A Longitudinal Study of the Effects of a LSC Project on Scientists' Teaching Practices and Beliefs

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INTRODUCTION
With the aim of increasing scientific literacy and student achievement in science, policy reports issued in the last two decades demand widespread changes in how science is presented in the curriculum, taught in schools, and assessed (National Research Council, 1996a; National Commission on Mathematics and Science Teaching for the 21st Century, 2000; Rutherford & Ahlgren, 1990). Disconcerting, however, are reports that suggest the teaching strategies used in many of our nation’s classrooms is essentially the same today as it was two generations ago and document a need to restructure science teacher education in the United States (National Commission on Mathematics and Science Teaching for the 21st Century, 2000).

The National Commission on Teaching and America’s Future (1996) identified six major problems in teacher education. The first problem is inadequate time. The Commission argues that too many teachers are licensed with insufficient knowledge in a content area, and they are provided inadequate time to practice teaching. The second problem is fragmentation. Course work often is separated from practice, and the faculty in colleges of education and colleges of arts and sciences are isolated from each other. The remaining problems include uninspired teaching methods, superficial curriculum, and traditional views of schooling. In another study, 1650 teachers who had been winners of various teaching awards were surveyed about their own teacher education experiences (Rigden, 1996). Results of this survey added to the list of problems in teacher preparation inadequate and unsupervised school-based experiences, poor quality of many teacher candidates, and university faculty inexperienced in the schools.

Recent research studies indicate that the classroom teacher is the most important factor in improving student achievement in school (Sanders, 1998a; Sanders, 1998b). The Glenn Commission (National Commission on Mathematics and Science Teaching for the 21st Century, 2000) reported that the most consistent and most powerful predictors of higher student achievement in science are: (a) full certification of the teacher and (b) a college major in the field being taught. Conversely, the strongest predictors of lower student achievement are new teachers who are uncertified, or who do not have a major or minor in their field. The difference a qualified teacher makes is often very dramatic. The National Commission on Teaching and America's Future (1996) reported that licensing examination
scores and teaching experience accounted for 43% of the gains in mathematics test scores in the early grades.

Yet, many schools staff science classes with uncertified teachers (National Commission on Mathematics and Science Teaching for the 21st Century, 2000). A report from the American College Testing Service (NSTA, 2002) indicates that the number of high school students indicating intent to pursue teaching-related degrees is decreasing. Other schools are unable to attract and keep new teachers, and countless universities find it difficult to recruit teachers into these subject areas (National Commission on Teaching and America’s Future, 1996). To add to this problem, many of the nation’s teachers are reaching retirement age. Some recent reports indicate that our nation will need 2.5 million teachers in the next ten years (American Council on Education, 1999). In Ohio, approximately 37,000 teachers are between the ages of 45 and 55 – approaching retirement age indicating that about 1/3 of our teaching force will need to be replaced in the next 8-10 years (ODE, 1999).

Increasingly, policy reports recommend a different approach to teacher preparation, because it has become increasingly apparent that no isolated college, department, or school district can provide the necessary depth of preparation that beginning teachers need (American Association for the Advancement of Science, 1990; Bell, & Buccino, 1997; Glass, Aiuto, & Anderson, 1993; National Commission on Mathematics and Science Teaching for the 21st Century, 2000; National Research Council, 1996b, National Research Council, 1997; National Science Foundation, 1996; and National Science Board, 1999). Partnerships among colleges of education and colleges of arts and sciences, and public schools are needed for excellence in teacher preparation. Thus, many states, universities, and colleges are urging collaboration between scientists in colleges of arts and sciences and education faculty in colleges of education. For example, a report by State University Education Deans to Ohio’s Inter-University Council (SUED, 2001) acknowledged that Colleges of Arts and Sciences and Education share the responsibility of educating future teachers and called for collaboration between educators and scientists.

