Florida Journal of Educational Research Fall 1994, Vol. 34, No. 1, Pp. 70-88.

The Elementary Mathematics/Science Specialist Program: Trying to Practice What We Preach!

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ABSTRACT. Current literature in educational research emphasizes the benefits of instructional strategies such as hands-on exploration, cooperative learning, team projects, and contructivist activities. However, the adoption and/or effectiveness of these same methodologies in college courses is evidenced far less frequently. This article describes the professional growth experienced by both instructors and students participating in a graudate level program that embodied these recommended practices. The Elementary Mathematics/Science Specialist Program, established at the Florida Institute of Technology, anwered the Department of Education Eisenhower Grant Program's call for improving teachers opportunities for learning math and science. This paper reflects the developmentttal nature of the transitions experienced by the programs' instructors as they moved through the reflective teaching process.

Research in recent years has demonstrated the benefits of new instructional methods with K-12 students (Barrow, 1985; Carpenter, Fennema, Peterson, Chiang & Loef, 1989; Cobb, Wood, & Yackel, 1990; Lampert, 1990; McCombs, 1993; Perkins, 1991; Resnick & Klopher, 1989). We in teacher education declare strategies such as hands-on exploration, cooperative learning, team projects, and constructivist activities good ways to help students learn. However, evidence of the effectiveness or usage of these methodologies in college courses is far less prominent (Halpern, 1994). After extended conversations with my graduate education students, we decided it was time to try to practice what we preach! Thus began the development of the Elementary Mathematics/Science Specialist Program (EMSSP).

The EMSSP was created as a Florida Department of Education Eisenhower grant program, answering the call for improving teachers' opportunities for learning math and science. We proposed a 12-credit in-service program for elementary school teachers that embodied many of the recommendations found in Florida's *Statewide Systemic Initiative* (SSI), Florida's *Blueprint 2000*, and *A Comprehensive Plan: Improving Mathematics, Science, and Computer Education in Florida*. We detailed an interdisciplinary, team-taught, hands-on, project-focused syllabus - all of the things we believed to be good models of science and math instruction. We further surmised that it would be a truly collaborative project if the elementary school teachers enrolled in the courses shared their pedagogical expertise with the college teachers.

Our goals were: (1) to further elementary school teachers' understanding of science and mathematics, and (2) to investigate college instructors potential for implementing contemporary instructional practice. Our rationale was that in order to create innovative courses for the elementary school teachers, we would have to design a program that redefined science and math instruction for both the teachers (who, in this case, were college instructors) and the students (in this case, the elementary school teachers). We hypothesized that the EMSSP would have to use a real-life environment, employ reflective practice, and make use of local resources if it was to provide a model for post-secondary teachers.

We created a content course rather than a methods course so we could investigate the relationship between conceptions of mathematics and science and instructional practice (Thompson, 1992). Specifically we were interested in two areas: (1) what effect increased proficiency with math and science concepts would have on elementary school teachers' views and beliefs about mathematics and science (Kelly-Benjamin, in preparation), and (2) what effect a change in instructional approach would have on college teachers' beliefs about teaching. As Thompson noted:

> The reconceptualization of teaching has led to a change in the research agenda-from determining the basics skills or competencies of teaching associated with student growth to understanding teaching from teachers' perspectives. An understanding of teaching from teachers' perspectives complements our growing understanding of learning from learners' perspectives, which, in turn, enriches the idea of schooling as the negotiation of norms, practices, and meanings (p.142).

The model we proposed for the EMSSP was math and science for elementary school teachers, *not* elementary school math and science. We wanted the participants to have an opportunity to learn, discuss their learning, and construct their own knowledge of science and mathematics, as suggested by current research on constructivism. As Schifter and Fosnot (1993) noted, "if teachers are expected to teach mathematics for understanding ... they must themselves become mathematics learners" (p.16).

