collecting data in the field. This final suggestion may insure the complete collection of data at the front end (at initial workshops).

Conclusion

This unique snapshot of teachers’ self-efficacy and outcome expectancy, as the result of a professional development outreach program, provides important information concerning selected characteristics of local teachers and their students. In terms of self-efficacy and outcome expectancy, the only significant difference among surveyed teachers was with regard to student SES and self-efficacy. This may reflect that those science teachers feel students from any SES level are capable of succeeding, however, it appears that the same science teachers blame themselves for an inability to successfully teach students from low SES backgrounds. With this result in mind, workshop developers and professional development designers should focus efforts on assisting teachers working with low SES students.

There were significant differences when teachers who responded once to the survey were compared to those teachers who responded twice. These results highlight another important issue for those involved in planning, organizing, and evaluating outreach programs. This group of teachers showed a distinct difference between those who responded to two data collection requests and those who responded only to an initial survey.

Elementary and middle school science educators can be provided with meaningful professional development programs, which can in turn help increase the likelihood of student learning. However, evaluation pictures are incomplete when many teachers do not provide data. It seems that science educators must carefully monitor the quality and extent of the data they collect.

The results of evaluating the pre-post self-efficacy data also provide added guidance. Those involved in evaluation that documents a project (and provides some guidance to science supervisors and researchers) might find it prudent to plan pre-post assessments in which there will be a realistic chance to observe a change, based upon the project of interest.

[Note: The opinions expressed in this paper are solely those of the authors and do not necessarily reflect the views of any organization.]

References

Ashton, P. T. (1984). Teacher efficacy: A motivational paradigm for effective teacher education. *Journal of Teacher Education, 35*, 38-42.

Ashton, P. T., & Webb, R. B. (1986). *Making a difference: Teacher’s sense of efficacy and student achievement*. New York: Longman.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavior change. *Psychological Review, 84*, 191-215.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist, 37*, 122-147.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. New Jersey: Prentice-Hall.

Education department National Aquarium in Baltimore (Eds.). (1997). *Living in Water: An*

Finson, K. D. (2000). Investigating preservice elementary teachers’ self-efficacy relative to self image as a science teacher. A paper presented at the annual meeting of the Association for the Education of Teachers in Science, Akron, OH.

Gibson, S., & Dembo, M. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology, 76*, 569-582.

Guskey, T. R. (1987). Context variables that affect measures of teacher efficacy. *Journal of Educational Research, 81*, 41-47.

Jackson, G., & Cosca, C. (1974). The inequality of educational opportunity in the Southwest: An observational study of ethnically mixed classrooms. *American Educational Research Journal, 11*, 219-229.

Riggs, I., & Enoch, L. (1990). Toward the development of an elementary teachers’ science teaching efficacy belief instrument. *Science Education, 74*, 625-637.

Sadker, D., & Sadker, M. (1981). The development and field trial of a nonsexist teacher education curriculum. *High School Journal, 64*, 331-336.

Wright, B. D., & Masters, G. N. (1982). *Ratings scale analysis*. Chicago, IL: University of Chicago, MESA Press.

Julie Saam is professor of education at IUPUI-Columbus where she also teaches science methods.

William Boone is an associate professor of science and environmental education at IU-Bloomington. His interests are survey and test development.

Valerie Chase is the staff biologist at the National Aquarium in Baltimore, Maryland. She has helped develop the Living in Water Curriculum.

Science and Mathematics Together: Implementing a Theoretical Model

A theoretical model is designed to describe or characterize the integration of science and mathematics education.

Overview of the Literature

The field of integrated science and mathematics education is not new. Since the beginning of the 20th century, the integration of science and mathematics education has been suggested as a promising path toward improved student understanding of, performance in, and attitude toward both subject areas. Having spent over 15 years acquiring and reviewing the literature related to the integration of science and mathematics education has resulted in the amassing of over 750 citations. To characterize this robust body of literature, five categories were chosen: Curriculum, Instruction, Research, Curriculum-Instruction, and Curriculum-Evaluation. A narrow definition of curriculum, i.e., the intended learnings or the outcomes of being educated, was used. Citations in the Curriculum section primarily deal with the content in a course or a group of courses or “what students are taught.” Instruction is the process of implementing the curriculum and deals with pedagogy, strategies, and activities. The Research section deals with theoretical models, concept papers, empirical research, and reviews of research. Two additional sections focus specifically on curriculum programs. The Curriculum-Instruction section includes instructional activities, and the Curriculum-Evaluation section includes evaluation information. The

initial review of the literature spanned the years 1905 through 1991 and included 555 citations (see Berlin, 1991). The years 1992 through the first six months of 1999 include an additional 210 citations (see Berlin, 1999). Clearly, the last six and one-half years has witnessed a tremendous growth in articles focused on the integration of science and mathematics education. The number of articles published in the last six and one-half years was nearly 40% of the number of articles published in the preceding 87 years.