However, other educators have described the system of science teacher education as hobbled by the dysfunctional relationships among scientists and teacher educators (Duggan-Haas, 2000). Druger and Allen (1998) state,

“There has traditionally been a gap between those who teach science at the K-12 level and those who do science. Few K-12 science teachers ever have science research experiences in their training; yet they attempt to teach students how science works. The true experts in
science are research scientists; yet they are at universities, colleges and research institutions, and may have little to do with K-12 science education” p. 344.

As a result, educators have engaged in numerous innovations and reform projects developed in partnership with scientists, often supported by grants, all of which address the needs for improvement in student achievement and teacher preparation in science (Moreno, Chang, Tharp, Denk, Roberts, Cutler, & Rahmati, 2001). The Center for Science, Mathematics and Engineering Education at the National Research Council, established Resources for Involving Scientists in Education (RISE) to encourage scientists’ involvement in K-12 education (NRC, 1995). Several research studies describe the positive impact of having scientists involved in teacher preparation and revision of coursework for teachers and others in general education (Stein, 2001), whereas positive results are also observed in programs where scientists work with pre-college students and their teachers (Caton, Brewer & Brown, 2001). Some successful programs link the scientific community with K-12 education programs through electronic networking (Bartolo & Palffy-Muhoray, 2001). When teachers work with scientists on science investigations, they have an increased interest in and understanding of science; their confidence in their ability to teach science also increases, and they are more likely to use inquiry-based teaching methods (Caton, Brewer & Manning, 1997; Canton, Brewer, & Brown, 2001).

Some research studies identified scientists’ beliefs about science education and teacher preparation. For example, Druger and Allen’s (1998) research indicates that research scientist hold negative views of K-12 science education with only 26% of scientists surveyed rating science education as good, very good, or excellent. Few scientists have worked with children or held a position influencing K-12 education. Their experiences in supporting K-12 science education were limited to presentations to students, research opportunities for high school students, and assisting with science contests. When asked how they might best assist K-12 science education, answers included presentations to students, teacher enhancement, developing curriculum, helping with science contests, tutoring, and involvement on committees such as textbook committees and school boards. The scientists’ perceived the biggest problems facing K-12 science education including the preparation of teachers (poor science background and isolation from scientists), science teaching methods used by teachers (too much emphasis on facts and too little emphasis on doing science), inadequate resources, lack of appreciation for science among the general public, less than motivated students, problems with educational systems, and low expectations or dilution of standards.
The literature reviewed here illustrates the benefits of programs that link scientists with K-12 teachers and students, however little is known about the effects of the collaborative partnerships on scientists’ beliefs about what elementary teachers need to know, be able to do, and be like in order to teach in accordance with the National Science Education Standards. Few studies examined the effect of the collaborative partnerships on the content and pedagogy of undergraduate general education classes the scientists teach. Thus, the purpose of this study is to examine these issues.

BACKGROUND

The scientists involved in this study have participated in a National Science Foundation Teacher Enhancement funded project entitled “TAPESTRIES: Toledo Area Partners in Education-Support Teachers as Resources for Improving Elementary Science.” This project is designed to achieve a comprehensive, system-wide transformation of science education in a partnership of schools and two Midwestern universities. The major goals of the project are to: 1) develop and utilize a cadre of Support Teachers; 2) provide effective and sustained professional development in science content, pedagogy, and assessment for a large number (approx. 1400) of K-6 teachers; 3) implement quality inquiry-based science curriculum and instruction; 4) coordinate curriculum, classroom practice and student assessment with the district adopted science courses of study and statewide curriculum models and assessments; and enhance the science content knowledge of elementary teachers in life, physical, and earth/space science. This program fosters a paradigm shift through the creation and development of collaborative structures that align the efforts of scientists, science educators, teachers, school administrators, and local school communities to improve the preparation of elementary teachers. Classroom teachers who participate in the TAPESTRIES project participate in two-week summer institutes, regular district level sessions during the academic year, and a spring institute. Support teachers, who are given full time release from teaching responsibilities, provide assistance for classroom teachers, help teachers with district assessments, and execute district action plans for improving science literacy. The purpose of this five-year project is to develop comprehensive school science programs through the sustained professional development of all K-6 teachers in two large, urban school districts. The project was designed to help prepare scientifically literate students who can comprehend and use science while being successful on high-stakes statewide science assessments. Thirty-two Support Teachers, are given full time release from teaching responsibilities, receive over 200 hours of training in the form of a two-week
Summer Institute, two three-semester-hour courses, a staff retreat, and a spring conference. The Support Teachers provide assistance for classroom teachers, help teachers with district assessments, and execute their district action plans for improving science literacy. Approximately 800 classroom teachers from the participating districts (approximately 50% of the teachers) receive over 104 hours of staff development in science content, pedagogy, and student assessment as they implement their district adopted curriculum materials.