Development of the EMSSP Program

With all of the major stakeholders represented (i.e., college faculty, elementary school teachers, county supervisors, area specialists, project researchers, education majors), we outlined the specific goals for the project. The 15 member planning group worked together for six months identifying the essential components of the course. We examined a variety of instructional models to determine a framework for the EMSSP. We studied current professional guidelines including the National Council of Teachers of Mathematics' *Professional Standards for Teaching Mathematics* (1991), and *Project 2061* (American Association for the Advancement of Science, 1989) to outline the course contents. We interviewed various resource personnel and investigated possible community projects that could serve as a site for the EMSSP.

Exploration of new models for teaching provided the EMSSP with a unique instructional format. We decided that there would be a core team of three instructors, one specializing in mathematics, one in the physical sciences, and one in the environmental sciences. Since most college math and science courses are taught by professors who specialized in those fields, we recognized they would probably have limited formal pedagogical training. For the EMSSP, we tried to select instructors who typified math and science college instructors. In order to compensate for their lack of pedagogical experience, and to encourage a constructivist framework for both teachers and students, we enlisted the support of other resource personnel who supplied specific training when necessary. For example, consultants provided instruction in journal writing, telecommunication, photography, etc.

The goals of the entire instructional team were to facilitate exploration and application of new areas of knowledge and skills in science and mathematics, and to guide learning throughout the program. This was a completely new experience for them. To improve the teams' facilitating skills, the entire project staff, including the instructors and resource personnel, went through facilitative leadership training. This allowed the group to practice new

techniques for guiding instruction and reflecting on practice. It also started the program out with the teachers reconstructing their own knowledge of teaching.

The planning group also decided the students should work in teams. Research indicated that the elementary school teacher candidates for this program might be hesitant about volunteering for a full-year graduate program in math and science (Kimball, 1989). The elementary school teachers we interviewed confirmed the research. They reported having limited exposure to higher level math and science and high anxiety about taking any college math or science courses. When we suggested using a team approach, some of their concerns were mitigated.

Another key decision was to make good use of all available resources. To do this, the team had to identify possible people, places, and materials that the students could use during the EMSSP. The integration of available resources into the model further ensured a "guide on the side" rather than a "sage on the stage" approach since no one person was the disseminator of all information.

Summary of the EMSSP

A Real-Life Setting. The planning group decided that involvement in a Brevard County environmental restoration project was the best setting for the EMSSP. The Malabar Scrub Site was selected to be our "outdoor classroom." This site had recently been acquired by the county to be restored as a wildlife sanctuary for some of central Florida's indigenous species. Future plans for the site called for development of passive recreation and educational facilities. No formal plans for restoration and development had yet been made. This made the site ideal for the EMSSP. The participants were able to suggest ways to advance the project that had the potential for being implemented.

The site provided the environment necessary for the EMSSP. It invited exploration of important math and science concepts and application of this knowledge to a meaningful situation. The EMSSP participants were able to help the site manager characterize the plant and animal populations of the site, and predict patterns of change and growth. They also helped shape a survey of area residents regarding sanctuary management practices. Public attitudes were surveyed and statistical conclusions were reported to county officials. The EMSSP became the reference group against which others' responses were compared.

The students' final projects provided the county with educational prototypes for teaching the community about the Malabar scrub site. These projects included two multimedia catalogs of the sanctuary (one Macintosh based and one MS-DOS based), blueprint plans for an educational kiosk and observation tower for the site, and two video-based tours of the site. Print materials about the site were also developed.

The EMSSP introduced elementary teachers to segments of more than 30 upper-division and graduate-level courses ranging from marine ecology to descriptive and quantitative statistics.[1] Participants were involved directly in field work, including characterizing the territorial distribution, behavior, and reproductive activity of various mammals, reptiles, amphibians, birds, insects, and aquatic species. Visits to the sanctuary were repeated to establish occupancy, seasonal distribution, and competition variances. Foraging, shelter, corridor travel, and nesting patterns were also investigated. The flora distribution was cataloged according to topography, hydrology, soils, micro-climate, and natural community structure.

For example, one of the first activities required each team to select a 100-meter square section of the site and find a way to mark off the area (not always easy with heavy underbrush in many of the areas). They had to describe the area, identify the species, characterize the dimensions of the wildlife (e.g., average height of the trees, size of the tortoises, etc.), and summarize their data. In order to complete the task, they had to determine the best ways to collect samples, measure, count, and extrapolate their data.