The most frequently mentioned mathematics concepts and skills include angular measurement, estimation, formulas and equations, fractions, functions, geometry, graphing, modeling, patterns, percentage, probability and statistics, problem solving, ratio and proportion, and variable.

Returning to the section divisions, one finds a consistent pattern for nearly 100 years—approximately 50% of the documents are categorized as instructional. Many published strategies and activities integrate science and mathematics education; however, most of the instructional activities are primarily science activities or lessons that include mathematics-related concepts. These science activities are most often found in the journals published by the National Science Teachers Association, including *Science and Children*, *Science Scope*, and the *Science Teacher*. The science processes most frequently cited in the instructional literature include: classifying, collecting and organizing data, communicating, controlling variables, developing models, experimenting, inferring, interpreting data, measuring, observing, predicting, and space-time relationships. The most frequently mentioned mathematics concepts and skills include angular measurement, estimation, formulas and equations, fractions, functions, geometry, graphing, modeling, patterns, percentage, probability and statistics, problem solving, ratio and proportion, and variable. The mathematics concepts are sometimes, but not often, explicitly stated as objectives, particularly in the science-based activities. Activities or lessons related to both science and mathematics can be found in

other journals, including *School Science and Mathematics* and journals published by the National Council of Teachers of Mathematics such as the *Arithmetic Teacher*, *Teaching Children Mathematics*, *Mathematics Teaching in the Middle School*, and the *Mathematics Teacher*. The aforementioned concepts, skills, and processes for science and mathematics are also often the basis for the curriculum and the instructional activities developed for specific projects, e.g., *Activities Integrating Math and Science* (AIMS); *Great Explorations in Math and Science* (GEMS); *Integrating Mathematics, Science, and Technology* (IMaST); *Minnesota Mathematics and Science Teaching Project* (MINNEMAST); *Teaching Integrated Mathematics and Science* (TIMS); and *Unified Science and Mathematics for Elementary Schools* (USMES).

As one reviews the literature by category, another interesting pattern is revealed. The Research section, including theoretical models, concept papers, and empirical research, consists of the smallest percentage of citations. For the first 87 years, only 7% of the documents were in this category. Furthermore, many of the documents included in this section were only tangentially related to integrated science and mathematics education. For example, a number of research studies related mathematics skills to science achievement; these include conservation, seriation, graphing ability, proportional reasoning, and spatial ability. Since 1991, the Research section has advanced to 17% of the citations, or 36 articles. Further exploration into the nature of the updated Research section suggests a grouping based on theoretical models/concept papers, empirical research, and tangentially-related empirical research. This subgrouping

reveals that the number of theoretical models and concept papers related to integrated science and mathematics education represents more than half of the Research section (20 citations). Unfortunately, one still finds a critical shortage of literature focused on empirical research (12 citations; 6% of the total citations). Only 4 of the articles listed in the Research section are classified as tangentially related to integrated science and mathematics education, e.g., research relating the development of graphing skills to the use of microcomputer-based science laboratories.

Since a review of all the literature related to science and mathematics education is well-beyond the scope of this paper, the focus will be on an analysis of various theoretical models. This discussion will set the stage for the Berlin-White Integrated Science and Mathematics Model, an interpretative or framework theory, not a normative goal-directed theory. As an interpretive or framework theory, this model is designed to describe or characterize the integration of science and mathematics education, not to specify goals related to successful integration. Therefore, this model is meant to be used and interpreted by researchers and practitioners within the context of their own cognition and experience.

One has little difficulty finding proponents of science and mathematics integration. Current reform documents in the United States recommend integration of content and instruction in a changing curriculum. The following documents recognize the integration of science and mathematics as a necessary component of reform: *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics,



One has little difficulty finding proponents of science and mathematics integration. Current reform documents in the United States recommend integration of content and instruction in a changing curriculum.

1989); *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics, 2000); *Reshaping School Mathematics. A Philosophy and Framework for Curriculum* (National Research Council, 1990); *Science for All Americans* (Rutherford & Ahlgren, 1990); *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993); and *National Science Education Standards* (National Research Council, 1996).