This study focuses on the scientists’ beliefs and practices as a result of participation in the project. The scientists from each university engage in a team teaching arrangement with a science educator and provide content expertise during the 2-week summer institute. They also assist teachers during the school year via visits, phone calls and e-mails.

The scientists teach general education classes in their respective departments (biology, geology, chemistry, physics or astronomy) throughout the academic year. This regular teaching load provides the scientists with the opportunity to explore issues related to both the content and pedagogy of these general education courses that prospective teachers take during their undergraduate experience.

**METHODOLOGY**

A qualitative evaluation of the scientists’ perceptions, beliefs, and experiences was undertaken, beginning in the Fall of 1999. This longitudinal study explored the following research questions:

1) What is the effect of the collaborative partnership on scientists’ beliefs about what elementary teachers need to know, be able to do, and be like in order to teach in accordance with the National Science Education Standards?

2) What is the effect of the collaborative partnership on the undergraduate general education classes the scientists teach in terms of content and pedagogy?

**Interview Process**

In order to answer the research questions, a series of 15 scientist interviews were conducted during Fall Semester of 1999. This was the semester following their initial experiences with
the TAPESTRIES program. Since this study is part of an overall comprehensive evaluation of the TAPESTRIES Project, the evaluation plan calls for scientist interviews on an alternate year schedule. Therefore, during the Fall 2001, a second round of 18 scientist interviews were conducted. Each interview lasted approximately sixty minutes. The interviews were audio taped and transcribed. To identify emerging themes, three readers independently reviewed the interview transcripts. The readers converged to negotiate and clarify the meaning and language of the identified themes. Strong agreement and censuses about the themes was evident. Methodology for the interview process was guided by the work of Bogdan and Biklen (1992). In addition, the development of interview questions was guided by Glesne and Peshkin (1992). These researchers reveal, “The questions you ask must fit your topic; the answers they elicit must illuminate the phenomenon of inquiry. And the questions you ask must be anchored in the cultural reality of your respondents; the questions must be drawn from the respondents’ lives” (p. 66). The following questions were used to guide the interview process:

1) Please describe your role in the TAPESTRIES Project.
2) With respect to undergraduate general education classes, how would you describe your current practices in terms of content and pedagogy? Have these changed or been influenced by your involvement with TAPESTRIES? How or why?
3) What are your current beliefs about what elementary teachers should know, be able to do, and be like in order to successfully teach science to elementary students in general (or in accordance with the National Science Education Standards?)
4) In your opinion, do undergraduate students have enough science content background to teach elementary science? What do you suggest?
5) How or to what degree do you work with: Science Educators, Elementary Teachers, Others involved in TAPESTRIES?

Survey

To confirm the validity of the interview responses, the researchers explored student perceptions of practices employed in the undergraduate classes. The CLES Survey (Constructivist Learning Environment Survey) developed by Taylor and Fraser (1991) was distributed to undergraduate students in 11 of the TAPESTRIES scientists’ classrooms.
The scientists were asked to volunteer to distribute surveys to their classes. Seven scientists were either on faculty improvement leave or unable to participate due to scheduling issues. A total of 260 surveys were returned representing a variety of classes (i.e. Biology, Geology, Physics, Environmental Science, & Chemistry).

