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ABSTRACT

Teams of teachers from four middle/junior high schools, in collaboration with faculty from the University of New Hampshire and consultants from the New Hampshire State Department of Education, implemented systemic changes in the teaching of mathematics and science. The curriculum goal was to design, adapt, implement, and evaluate hands-on, inquiry-oriented integrated mathematics and science units. Adolescents, teachers, professors, alternative assessments, national standards, and integrated curricula were wound together in a collaborative approach. This paper describes project expectations, changes brought about by the project, the project's basis in constructivist pedagogy, redefinition of participants' roles, teacher empowerment, student empowerment, conditions of change, recognition of growth and change, the community of learners, and the products of change. (Contains 17 references.) (JDD)

Saturday
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55.03 Roundtable #21
Curriculum Research by School and University Collaborators
1:15 - 1:55 Hilton, Plaza Ballroom, Lobby Level

Integrating Mathematics and Science at the Middle/Junior High School Level Using Collaborative Action Research

The Voices of Teacher-Directed Change

A presentation to the 1995 American Educational Research Association

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University of New Hampshire

Brad Gregg, Deborah LaChance, Diane Moreau and Bruce Turnquist
Teachers in Dover, Rochester, Exeter and Deerfield, NH

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The purpose of this paper is to document the people, processes and products that encouraged teacher growth and reflection leading to change within the context of mathematics and science classrooms at four middle/ junior high schools.

Overview of the Mathematics and Science Collaborative

The current study, A Middle School Mathematics and Science Collaborative (MSC), was planned by teams of teachers from four middle/ junior high schools in collaboration with faculty from the University of New Hampshire and consultants from the New Hampshire State Department of Education. Funding for the project was provided by the National Science Foundation.

Goals

The Goals of the collaboration are to introduce and implement systemic changes in the teaching of mathematics and science at the four schools and the university. Teachers participating in this collaborative come from schools that differ in terms of their patterns of staffing, management approaches, philosophies, and grade-level configurations. The university faculty in the collaborative represent a cross section of the departments of education, the sciences, and mathematics. The study is based on the belief that collaboration of school and university educators provides a curriculum change framework utilizing the unique skills and insights of each participant in moving toward a common goal. The common curriculum goal, in the case of this study, was to design, adapt, implement, and evaluate hands-on, inquiry oriented, integrated mathematics and science units.

A larger goal of the project is to empower middle school science and mathematics teachers to challenge the status quo by developing new reform-based curricula designed to stimulate their students to attain an accurate, sustained, and applied understanding of basic concepts in the sciences and in mathematics while having fun. A further goal is that teachers at the four New Hampshire sites become participants in a school-university collaborative effort to substantially change their own practices and existing structures within their schools. A working collaborative association with shared goals among veteran teachers, novice teachers and university faculty in science, mathematics, and teacher education is leading to long-term change in teachers' perceived status and children's knowledge levels and interest in mathematics and science.

Collaborative Action Research

Research Issues

Research in and on the Mathematics and Science Collaborative is based on the following project expectations:

- development of new or newly-adapted curriculum materials
- constructivist-oriented changes in teaching approaches
- increase in activity-based learning environments
- change in participants' beliefs
- improved knowledge and application of mathematics and science reform efforts
- new approaches to work
- reformulation of school structures
- new roles for university collaborators
- adoption of action research roles by teachers and university faculty.

Sources of Data

Sources of data include classroom lesson observations recorded using both narrative formats and time-sampling techniques; curriculum action research plans and revisions; student work; student evaluations of teaching techniques

and lessons; curriculum reviews by mathematics and science content experts and by peers; interviews of participants (teachers, administrators, university faculty, students); journal entries; and documentation of meetings among various constituents. Data from these sources are being analyzed using both qualitative and quantitative methods. Results culled from the data will guide the next cycles of action research which are focused on curriculum development and "packaging" of products and on institutionalization of new instructional practices influencing individual and systemic change.

Teachers in the Midst of Change

Actions of Change

Preliminary data analyses indicate that the Mathematics and Science Collaborative has provided an environment which has contributed to many changes in the ways teachers, students, university site facilitators and education in general are viewed. Listed below are some of the changes that have been observed and documented.

- Priorities have shifted away from specific subject-based concerns to a holistic view of a child's educational experiences.
- Recent reform efforts were investigated and brought to bear on activities and curricula.
- The classroom door has opened to allow observers to see the processes that are going on. Teachers collaborate with others, plan, observe, and teach together to improve their practice.
- Students are assisted in acquiring accurate understandings of their world with numerous, varied opportunities to apply that understanding.
- Mathematics and science education are seen as complementary, each benefiting from and strengthening the other.
- Teachers have become reflective professional learners. They see themselves learning from each other and from their students as well as from "experts."
- Teachers have become facilitators rather than directors of learning. Students have become more active learners. Both have developed new views of themselves.