Since mathematics is both the language of science and a science of patterns, the special links between mathematics and science are far more than just those between theory and applications. The methodology of mathematical inquiry shares with the scientific method a focus on exploration, investigation, conjecture, evidence, and reasoning. Firmer school ties between science and mathematics should especially help students' grasp of both fields. (National Research Council, 1990; pp.44-45)

Although the area of integrated science and mathematics education

is not new as evidenced by writings dating back to 1905, it is complex, not well defined, and inadequately studied. The literature in the last decade has increasingly focused on defining integrated science and mathematics education through theoretical models. An earlier theoretical model, proposed by the participants of the Cambridge Conference on Integration of Mathematics and Science Education held in 1967 (Education Development Center, 1970), defined five categories of interaction between science and mathematics. These categories include: math for math, math for science, math and science, science for math, and science for science. Brown and Wall (1976) fashioned these categories into a continuum consisting of mathematics for the sake of mathematics, mathematics for the sake of science, mathematics and science in concert, science for the sake of mathematics, and science for the sake of science. Recent theoretical models have used this same continuum with minor wordsmithing. For example, Lonning and DeFranco (1997) describe their continuum as independent mathematics, mathematics focus, balanced mathematics and science, science focus, and independent science. Similarly, Huntley (1998), using an interesting foreground/background analogy, suggests a continuum from mathematics for the sake of mathematics, mathematics with science, mathematics and science, science with mathematics, and science for the sake of science. Finally, Roebuck and Warden (1998) modify the Brown and Wall continuum to include math for math's sake, science-driven math, mathematics and science in concert, math-driven science, and science for science's sake. Only one recent theoretical model, the Berlin-White Integrated Science and Mathematics

Model (Berlin & White, 1994, 1995, 1998), uniquely describes the center of the continuum, mathematics and science. The multidimensionality of the model also addresses the critical need posited by Miller and Davison (1998, 1999) for paradigmatic change in school pedagogy to successfully integrate science and mathematics education.

The Berlin -White Integrated Science and Mathematics Model

The Berlin -White Integrated Science and Mathematics Model has been recognized in both the science and mathematics education communities (Berlin & White, 1994, 1995, 1998). Evolving over a period of 15 years, it reflects and combines multiple perspectives and endeavors, including empirical research, a comprehensive review of the literature, the perspectives of the science and mathematics communities, curriculum research and development projects, and valued classroom practice. With support from the National Science Foundation (Berlin, 1994; Berlin & White, 1992) and the Department of Education, Office of Educational Research and Improvement (Berlin & White, 1995), two national level conferences on the integration of science and mathematics education helped to delineate the multiple aspects of this model.

The Berlin-White Integrated Science and Mathematics Model includes six aspects: (a) ways of learning, (b) ways of knowing, (c) content knowledge, (d) process and thinking skills, (e) attitudes and perceptions, and (f) teaching strategies.

- *Ways of learning.* Integration can be based on how students experience, organize, and think about science and mathematics. Based on a con-

structivist/neuropsychological perspective or rationale, students must do science and mathematics and be actively involved in the learning process.

- *Ways of knowing.* Integrated school science and mathematics can reinforce the cyclical relationships between inductive-deductive and qualitative-quantitative views of the world. In science and mathematics, new knowledge is often produced through a combination of induction and deduction. For this discussion, induction means looking at numerous examples to find a pattern (qualitative) that can be translated into a rule (quantitative). The application of this rule in a new context is deduction.
- *Content knowledge.* Science and mathematics can be integrated in terms of content that is overlapping or analogous. Big ideas or themes such as change, conservation, models, patterns, scale, symmetry, and systems can be found in both science and mathematics. The examination of concepts, principles, laws, and theories of science and mathematics reveal ideas that are unique to each discipline and ideas that overlap or are analogous (e.g., the fulcrum of a lever and the mean of a distribution).

Integrated science and mathematics can develop processes and skills related to inquiry, problem-solving, and higher-order thinking skills.