The CLES was developed to enable classroom teachers to monitor and reflect on their own development in constructivist teaching practices. The instrument included sub scales to assess student perceptions of the degree to which opportunities for student prior knowledge, autonomy, and negotiation existed in the classroom. In 1994, the authors revised the CLES in light of the realization of dominant "socio-cultural restraints" that often impede the ability of teachers to use constructivist approaches. As such, the revised instrument reflects a critical constructivist theoretical framework which includes both prior knowledge and interpersonal negotiation of meaning as the fundamental components in creating opportunities for conceptual understanding.

The revised CLES reflects a social constructivist perspective by including sub scales measuring student perceptions regarding the degree to which five related components are present in the classroom environment. The components include:

1. **personal relevance** - students recognize the relevance of science to their "out-of school, lived experiences". *CLES example: "Students learn how science can be part of out-of-school life"

2. **student negotiation** - students explain and justify their newly developing ideas to other students and collaboratively reflect on the viability of the ideas; *CLES example: "Students get the chance to talk to other students"

3. **shared control** - students share control with the teacher in the total learning environment (i.e. classroom management, curriculum, and assessment); *CLES example: "Students help you plan what they are going to learn"

4. **critical voice** - students are free to question the teachers planning and teaching strategies and are encouraged to express concerns about perceived obstacles to learning; *"Its okay to ask the teacher 'why do we have to learn this'" and

5. **science uncertainty** - students experience opportunities to view:
   a) scientific knowledge as arising from human experience; and
   b) values as evolving and insecure, and as culturally and socially determined. *CLES example: "Students learn that science cannot provide perfect answers to problems";
Since its development, the CLES has become a valuable research tool that enables both teachers and students to examine and reflect upon the social constructivist nature of the classroom. For the purposes of this research, the CLES survey was modified to include a short addendum of questions to indicate the frequency of specific pedagogical practices.

**ANALYSIS**

**Interviews**

Data analysis from the interviews indicates several themes as indicated in Figure 1. The following section provides examples of scientists’ quotes for each theme.
Figure 1

Themes

- Pedagogical & Curricular Modifications
- Content Knowledge & Dispositions
- Empathy & Appreciation
- Reflective Thinkers
- Perceived Barriers

Collaboration
Research Question 1: What is the effect of the collaborative partnership on scientists’ beliefs about what elementary teachers need to know, be able to do, and be like in order to teach in accordance with the National Science Education Standards?

**Theme 1: Content Knowledge & Disposition**

The scientists indicated that one of the most important factors contributing to being an effective science teacher is disposition. The consensus among their responses reveals that although basic understandings of science concepts are important, a positive disposition is critical to successful science teaching and learning. One scientist revealed, “I think just a positive attitude is the single most important thing that they could take with them into the classroom.”

In addition, the scientist value science processes skills as opposed to memorization of science facts. Examples of other responses included:

*I think much more now, having been involved in TAPESTRIES, that content is not as important. I think they need to know scientific processes and developmentally appropriate processes. They need to know how to keep science interesting and fun.*

*Yes. People have to memorize facts, but knowing the concept and the process of how science works, especially at the elementary level. It is much more important to have a teacher being able to present the scientific method and get the kids doing science without realize that they’re doing it than having a teacher who knows all of the facts about whatever the field it. You can go to a book to find facts.*

*They should know enough science content to feel confident talking with students and not feel nervous that they’re going to get caught off guard by a second grader. They should know enough content to be able to read articles in popular magazines like National Geographic, Discover, or Scientific America. So, in terms of content, they don’t need to know a huge among of terms or equations or anything like that, but enough to make them feel confident that they can relay the information and learn more about the particular topic.*

*I really don’t think they need to know a lot to be a successful science teacher...science is not just the facts but how you get to the facts – it’s discovery. So, the teacher should be*
confident enough that they can discover these things with the students. I really don’t think they need to know a whole lot. I think that they should have the proper attitude.