The particular task was not the important focus; many other tasks could have been selected to accomplish the same goals. What was critical was that it was a meaningful task for all participants, and that everybody had to investigate together. This task provided a situation where the course facilitators did not have the answers. As such, they were able to help the teams explore the usefulness of a variety of tools but did not have all the facts. In essence, they were learning about the site along with their students. Their role became one of offering reasonable recommendations and helping the teams understand the meaning of their data.

Resources. When not at the Malabar Scrub Site, the EMSSP was held at the Space Coast Center for Excellence, which is housed at Florida Tech. This setting gave the participants access to many resources. They were able to use state-of-the-art technology, borrow print and computer-based materials, and interact with various support personnel. In addition, each team received a supply of resource materials for their schools (i.e., field guides, manuals, and

references). Each team received a modem, a copy of *ClarisWorks*, and a $600 budget for purchasing other supplies. Each participant also had a travel budget of $100, which allowed them to attend conferences and/or take field trips to collect additional information.

Resource personnel primarily provided help with the technology, information about Florida's environment, and familiarization of the Malabar Scrub Site. Most of the teams also developed support personnel at their own schools. These ranged from editors to architects. Most also involved their students, taking them on field trips to the site and/or involving them in their final projects.

The elementary school teachers gained exposure to a wide range of state, county, and community resources that can contribute to elementary education. The teachers in the EMSSP relied heavily on multimedia technology to develop and evaluate alternative solutions for course projects. The participants made use of many of the educational technologies available in Florida's school system. This proficiency, in turn, helped the teachers expand their instructional methods to facilitate student understanding of mathematics and science concepts and interrelationships.

Reflective Practice. All participants, instructors, and resource personnel were involved in the ongoing evaluation of the EMSSP. Participants were surveyed and interviewed throughout the program. Each team kept a journal which was reviewed by the instructional team and researchers. All input was used to modify the context, procedures, and instructional strategies of the EMSSP. Throughout the program participants were also encouraged to assess their own views about mathematics and science, and improvements in their competence and attitudes toward mathematics and science.

The constructivist framework of the EMSSP ensured that evaluation of the program was directly applicable to the needs of all students, especially those with "non-traditional" learning styles. The participants, both the college and the elementary school teachers, gained a different perspective, by assessing their own learning as a developmental process. The dynamic nature of the evaluation of the EMSSP provided teachers with a different model for learning math and science.

The Participants

The Instructors

Three of the planning group members volunteered to be the course instructors. They agreed to teach the two semester course as a team, using the techniques they had studied in their graduate programs (i.e., constructivist, discovery-oriented, hands-on, cooperative, etc.). In addition, they agreed to allow the research team to study their development over the duration of the project. They were observed, kept journals, submitted periodic reports, and were interviewed regularly throughout the two semesters.

All three were graduate students in the science or mathematics education department at Florida Tech. Each had some experience teaching at the college or professional level, none had K-12 teaching experience. The first instructor (I1) was a Ph.D. candidate in science education. She was also an adjunct in the aeronautics and physics department. The second instructor (I2) was also a Ph.D. candidate in science education. Her experience included three years as a teaching assistant for the oceanography and science education departments. She was the only member of the team who had any experience with field-based instruction. The third instructor (I3) was a masters student in mathematics education. He had recently retired from the military and was seeking teacher certification. His primary instructional experience at the beginning of the project was military-based lectures and demonstrations. However, midway through the project, he began teaching mathematics part-time at two area high schools.

The three instructors provided a balanced team for the EMSSP. Their knowledge of math and science content was very diverse, as were their own learning styles. Their lack of elementary school teaching experience and limited experience with non-lecture forms of teaching allowed us to study their experiences with hands-on, team-taught, project-based instruction. And their willingness to try new things and learn right along with their students provided good models of math and science education.