- *Process and thinking skills.* Integrated science and mathematics can develop processes and skills related to inquiry, problem-solving, and higher-order thinking skills. Integration of science and mathematics can focus on ways of collecting and using information gathered by investigation, exploration, experimentation, and problem solving. Skills representative of this aspect include classifying, collecting and organizing data, communicating, controlling variables, developing models, estimating, experimenting, graphing, hypothesizing, inferring, interpreting data, measuring, observing, predicting, and recognizing patterns.
- *Attitudes and perceptions.* Integration can be viewed from what children believe about science and mathematics, their involvement, and their confidence in their ability to do science and mathematics. Similarities and differences related to scientific and mathematical attitudes/perceptions or “habits of mind” can be identified. The values, attitudes, and ways of thinking shared between science and mathematics education include accepting the changing nature of science and mathematics; basing decisions and actions on data; a desire for knowledge; a healthy degree of skepticism, honesty, and objectivity; relying on logical reasoning; willingness to consider other explanations; and working together to achieve better understanding.
- *Teaching strategies.* Integration can be viewed from the teaching methods valued by both science and mathematics educators. Integrated science and mathematics teaching should include a broad range of content, provide time for inquiry-based learning and problem solv-

Integrated science and mathematics teaching should include a broad range of content, provide time for inquiry-based learning and problem solving, provide opportunities to use laboratory instruments and other tools, provide appropriate uses of technology.

ing, provide opportunities to use laboratory instruments and other tools, provide appropriate uses of technology (e.g., calculators and computers), encourage cooperative learning, embed assessment within instruction, and maximize opportunities for successful connections between science and mathematics.

Some of the aspects, namely, ways of learning, attitudes and perceptions, and teaching strategies, are not unique to integrated science and mathematics education. However, they often are found in the descriptions of integrated science and mathematics activities or integrated science and mathematics curriculum programs. These aspects may be perceived as necessary for effective integration, but in no way are they sufficient conditions. The three substantive and cogent aspects related to integrated science and mathematics teaching and learning are ways of knowing, content knowledge, and process and thinking skills.

The identification and elaboration of these aspects is meant to clarify the characteristics in constant interplay in defining integration. It is expected that the real value will be in identifying the links and overlap among the aspects, rather than attending to them in isolation. The Berlin-White Integrated Science and Mathematics Model is designed to provide a conceptual base and a common language that advances the research agenda, to serve as a template for characterizing current resources, and to guide in the development of new materials related to integrated science and mathematics teaching and learning. The Berlin-White Integrated Science and Mathematics Model is an interpretive or framework theory. The value of an interpretive or framework theory cannot be determined by testing, but rather is judged by communication and implementation. To assist in the use of the Berlin-White Integrated Science and Mathematics Model, a checklist-type template also has been developed to identify the relevant aspects of science and mathematics integration that are directly observable in an integrated science and mathematics lesson or activity.

Classroom Example: Natural Selection

An example of an integrated science and mathematics activity is a commonly taught science lesson on natural selection. The science concepts and processes involved in this lesson include collecting and organizing data, diversity and adaptation, genetic variation, hypothesizing, interpreting data, measuring, modeling, observing, organisms and their environment, and prediction. The activity provides a natural and logical connection between the teaching and learning of science

and mathematics. The mathematics concepts and skills involved in this activity include area measurement; graphing; non-standard and standard units of measurement; ratio and proportion; percentage; probability; randomization; and sampling, measurement, and experimenter error. Materials needed for this activity include three environments represented by three sheets of 8 1/2 x 11 inch white paper, one with two black squares, one with a black circle, and one with a black irregular shape on it (see Figures 1 to 3); a supply of black-colored and white-colored hole punches; an 8 1/2 x 11 inch box with a lid (boxes from a copy store work well); graph paper; and a transparent centimeter grid.

Figure 1. Environment: Square shapes.

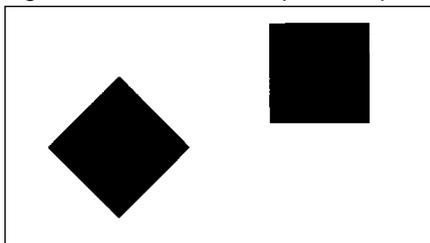


Figure 2. Environment: Circular shape.

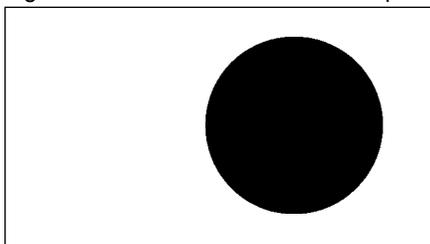
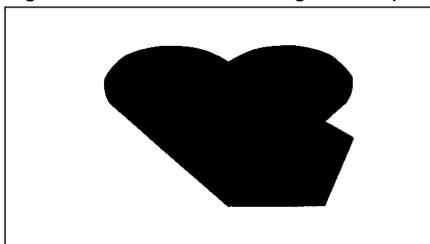


Figure 3. Environment: Irregular shape.