They need to not be afraid of science. And, what we do in our courses should help them build the skills and the confidence to ask questions, know what kinds of questions are scientific, know how to begin to look for answers, or design experiments. They need to be able to evaluate events and make decisions. If I leave them with a fear of science, then it doesn’t matter how much I’ve taught them, they’re not going to do it in the classroom because they’re afraid of it.

Related to the notion of science content, there is an overwhelming view that the current undergraduate science preparation program for elementary teachers is inept and not meeting needs of the preservice teachers. Although many of the scientists indicate being unaware of the College of Educations’ course load requirements for preservice elementary teachers, the scientists agree that the way science courses are currently delivered is not effective. A dilemma exists on how to fix this problem. Some argue that more content courses are needed while a few discuss the need to restructure university courses to better meet the needs of teachers (i.e. make them inquiry-based and adhere to The Nationals Science Education Standards). One scientist revealed,

The undergraduate preparation is not enough. Particularly in physical science. Most elementary students take only two science classes, and often both are biology. In addition, the subject material in the courses is often irrelevant to the science that the teachers need to know for elementary school. Finally, science in these classes is too often taught as a body of facts, not as a process of inquiry into the natural world.

I think that a lot of the content courses that the education majors take do not necessarily help them with the material that will end up being useful in the classroom. And, even though they’re taking courses, they’re not necessarily of great use to them. They’re taught in a way that they’re not going to remember the content, or they’re not going to remember the important parts of the content. Or, they are going to know all this trivia but not understand why we should care about the trivia or how science is done and what science is all about.
**Theme 2: Empathy & Appreciation**

The second theme focuses on the scientists’ appreciation for the TAPESTRIES program as well as the issues surrounding science education reform. Most of the scientists interviewed had high praise for the goals and structure of TAPESTRIES. One scientist described it as “a mammoth undertaking that he would not have been able to organize and deliver.” Another revealed, “I think it’s a fine program. I am awed by the administration of it. I mean it’s such complex thing. It makes me tired to think about having to orchestrate and organized this.” Others indicated that goals of the project were highly congruent with their own views of how science should be taught. Another scientist stated, “I think the TAPESTRIES Model has been a phenomenal model that has really set the standard for they way we collaborate across colleges in science and math. It’s one we cite frequently because it is just so effective having the educators and scientists in the same room collaborating.”

The scientists were pleased with the workshops themselves, noting that organization and delivery as well as the logistics was extraordinarily competent. In addition, a strong desire to continue the program was indicated. Responses are as follows:

*I hope it can continue. I think it's a great program, I think it had great benefits for the scientists that were involved. I think it gave them a chance to learn about innovative teaching methods and I think that probably lead to more than just me implementing at least some parts of those strategies in their own teaching and improving their teaching as a result. And so I would be in strong favor of finding some way to continue it.*

*I am really sympathetic toward elementary teachers because they have so much to cover and one of the things that I would like to encourage them to do is keep an open mind. They’ve got so much to do at the elementary level…it’s not just science. The more help they can get, I think the better off everyone is, especially the kids.*

*I think they’re almost the salt of the earth as far as what they’re trying to do. I never get the sense from teachers that they have sort of given up; that they’re sort of cynical; that they’re not interested in doing a better job – but, you know, I really see a very sincere effort to want to improve themselves and want to be better. But, certainly, the ones that I’ve had contact within TAPESTRIES and other workshop contexts, have been very dedicated people – people that I’d be delighted to have my children be taught by.*
The experiences of TAPESTRIES also lead to empathy and understanding about the complex nature of science education reform. One scientist revealed, “I think we are just looking at TAPESTRIES as being a five-year program and that just conflicts with reform and systemic change that we’re trying to implement. But, this is a very complex problem-reforming science education- and I think we did a pretty good job.” The scientists also indicated their concern with lack of district administrative support and lack of on-going training or resources that would sustain the positive effects of the TAPESTRIES program.