None of the three instructors were familiar with the Malabar Scrub Site before classes began. Their knowledge of the actual characteristics of the site was almost as limited as their students (they had only made one or two additional tours with the rest of the development team). The team relied heavily on three of the project's support personnel for guidance: the director of the environmental agency responsible for the reclamation and development of the site, and two Florida Tech graduate students working on masters degrees in

environmental education. These three provided the participants of the EMSSP with information, direction, and access.

The director spent many Saturdays at the site with the teachers, helping them discover the features of the site. She welcomed the teachers into the county project and encouraged them to become stewards of the site. Her knowledge and enthusiasm motivated everyone.

One of the graduate students, who had been an elementary school teacher herself prior to returning to college, served as day-to-day coordinator for the first semester of the project. She kept up with everyone's schedules, resources, paperwork, etc. In addition, she helped the instructional team better understand the elementary teachers' experiences and the researchers understand the dynamics of the project. She moved on to another research project after the first semester, but she was still available to the instructional team throughout the EMSSP.

The other graduate student served a plethora of roles. She was very familiar with the flora, fauna, and wildlife populations of the scrub site and shared her knowledge freely with the participants. She was the administrative assistant for the Center of Excellence, so she kept the teachers informed about available software. And she engaged the students in the development of the survey used during the EMSSP to assess the public's knowledge of environmental issues pertinent to the site (this was her masters degree project).

Each of these three people made a significant contribution to the success of the EMSSP. They provided the students and the teachers with guidance and support. Their involvement in the project gave the participants additional models for learning science and math, since each trip to the site brought shared discoveries.

The Students

Ten teams applied for participation in the EMSSP, and six teams were selected. The application explained the incentives of the program (12 free graduate credits, free books and software, etc.), required a team statement indicating their reasons for wanting to participate in the program, an explanation of the experience and special talents of the team members, and a letter of support from their school administrators. Selection was based on the teams' applications as well as their location and representativeness (one of the special focuses of the grant was inclusion of underrepresented teachers and students).

The six teams came from three counties. The combination of teams provided a very diverse student population. For example, one team was from a Catholic school; one from a school that relied heavily on technology for instruction, and one team was made up of teachers from three different schools, two of which were SSI lead teachers. The size of the teams ranged from two to five. The range of teaching experience was from 2 to 25 years. Grade levels ranged from first to sixth.

In the main, the teachers selected for the EMSSP were representative of the areas' elementary school teachers. There were 21 females and 2 males. Two of the teachers were African American and the rest were white. The project started with 24 teachers. One teacher dropped out after only three class sessions, due to time constraints, leaving one team with only two members. All of the other teachers completed the program.

Since the focus of this article is the instructors, more specific information about the student population has been omitted from this article. Another article is in preparation that specifically describes the elementary school teachers' development (Kelly-Benjamin, in preparation).

Results

Analysis of the changes in the instructors' levels of reflective teaching during the EMSSP were based on a model suggested by Grimmett, MacKinnon, Erikson, & Riecken (1990). They defined three perspectives for reflective teaching: (1) reflection as a mediation of action, (2) deliberation among competing views of teaching, and (3) reflection for reconstructing experience. These three stages are used to frame the results of this study.

Throughout the development, implementation, and evaluation of the EMSSP, the instructors discussed their interpretations of how the project would build upon the research we had studied. Their reflections, both written and oral, depicted their perspective on how the research could best be implemented. Much of their thinking fit the model Grimmett et al depicted.

Reflection as a Mediation of Action

At first, the instructional team was very much focused on "putting the research into practice." At this point in their development, they were primarily concerned with fitting the EMSSP into a theoretical framework of team teaching, constructivism, discovery learning, etc.

In the beginning of the EMSSP, I1 approached the task of teaching the EMSSP very analytically, like a math problem to be solved. She repeatedly tried to systematically figure out the steps to go through, how to sequence the steps, who would "cover" each step and how. She constructed many matrices to try to overlay the theory on the proposed practices. In the statement below she explained her thinking.

> During our planning sessions I can frequently remember thinking to myself, 'we can have them do X, some example within our framework, and then they can see how a concept applies.' In other words, the goal of the exercise was to learn by doing. This seems to me to be a more constructivist approach, using examples to help the student build structure.