The following worksheets are used by students in a cooperative group setting to teach science and mathematics together (see Figures 4 to 6). After the students have completed the activity, each group shares the data from their Group Data Record sheet. Discussions related to ratios and proportions (e.g.,

white bugs to black bugs, white bugs to total bugs, black bugs to total bugs, white area to black area, white area to total area, and black area to total area) become meaningful in the context of this activity. Small group and whole class discussions can seamlessly flow between science and mathematics.

Figure 4. Group worksheet page 1.

Group Worksheet

Circle the letter of your group and write the student names.
 Group A B
 Student Names _____

You should have 3 sheets of white paper with black figures on them. One sheet has two black squares, one sheet has a black circle, and the third sheet has an irregular black shape on it. You should also have some white and black hole punches and a transparency with a centimeter grid on it. Each white sheet represents a different environment, and the hole punches represent white and black bugs.

Step 1: Count out 20 bugs (hole punches) of each color. This is the first generation of bugs for this activity.

Step 2: Tape the environment with the two large squares in a box and randomly distribute the bugs over the environment by putting the lid on the box and shaking the box. Be careful that none of the bugs escape or get lost.

Step 3: Predators, like birds, often catch and eat bugs that stand out from the environment. Open the box and capture all of the bugs that stand out due to color.

Step 4: Count the bugs that are not captured for this first generation and record the number of each color on the Group Data Record.

Step 5: Determine the area of the black and the white regions of the environment. Describe how you determined the area and record your value in the space provided on the Group Data Record.

Description: _____

Predictions: Predict the number of white bugs and the number of black bugs you would expect to survive from the first generation for:

(1) the environment with the black circle
 Number of white bugs = _____
 Number of black bugs = _____

(2) the environment with the irregular black shape.
 Number of white bugs = _____
 Number of black bugs = _____

Figure 5. Group worksheet page 2.

Group Worksheet

Circle the letter of your group and write the student names.
 Group A B
 Student Names _____

A Groups: Determine the actual number of each color bug from the first generation that survives in the environment with the black circle. Enter here and on the Group Data Record sheet.

Number of white bugs = _____
 Number of black bugs = _____

B Groups: Determine the actual number of each color bug from the first generation that survives in the environment with the irregular black shape. Enter here and on the Group Data Record sheet.

Number of white bugs = _____
 Number of black bugs = _____

Step 6: Using the first generation survivors in the environment of your choice (squares, circle, or irregular shape), add one white bug for each white bug survivor and one black bug for each black bug survivor. Collect all of the bugs and randomly distribute this new population over the environment. Repeat steps 3 and 4 from the Group Worksheet (page 1) and record the number of black bugs and the number of white bugs remaining in the environment on the Group Data Record.

Step 7: Repeat step 6 three more times using the most recent generation each time. Record the number of bugs of each color left in the environment after the birds have captured the bugs that stand out.

Question: What happens to the number of white bugs, the number of black bugs, the number of bugs overall?

Step 8: Make a graph of the number of white bugs and black bugs on one set of axes to help describe the trends of natural selection.

Predictions: Predict the number of white bugs and the number of black bugs you would expect to survive from the first generation for:

(1) the environment with the black circle
 Number of white bugs = _____
 Number of black bugs = _____

(2) the environment with the irregular black shape.
 Number of white bugs = _____
 Number of black bugs = _____

Figure 6. Group data record page 3.

Group Data Record

Circle the letter of your group and write the student names.
 Group A B
 Student Names _____

Environment: Square Shapes

Generation	<u>Number of Bugs</u>		Total
	White	Black	
1			
2			
3			
4			
5			
Area:			
	White	Black	Total

Environment: Circular Shape

Generation	<u>Number of Bugs</u>		Total
	White	Black	
1			
2			
3			
4			
5			
Area:			
	White	Black	Total

Environment: Irregular Shape

Generation	<u>Number of Bugs</u>		Total
	White	Black	
1			
2			
3			
4			
5			
Area:			
	White	Black	Total

To characterize this integrated science and mathematics activity, the Berlin-White Integrated Science and Mathematics Model template was used (see Figure 7). This template highlights the characteristics that are inherent in this activity with respect to five of the Berlin-White Integrated Science and Mathematics Model aspects: ways of knowing, content knowledge, process and thinking skills, attitudes and perceptions, and teaching strategies. The sixth model aspect, ways of learning, is not included in the template as it is a rationale supportive of the other aspects. This exercise can be useful in selecting and developing activities and in planning instruction; the composite may serve as an operational definition to support and promote future empirical research.