In addition, the scientists praised the Full Option Science System (FOSS) curricular materials that were used during the project. One scientist stated “I like the kits that FOSS had. It was nice to see how the kits progressed as the children got older. And, I think it is a nice program.”

Research Question 2: What is the effect of the collaborative partnership on the undergraduate general education classes the scientists teach in terms of content and pedagogy?

Theme 3: Pedagogical & Curricular Modifications

The third theme focuses on pedagogical and curricular changes that are attributed to the TAPESTREIS project. When asked about the ways TAPESTRIES had an impact on their own teaching, most reported that the experience caused changes. Many of the scientists indicated that one important change had been in the level of pre-assessment they were doing with students. Examples include, “I try to get them to examine their misconceptions about the material we are covering.” Although most maintain that lecture still dominates their classes, they have begun implementing a variety of strategies such as cooperative learning and a learning cycle approach to lesson development (i.e. The 5 E Model of Instruction: insert citation here…). For example, one scientist indicated, “Admittedly, I still convey a lot of information via the lecture format, but that’s not the only way.” The scientists also revealed that they are trying to make their courses more enjoyable and relevant for the students. One revealed, “What I try to do is engage the students in what I am doing by relating it to their everyday life.” Additional responses included:
I have incorporated the 5E model and found it very effective when I figure out good ways to use it. I have also made my classes more hands-on and inquiry-based because of the information that I have encountered in TAPESTRIES. I am convinced that this approach is likely to be more effective with most of our students.

I have learned a lot through working with the science educators and I’ve had chances to practice things, try things, and see things in action that I might have read about before.”

Working with TAPESTREIS was the first time I encountered something called the 5E Plan that I’ve attempted to make use of in my classroom. The initial engage strategies do seem to heighten the class and get their attention focused. And, I have also taken the initiative to try to incorporate more spots of exploration through additional activities. I can tell that there is a shift…that they are active and not just staying with the lecture format is something they enjoy.

They have become much more hands-on and inquiry-based. Right now I am teaching a general education natural science course in which students are investigating the possible contamination of water wells by crude oil from improperly manned oil wells.

I approach it with the understanding that my audience is primarily not scientists. I try to focus on larger issues, the interesting questions that get raised, rather than get bogged down in details and memorization.

**Theme 4: Reflective Thinkers**

In addition to modifying some of the instructional practices, the scientists demonstrated a reflective nature when discussing issues surrounding teaching and learning. Most point to the fact that they were never formally trained to teach. They indicated that this is a problem in higher education and expressed a continued desire to learn more about teaching and learning issues. One scientist revealed, "I used to think I was teaching if I organized material and concepts in what I considered a meaningful way. Now, I realize that I have to be analyzing student perceptions. Another declared, “The main change has been
that I see how bad I’m doing. The lecture format really isn't the best way to get students to learn.” Additional responses included:

When I started teaching, I knew how I didn’t want to teach because I had enough professors that got up there and just talked at me. I tried a number of things with mixed success. But my involvement with TAPESTRIES actually got me exposed to some of the well-tried theories and well-tried practices that have been used. And, being around science educators and other teachers, it took me into that area where people were actually looking at the stuff. Because, unfortunately, professors aren’t trained to teach. It’s assumed that they know what to do.

I think what the summer institute has shown is that pedagogy ad context should go hand-in-hand, and very seldom does that occurs, not only at the elementary level, but also at the university level. I mean you are better-off teaching less things but just do it right and doing it right involves all those things we talked about. Inquiry and not just hands-on, but there’s got to be a purpose for doing those activities. There has got to a method to do that and to accomplish those goals.

Two and a half years ago, I was a complete traditionalist (lecture), but I have been steadily moving away from that way of teaching through teaching elementary teachers, working with elementary students, learning about the connection between brain research and learning, and interactions with science educators at the University.