> When we started planning EMSSP, I had in my mind a curriculum format that was largely traditional learning, only with a thematic approach to the curriculum design ... I talked about ideas and concepts that I wanted the teachers to learn couched in activities that the teachers found interesting. If we talked about discovering what concepts the teachers themselves wanted to learn, I either ignored it or twisted it around to my own frame of reference.

The team as a whole focused on activity lists, topics, skills, and accountability. For example, when setting the agenda for their next meeting, a memo directed members to "make a list of student activities for the first semester, list activity development, and then categorize them under specific, agreed upon headings." The memo went on to detail the list of criteria and headings, many of which were right out of the textbooks.

For the most part, the teachers began their teaching seemingly focused on coverage rather than restructuring. Rather than viewing the course as a new paradigm, the team kept trying to "add on" discovery tasks, constructivist activities, etc. This perspective of reflective teaching fits with Grimmett et al's model. The first level of reflection is often geared towards adoption with little questioning. Comments, from the three instructors illustrates the point.

> I1 - When the first semester started, as facilitators, I thought we were being flexible in planning the activities. But in retrospect, we were still very structured. ... I remember you getting on us about being too structured but it wasn't until the second semester that I saw your point.

> I2 - The semester went very well. We were able to introduce the teachers to a number of new ideas and concepts, or maybe more accurately, introduce them to new ways of looking at old concepts and knowledge.
>
> I3 - Discovery learning is very difficult for me to use. I am constantly fighting the urge to be in more control, although I have made some improvement. Once the students were off and running, as facilitator, I feel we probably spent more energy trying to define our new roles than in offering guidance to the various student teams. But this was part of the process and was rewarding in itself.

Deliberation Among Competing Views of Teaching

At this level of reflective teaching, one uses research to inform practice rather than direct it, realizing the gap that exists between theories and practice. Thought is given to how to bridge the gap and how to use the research findings to transform one's own practice.

I1, the team member with the most teaching experience, was the first to see the need to change her thinking. The other two seemed to struggle with the dilemma of coverage verses construction throughout the project. The teachers' statements illustrates the point.

> I3 -This program provided me with a fabulous opportunity to grow as a teacher, a member of an educational team, and as an individual. I learned that the most powerful and successful learning platforms that I have been exposed to is by far a hands-on, project-based, self-discovery environment that allows the maximum of control over the learning process to be in the hands of the student. This was not easy for me. I have always felt more comfortable in an educational environment where I was in control of the curriculum development and implementation. Couple this requirement, to transfer control to the students, with the need to share what is left with the other members of the facilitative team involved with the program, and I had a major adaptation to confront. But we succeeded.
>
> I2 - The concept of team teaching worked all right in this project, different points of view could contribute, but I'm not sure that it is necessary in the design. While there were many good points to

> it, sharing different views, sharing the load so to speak, each sharing a different expertise... conflicts as opposite views and philosophies of teaching were expressed. And some views can never be entirely smoothly melded. While team teaching is always a possibility, I think it would be possible for the course to be taught by a single person and still be successful, as long as all of the aspects of the sciences and math were addressed.
>
> I1 - When we first planned to have the teachers in teams, I saw it as a convenience. But from the beginning, it was interesting to note the interaction within the teams, the dominance of some members, the quiet determination of others, the expression of aversion to the idea of math and science or nature by still others. I could see that the personalities, attitudes, learning styles, and social interactions in turn affected the learning that occurred. As a result, different people learned different things within the same team and different teams learned different things.

Each of these comments emphasizes the difference in focus that the three team members developed. Even through they were working together to create the EMSSP, as illustrated above, the effects were not the same. Their reflections were often about totally different aspects of the program. While this expanded the total teaching/learning experience for the students, it was not always useful for the instructors. Sometimes they had difficulties trying to explain their thinking, other times they were able to make observations about each other and/or the students, but not about themselves. For example, I2 said, "All participants in this endeavor have learned exponentially and will continue to do so." However, she when asked to elaborate, we discovered she was not talking about herself.