References

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Berlin, D. F. (1991). *Integrating science and mathematics teaching and learning. A bibliography*. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Berlin, D. F. (Ed.). (1994). *NSF/SSMA Wingspread Conference: A network for integrated science and mathematics teaching and learning. Conference plenary papers*. Bloomsburg, PA: School Science and Mathematics Association.

Berlin, D. F. (1999). *A bibliography of integrated science and mathematics teaching and learning: 1991-1999*. Unpublished manuscript.

Figure 7. Berlin-White Integrated Science and Mathematics Model template.

I. WAYS OF KNOWING	
Induction	✓
Deduction	✓
Inductive-Deductive Cycle	
II. CONTENT KNOWLEDGE	
Number and Operation	✓
Patterns, Functions, and Algebra	✓
Geometry and Spatial Sense	
Measurement	✓
Data Analysis, Statistics, and Probability	✓
Change	✓
Conservation	
Models	✓
Patterns	✓
Scale	✓
Symmetry	
Systems	✓
III. PROCESS AND THINKING SKILLS	
Classifying	
Collecting and Organizing Data	✓
Communicating	✓
Controlling Variables	✓
Developing Models	✓
Defining Operationally	
Estimating	✓
Experimenting	
Graphing	✓
Hypothesizing	✓
Inferring	✓
Interpreting Data	✓
Measuring	✓
Observing	✓
Predicting	✓
Recognizing Patterns	✓
IV. ATTITUDES AND PERCEPTIONS	
Dynamic Nature of Science and Mathematics	✓
Habits of Minds/Dispositions	✓
Reasoning/Data-Based Decisions	✓
V. TEACHING STRATEGIES	
Alternative Assessments	
Cooperative Learning	✓
Educational Technology	
Inquiry-Based	
Multiple Representational Modes	
Problem Solving	✓
Mathematics Manipulatives	✓
Science Equipment	

- Berlin, D. F., & White, A. L. (1992). Report from the NSF/SSMA Wingspread Conference: A network for integrated science and mathematics teaching and learning. *School Science and Mathematics*, 92, 340-342.
- Berlin, D. F., & White, A. L. (1994). The Berlin-White Integrated Science and Mathematics Model. *School Science and Mathematics*, 94, 2-4.
- Berlin, D. F., & White, A. L. (1995). Connecting school science and mathematics. In P. A. House & A. F. Coxford (Eds.), *Connecting mathematics across the curriculum. 1995 National Council of Teachers of Mathematics Yearbook* (pp. 22-33). Reston, VA: National Council of Teachers of Mathematics.
- Berlin, D. F., & White, A. L. (1998). Integrated science and mathematics education: The evolution of a theoretical model and implications for instruction and assessment. In B. J. Fraser & K. Tobin (Eds.), *International handbook of science education* (pp. 499-512). Netherlands: Kluwer Publishers.
- Brown, W. R., & Wall, C. R. (1976). A look at the integration of science and mathematics in the elementary school – 1976. *School Science and Mathematics*, 76, 551-562.
- Education Development Center. (1970). *Final report of Cambridge Conference on School Mathematics, January 1962 – August 1970*. Cambridge, MA: Author. (ERIC Document Reproduction Service No. ED 188 904)
- Huntley, M. A. (1998). Design and implementation of a framework for defining integrated science and mathematics education. *School Science and Mathematics*, 98, 320-327.
- Lonning, R. A., & DeFranco, T. C. (1997). Integration of science and mathematics: A theoretical model. *School Science and Mathematics*, 97, 212-215.
- Miller, K. W., & Davison, D. (1998). Is thematic integration the best way to reform science and mathematics education? *Science Educator*, 7(1), 7-12.
- Miller, K. W., & Davison, D. (1999). Paradigms and praxis: The role of science and mathematics integration. *Science Educator*, 8(1), 7-12.
- National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.
- National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.
- National Research Council. (1990). *Reshaping school mathematics: A philosophy and framework for curriculum*. Washington, DC: National Academy Press.
- National Research Council. (1996). *National science education standards*. Washington, DC: Author.
- Roebuck, K. I., & Warden, M. A. (1998). Searching for the center of the mathematics-science continuum. *School Science and Mathematics*, 98, 328-333.
- Rutherford, F.J., & Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University Press.

Donna F. Berlin, Professor of Education, The Ohio State University School of Teaching and Learning, 333 Arps Hall, 1945 North High Street, Columbus, OH 43210.

Arthur L. White, Professor of Education, The Ohio State University School of Teaching and Learning, 333 Arps Hall, 1945 North High Street, Columbus, OH 43210.

Science Education Tomorrow: Connecting Students to a Changing World

Preparing students for the use of science knowledge is essential for the implementation of a modern science curriculum.