**Sub-Theme: Perceived Barriers**

The desire to implement a variety of instructional strategies in the college science classrooms is clearly discussed by the scientists. However, many point to barriers such large class sizes, time, and tenure & promotion policies. One scientist sums up the barrier of class size by stating, “I’ve become aware of best practices but the size of the classes makes, I think, it a little difficult to handle a big change.” Similar responses included:

I have to say that TAPESTRIES has changed the way teach. But, having said that, I can only utilize what I learned in certain contexts. For instance, I teach a class about scientific writing where I have around 18 students and I have permission from my chairperson to do what I want in that class. It’s a class that seniors take and the evaluations for the class are amazing. I want to be a teacher because of that. Then, I’m
teaching other courses that I don’t have the luxury of doing that; I have a syllabus that I have to follow and I have anywhere between 50-75 people in class.

I do large lecture courses. I have 140 or 160 students. So, that dictates that I have to use the lecture method which I understand is probably the least effective way to transmit knowledge, but it’s the most economically effective way to get students through the university.”

**Theme 5: Collaboration**

The final theme focuses on new collaborative projects. Unanticipated effects of TAPESTRIES have resulted in greater collaboration among scientists and science educators. Several recent projects and grant-funded activities have resulted. All projects are aimed at improving the quality of undergraduate science preparation.

One scientist revealed,

*I have recently received a title II grant (Ohio Board of Regents) to revise our course, *The Nature of Science. The revision will align it with the College of Education’s Science Methods Courses, with the 4th and 6th grade Ohio Proficiency Test outcomes, and with *Praxis II for Middle Childhood Science Education. The revisions will also incorporate the 5-E Model of instruction and include a variety of assessment mechanisms into all of the lessons in the course.*

*Typically we meet once a week with certainly everyone in Arts and Sciences who’s involved in math and science education. And usually the science educators pop in and out of those meetings as well. So, I think we have a fairly high degree of working with them because we have good collaboration going on here.*

*(Jodi: I still need to finish this theme…)*

**Survey Results**

The preliminary findings from the surveys that were completed by 260 undergraduates enrolled in general education courses this semester depict their perceptions of the degree to which constructivist teaching strategies, as defined by Taylor, Fraser, and White (1994) were implemented by eleven TAPESTRIES scientists from two universities.
On the CLES section of the survey, the mean scores for the five constructs were as follows: personal relevance (3.83), scientific uncertainty (3.40), critical voice (3.82), student autonomy (2.44), and student negotiation (3.35). The CLES construct Likert scale values appeared on the survey as follows (1 = never, 2 = seldom, 3 = sometimes, 4 = often, and 5 = almost always). Although no statistical analyses have been completed at this time, the mean scores indicate that the undergraduates perceived more personal relevance and critical voice opportunities (mean rating of "sometimes") than that student autonomy opportunities (mean rating of "seldom").

The second part of the survey gleaned the undergraduates perceptions of specific reform based (versus traditional) teaching strategies. The Likert Scale categories for this section were 5 = always (every class), 4 = frequently (1- 2 times/week), 3 = occasionally (a few times/month), 2 = rarely (once/month), or 1 = never. The mean scores for the following strategies were reported: lecture (4.6), discussion (3.9), demonstrations (3.7), working with other students (3.7), use of science materials other than the textbook (3.6), hands-on activities (3.4), sharing responsibility for learning with students (3.4), recitation of acquired knowledge (3.3), rigidly following the science textbook (3.1), use of technology (3.1), reading from the book (2.8), brainstorming exercises (2.7), debate (2.6), peer teaching (2.3), 5-E lesson planning (2.2), field trips (1.8), and guest speakers (1.6). These strategies were grouped into one of three categories, traditional, reform-minded and TAPESTRIES reform strategies. The traditional strategies (mean = 3.47) included lecture, reading from the book, rigidly following the science textbook, and recitation of acquired knowledge. The reform minded strategies included all others listed above (mean = 2.92). The reform strategies specifically focused upon during the TAPESTRIES professional development experience included: 5-E lesson planning, hands-on activities, working with other students, sharing responsibility for learning, use of science materials other than the textbook, and brainstorming exercises (mean = 3.17). Once again, statistical analyses are not yet available, but it appears traditional teaching strategies are still more prominent than the reform-based
strategies, but the strategies are being implemented to some degree and the TAPESTRIES reform based strategies to a greater degree.