Reconstructing Experience

Reflective teaching as a reconstructing experience places the teacher in the role of the researcher. At this level of reflection, a teacher is able to evaluate theory and experience to reform practice. They subject their own teaching to critical analysis, examining personal practices and beliefs. It is at this level that teachers can change what they do, since they are able to relate their behaviors to theories and outcomes. I1 illustrated this way of thinking in her final summary of the EMSSP.

> The first semester, within our guided framework, *we* let them make small discoveries; *we* had them identifying plants, *we* had

> them figure out, ... *we* had them measure ... . Then I learned that there's discovery learning as we did it in the first semester, and then there's DISCOVERY LEARNING like what occurred in the second semester.
>
> The second semester they went off on their own and worked on their projects. *They* decided what was important, *they* decided what problems needed solving, *they* found the solutions to their problems ... . The second part of the course is what the teachers will talk about forever. They made their projects part of themselves. They will relive it, tell stories, and relate it in a way that no traditional classroom could achieve.
>
> It was a foreshadowing when one teacher told me the best activity at the site on Saturday was when we had them go off on their own and just observe and think. No guidance from us, just on their own.

I1 clearly began to understand by end of the second semester how to play a different kind of "teacher role." She went from being the one who wanted everything specifically structured from the first day, to a teacher-researcher. Her instructional style changed from one of dissemination of knowledge to a model of exploration and learning.

Conclusions and Implications

On many levels the EMSSP can be viewed as a successful project. It opened up new areas of learning for at least 26 people (23 students and 3 instructors), provided an environment to experiment with learning and teaching, and put forth some evidence of the possibilities for new college level courses. But how likely is it that the structure of the EMSSP can be replicated?

Let's examine what we learned about the three Rs — real-life, resources, and reflective teaching. There is no doubt that at least some of the credit for this project goes to the selection of the Malabar Scrub Site as the outdoor classroom. The sanctuary, along with its staff, provided stimulation for all involved. Since the instructors and the elementary school teachers were all learning about the site together, good learning often took place serendipitously. Others looking to repeat the experience of the EMSSP could likely find a comparable project. The main components can be found in many community projects.

Having all resources available when needed was another contributing factor to the program's success. The people and materials that the grant provided left the participants less encumbered than is normally true. If they needed to consult with someone, buy a piece of software, or order a manual, they could. While we would wish this of all courses, we know that it is not often the case. However, we did find many people willing to give freely of themselves, especially when asked to teach about something they were interested in. In reality, the EMSSP had far more than three instructors, if you count the seventh graders who edited the video for their teachers, and the fathers who demonstrated the use of a CAD program. Other projects would likely find similar assistance.

The levels and styles of reflective teaching identified during the EMSSP provided useful information for others interested in pursuing similar projects. However, it is not only the specific changes that are of particular interest but the contributing factors. Consistently the teachers told us that time was the biggest factor. No matter how many times they heard or read about reforming teaching, it was only after protracted exploration that at least one of the instructors were able to understand what it means to "learn by making meaning." And some of their insights came from watching their students go through a similar struggle to manage their own learning.

One of the elementary school teachers summarized the EMSSP very well. She said,

> I would recommend this program to other teachers, but with the caveat that they should be prepared to work very hard for close to a year. It is a big commitment and should be entered into with full knowledge that this is not a frivolous Saturday course, but one that will challenge you like few others and reap an untold number of rewards.

From a research perspective, we learned that current theories of instruction can be adopted by teachers at any level. We also learned that the problems are virtually the same. Constructing knowledge, whether its knowledge of science, mathematics, or teaching, requires guidance, time for reflection, and empowerment. As illustrated in the above quotes, the EMSSP teachers struggled with change, working through at least some of the stages of reflective practice. The students did likewise. The three Rs made the journey doable and interesting but never easy.

Recommendations

One of this article's reviewer asked some questions related to the pragmatic value of the EMSSP. These questions provided an excellent way to make some recommendations for others who may be thinking about creating a similar program. Each question is addressed below.

"*Why should the reader go through all the trouble to select a site, plan team teach, etc. if they can achieve the same goals in a 'regular' methods course*?"