Twenty-five years have passed since efforts began to reinvent science education. A total of 150 countries are now engaged in the process, but little progress has occurred. Only one new science education goal is agreed upon by all countries: "Learning to Learn." One issue we face today in reinventing science curricula includes changes in the ethos, culture, and practice of today's science. The nature of science has undergone major changes in the last 50 years. Today, dimensions of science extend into the social sciences and humanities, as well as ethics, values, and the law. These aspects of modern science have been ignored in efforts to reinvent an education in the sciences.

Knowledge in the sciences has exploded over the past century. More than 80,000 research journals now report on advances in the sciences. Classification of science as disciplines: biology, chemistry, earth sciences, and physics, is no longer adequate. The concept of a "discipline" has given way to

Knowledge in the sciences has exploded over the past century.

a "field," representing a single area of research. Biology, for instance, today is represented by 400 named research fields; many others remain unnamed. Traditional disciplines of science are gradually being absorbed into fields of biology; some of these include biophysics, biochemistry, and biotechnology.

Science research is now centered in industry, with more than 50% of today's science researchers employed in industry, a shift from universities and colleges. Increasingly, the framework for research in the sciences is finding solutions to personal, social, and economic problems, instead of seeking theories related to the natural world. More strategic focus in research is problem oriented, such as finding a cure for AIDS.

Research in the sciences today is done by teams of six to eight persons, rather than by individuals. Teamwork can increase the fertility of hypotheses related to a problem and its resolution. Computers keep track of observations and organize data, and robots serve as research assistants, with the capacity to search for and record information 24 hours a day. Some robots have been sent to the moon or planets, making observations and sending them back to earth.

From the very beginning of modern science, advancement has been dependent upon developments in technology. Before the 17th century, Egyptian astronomers verified 5,000 stars in the heavens, plus two double stars. Today's telescopes identify hundreds of millions of stars.

Anton van Leewenhock's development of the simple microscope in 1675 opened the door to the previously unknown worlds of protozoa and bacteria. Today, science is a tool for generating new technologies and a means for extending the frontiers of science. Science and technology are two sides of a single coin.

Over the past 50 years, the United States has become a knowledge-intensive society. One result of this change is to make "learning to learn" a goal of science teaching, along with the utilization of knowledge.

The majority of science textbooks commonly used in grades K-12 are history books; their goals and standards are unlike today's sciences.

The current education reform movement recognizes that it is time to develop science curricula that do not isolate science from human welfare, personal development, and social and economic progress. This relationship is often described as a “lived curriculum.”

Today’s science differs from that of past centuries. The majority of science textbooks commonly used in grades K-12 are history books; their goals and standards are unlike today’s sciences. Traditionally, science courses were taught in the context of career preparation with inquiry skills as the major focus. The new curriculum framework focuses on proper utilization of science knowledge to resolve problems related to life and living, or personal-social contexts. This goal requires teaching science and technology aspects that can be experienced by students and used in human adaptability.

For the past century, all science curriculum reforms have stated their purpose to be “meeting the needs of students.” The curriculum proposed, however, always focused on the students becoming scientists. The present reform movement recognizes a need to *reinvent* school science curricula. Past efforts to identify facts, principles, and generalizations that characterized biology, chemistry, earth science, and physics now identify science principles as *standards*.

Revolutionary changes are taking place in the sciences within our knowledge-intensive society, and they are impacting our culture, the economy, and the adaptability of people. We must have new criteria for the reinvention of science curricula. Traditionally, science curricula focused on inquiry and the facts and theories characteristic of a discipline, but a new view of science education is emerging. Its central

Past efforts to identify facts, principles, and generalizations that characterized biology, chemistry, earth science, and physics now identify science principles as *standards*.

theme is the utilization of science knowledge for human adaptability and welfare. In other words, students and their quality of life are the major focus of an education in the sciences.

The “standards” for the reinvented science curricula are seen as life skills: intellectual and social skills likely to increase the adaptive capacities of students and equip them for more productive lives. Examples of these skills include: (1) acquiring a literacy concept of the interaction of science and technology; (2) making decisions that recognize elements of risk; (3) recognizing the place of values, feelings, emotions, and ethics in making decisions about one’s life (Botvin, 1979; Hamburg, 1990; Hurd, 2000; Morganett, 1990; Saskatchewan Newstart, 1972; Tokanishi, 1993). Life skills provide a means of relating science and technology to everyday life.