IMPLICATIONS

Evidence from this study indicates that collaboration opportunities may be impacting some of the scientists’ pedagogical practices in their general education courses. Data from this study indicates that scientists are reflecting upon and modifying their own pedagogical practices to better meet the needs of their students. Therefore, it is important that The National Science Foundation and others continue to fund collaborative projects like ours.

Colleges of Arts and Science and Education share the responsibility of educating future teachers, however, the university subsidy model in Ohio (and we suspect other states) place teacher education courses among the lowest funded courses on state campuses. Other clinical programs are funded one or two levels higher. As a result, unless university presidents and provosts reallocate money internally, colleges of education typically receive less funding for delivering instruction to a similar number of students as faculty in other colleges on campus. The net result is fewer faculty members to teach students enrolled in colleges of education and few incentives for university-wide collaboration in teacher education.

Of emerging importance is the role of teacher education and licensure programs where preservice elementary and middle childhood teachers must also focus on acquisition and comprehension of content knowledge in addition to understanding the principles of teaching and learning. For example, recent changes in Ohio teacher education and licensure programs have resulted in new standards aimed at improving education for all of Ohio’s students (Chapter 3301-24 of the Administrative Code: Teacher Education and Licensure Standards, 1998). These standards increase the rigor in the teaching profession as they summon colleges and universities to improve their teacher preparation programs by developing programs that focus on what teachers should know and be able to do. In addition to understanding student learning processes and pedagogical practices, the new standards emphasize the acquisition of content knowledge. Thus, preservice and practicing teachers must demonstrate a thorough understanding of the subject matter and uses of such
knowledge to create effective learning experiences for students. Our findings suggest that collaborative programs such as this NSF funded Local Systemic Change program, have influenced the work of scientists in content courses thereby improving the content courses taken by prospective teachers both in terms of pedagogy and content.

Therefore, opportunities for collaboration among Arts and Science and Education faculty should encourage science literacy reform by redesigning general education science courses for preservice teachers. In these courses, the methodology should be taught implicitly by modeling appropriate teaching techniques recommended by the national standard reform reports. Activities should focus on the needs of the preservice teachers by addressing relevant content recommended in The National Science Education Standards and use equipment available to teachers in the schools. These courses should offer preservice teachers opportunities to design and implement inquiry-based, hands-on activities and to use proper safety precautions when teaching the science content. Moreover, the courses should also aim to develop positive attitudes towards science and science teaching.

However, most preservice teachers enroll in survey courses that serve students in many different fields of study and do not address the content that is recommended by national and state science education standards. In addition, those courses are typically not taught in ways consistent with national and state standards for the teaching of science. For example, many of the laboratory experiments do not emphasize scientific inquiry and they often employ activities and technology not easily transferable to elementary or middle childhood science classrooms. By increasing the opportunities for collaboration, as modeled in the TAPESTRIES Project, we will help to better prepare preservice teachers to become confident and effective teachers of science.

Our findings also suggest that scientists need professional development addressing how to teach and assess students in ways different from traditional lecture-based models. Universities need to establish structures to provide professional development to faculty in higher education and reward good teaching. Part of the overall preparation for faculty teaching in higher education in all fields should include courses related to best practices in teaching and learning. It is unfortunate that...besides colleges of education...other college faculty typically has no preparation effective teaching strategies, curriculum, or assessment.
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