The EMSSP was designed to be a methods course for the college instructors and a content course for the elementary school teachers (although I do not think the two are easily seperated). We specifically wanted to test the application of constructivist theory to the practice of teaching. As such, we defined the goals of the course to provide the teachers with opportunities to explore ways to reconstruct their views and knowledge about teaching and learning science and mathematics. "Methods" activities were designed to help them examine their views and beliefs and develop their facility with guiding learning. The selection, planning, etc. was the result of the process we went through as we constructed a shared vision for the exploration of the Malabar Scrub Site.

This is a different approach from the traditional methods course. The goals are different. In my experience, the "regular" methods course offers opportunities to practice teaching and evaluating a variety of topics using a variety of instructional methods. The syllabus is planned by the instructor and the bulk of the course takes place in a college classroom, rather than in actual classroom situations. As the instructors, our focus is to get students to understand how we think, rather than trying to understand how they think about teaching (Chambers, 1993).

I do not mean to suggest that the two are mutually exclusive. I believe constructivist activities can be built into a regular methods course. Projects that help the student-teachers and their instructors can be done on a smaller scale. The scale is not as important as the process of exploring one's knowledge and beliefs. But be warned! Projects that promote construction of knowledge do not fit neatly into one's syllabus—they grow in all directions, take blind turns, create frustrations and uncertainty.

"What makes this program worth the extra effort?"

Learning together was the primary benefit of this course. The collaborative model allowed everyone to contribute and gain new knowledge. The instructors, because they were willing to take the risks and make the commitment to the project, learned more about themselves as teachers then they would have in a more traditional situation. The students willingly shared their expertise with the instructors. The instructors, relieved of the responsibility of imparting knowledge, learned as much or more than their students. For the most part, the extra effort involved accepting change (i.e., giving up control, letting learning happen, working as a team, etc.).

"Are the benefits worth the cost?"

My answer to this question is a question — can we afford to keep losing students to higher level math and science? There is no short cut to reforming our instructional approaches. Teachers need time and support to grow and become confident in their knowledge of science and mathematics.

Short-term, the EMSSP helped at least 26 teachers reform their practice by helping them construct knowledge of mathematics and science. Long-term, the benefits to their students can make programs like the EMSSP very cost effective. We saw evidence even during the first semester that the teachers were involving their students in their projects. Future involvement with the Malabar Scrub Site will further insure opportunities for the teachers and their students to explore real-life math and science.

"Are there components of the course which cannot be replicated in the college classroom?"

The process for developing a situation that encouraged the construction of knowledge was the primary component of the EMSSP that others would find useful. Therefore, I think as long as the activity that facilitates exploration is meaningful to all involved, the process could be replicated in any learning situation. An important point to remember, however, is that the instructor should ideally be one of the learners.

"If the instructor does not have the advantage of adequate funding to support this type of project, what could be done to replicate it on a small scale?"

Funding is always an issue, whether it be for the extra instructor needed for the instructional team, or the budget needed for the resources. Funding

buys you time, our most precious commodity. It is definitely easier with funding! However, it can be done without it.

For example, let the course participants identify local projects and resources that fit the parameters of the area of interest (e.g., learning science and math). Take advantage of "non-traditional" teachers. Negotiate for other resources, e.g., free credits, in-service points. Charge all participants with the responsibility for teaching and learning. Engage everyone in the teaching process.

In summary, the questions above reflected many of the concerns we had when we began the EMSSP. They relate to the issue of change. They were impossible to answer before the courses. Now they are not difficult to answer, but perhaps impossible to explain to the uninitiated. The answers rely on a different frame of reference, comparing traditional to contemporary. They reflect a shift in our educational paradigm.

The final recommendation of the EMSSP takes us back to where we started. It is time to practice what we preach. What generalizes to other projects is the process not necessarily the content. The EMSSP changed everyone's perspective of mathematics and science. Our work verified the research about constructivism — good learners make good teachers — and reflective practioners make good learners.

Notes

[1] A detailed curriculum and samples of the students' projects are available from the author.

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