Historically, efforts have been proposed to make the general education in the sciences different from that of the career scientist. Introduction of science into western civilization around 1500 led Francis Bacon in 1620 to describe goals for a general education in the sciences. He saw the ideal of human service as the ultimate goal of science

education, to the end of equipping the intellect for a “better and more perfect use of human reason.” The subject matter selected to achieve this end should be that “which has the most for the welfare of man” (Dick, 1935, pp. 441-487). This context for science education persists today, nearly 400 years later, though without supporting science curricula in schools.

Efforts have often been made, throughout history, to develop an education in the sciences that serves human ends. James J.G. Wilkinson delivered a lecture in 1847 that was an appeal for a diffusion of scientific knowledge beyond the learned class that produced it. He emphasized the view that “intellectual property” should serve human life, noting that there is a difference between the creation of knowledge and those who wish to apply it to human ends. He criticized scientists for wanting only to be judged by their peers and their own intentions, without concern for the business of life: the living spheres of knowledge (1847).

In 1932, a commission was appointed by the Progressive Education Association (PEA) to study the educational process and goals relevant to the needs of learners as they interact with their social medium in situations confronting young people in the home, school, community, and the wider social sciences. After seven years of debate, the goals for science teaching were defined in terms of personal living, immediate personal-social relations, social-civic relationships, and economic relations (Thayer, 1938). Science educators responded to these goals with a number of studies identifying the principles and generalizations that represented the present [1932] status of biology, earth science, chemistry, and physics. These studies

were products of professional science organizations and doctoral dissertations, but were never combined into a single list, and there is no evidence that the studies fulfilled the goals of the PEA (Thayer, 1938).

In the 1950s, the National Science Foundation (NSF) financially supported scientists, colleges, and universities to reform the teaching of science and to develop new science courses (Hurd & Gallagher, 1968; Hurd, 1969, 1970). School science courses were brought up-to-date in terms of discipline content, but not in terms of human life, a knowledge-based economy, or utilization of science knowledge for life benefit.

A future perspective, “learning to learn,” is a first step forward in reinventing science education. For the first time, standards for technology literacy have been developed. These standards represent technology as a subject in itself, not as a factor in the practice of science (International Technology Education Association, 2000). A broader point of view is presented by UNESCO (*Connect*, 1999).

Nearly 400 years have passed since Francis Bacon (1620) proposed a framework for science education in terms of the “welfare of man.” We face the same issue today, with a call for reinvention of science education. A quarter of a century has gone by

without a philosophical framework based on the “welfare of man.” For example, efforts to have students think like scientists and behave like scientists, based on the structure of science disciplines, is essentially a career-oriented curriculum. By contrast, the reinvented science curriculum being sought has a framework of developmental needs of students for productive lives in a continuously-changing world. Responsibility for developing a new science curriculum for grades K-12 belongs to professional science educators who are willing to work within the framework of today’s science and the quality of life.

References

Botvin, G.J. (1979). *Life skill training: Student guide*. New York: Smithfield Press.

Connect, 24(9), 1999. UNESCO, Education Sector. Paris, France.

Dick, H. (Ed.). (1935). *Selected writings of Francis Bacon*. New York: Random House.

Hamburg, D. A. (1990). *Life skills training: Preventive interventions for young adolescents*. Washington, DC: Carnegie Council on Adolescent Development.

Hurd, P.D. (1969). *New directions in teaching secondary school science*. Chicago: Rand McNally.

Hurd, P.D. (1970). *New curriculum perspectives for junior high school science*. Belmont, CA: Wadsworth.

Hurd, P.D. (2000). *Transforming middle school science education*. New York: Teachers College Press.

Hurd, P.D. & Gallagher, J.J. (1968). *New directions in elementary science teaching*. Belmont, CA: Wadsworth.

International Technology Education Association. (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

Morganett, R.S. (1990). *Skills for living: Group counseling activities for young adolescents*. Champaign, IL: Research Press.

Saskatchewan Newstart, Inc. (1972). *Life skills: A course in applied problem solving*. Prince Albert, Saskatchewan: Author.

Thayer, V.T. (1938). *Science in general education*. New York: D. Appleton-Century.

Tokanishi, R. (Ed.) (1993). *Adolescence in the 1990s: Risk and opportunity*. New York: Teachers College Press.

Wilkinson, J.J.G. (1847). *Science for all*. Paper presented at the meeting of the Royal College of Surgeons, March 25, 1847.

Paul Dehart Hurd is Professor Emeritus, Stanford University, Stanford, Calif. His mailing address is 549 Hilbar Lane, Palo Alto, CA 94303.