- New approaches are being tried out. Failure is viewed as part of a process leading to success. Revision and reform have become standard procedures.
- New structures are being formed in the schools to facilitate mathematics and science teachers' working together.
- New approaches have been extended to teachers beyond those in the MSC collaborative, and, in some cases, to the local community.
- Teachers actively seek and participate in appropriate staff development forums.
- University faculty serve as resources and facilitators, responding to needs raised by teachers rather than providing them with a predetermined curriculum.

These changes have occurred as the result of an approach that provides the time, the tools and the support for teachers to become researchers within their classrooms, their subject areas, and their schools.

Starting Point for Change

The starting point for much of the change that has occurred within this project was a review of the national reports focusing on the reform of science and mathematics education. The American Association for the Advancement of Science reports, Science for All Americans (1989) and Benchmarks for Scientific Literacy (1993), the National Science Teachers Association's, Scope Sequence and Coordination and the National Research Council's, National Science Education Standards (1994) provided the impetus for reformulating the content of science to emphasize concepts over facts, constructivist teaching approaches, and alternative assessments of student achievement. The National Council of Teachers of Mathematics reports, Curriculum and Evaluation Standards for School Mathematics (1989) and Professional Standards for Teaching Mathematics (1992) highlight a restructured view of mathematics education, changing the focus from acquisition of isolated skills to a deep understanding of mathematical concepts and their application in a variety of areas such as problem solving, data analysis and display, etc. These documents recommend hands-on, process-oriented teaching approaches, but not at the expense of content acquisition. Authentic, embedded performance-based assessment is a logical evaluative extension.

The MSC teachers reviewed these works from the perspective of their own teaching and their students' learning. They understood the overall "messages" of the standards and, together, began to develop lesson plans and curricula that reflected the standards. Teachers became critical observers and adapters. As one teacher put it: "Given all the recent research on education, what can I do or implement to make education more effective? What do these studies say about education in *my* classroom?"

Collaborative Process

The MSC collaborative is based in constructivist pedagogy. Teachers' viewpoints and their knowledge bases provide the foundation upon which the program is built. University site coordinators serve as facilitators for the school sites, participating as "resources" in the school site team meetings, not as "directors." The teachers themselves determine the direction of the project, guided by parameters and goals established in the initial proposal. The approach reflects advice proffered by Sarason in *The Case for Change* (1993) in which he highlights the importance of the scientific learned societies taking control of reform in science education in ways that speak to teachers. At the same time, he highlights the importance of students and teachers becoming collaborative discoverers of knowledge who become invested in their own learning. Teachers in the MSC collaborative have drawn on the reform recommendations to inform themselves about what is possible. At the same time, they have carefully considered their own school and classroom contexts in deciding what they needed from the project. These dual perspectives are apparent in the summer institute planning process and in the academic year work. The three-week summer institutes for the last two years have focused on mathematics and science content in the context of teacher-raised issues such as integrated studies and alternative assessments. The planning process involved a "give-and-take" among university faculty, whose expertise was mainly in science and mathematics content, and teachers, who were concerned with real-world translations. Participants from both groups had to redefine assumptions and priorities, then move toward a common goal. During the ensuing academic years, there has been ongoing collaboration with university faculty and consultants and among participants within and across the four

schools. Topics such as "how to build a teaching team," and "how to evaluate a curriculum plan" are examples of collaborative problem-solving.

The program's summer and school-year components have been successful largely because teachers were given the resources to address concerns arising within their own classrooms and students. We believe that for meaningful change to come about in schools, teachers must be given the tools and time needed to address the concerns that have meaning for them and their students. Teachers are in the foreground of the educational pursuit. Collaborative action, based upon sound research, leads to effective reform.

The original timeline and framework of the project were modified to meet the needs of the teachers. University faculty became instrumental in communicating teachers' needs to all participants, providing requested resources and information, and facilitating collaborative problem-solving. The consensus-building behavior modeled by project collaborators reinforced for the teachers the importance of being able to remain flexible, build consensus in their school site teams, and take the role of learners. The design of the summer institutes that offered choice amidst the overall common goals was a model that the MSC site teams could implement to achieve similar educational goals with their pupils. A spirit of "We are learning together," became apparent.

Re-definition of Roles

Changes in each participant's beliefs and actions are based on his or her personal experience of collaboration within the project. In several of these experiences, traditional role boundaries of student, teacher, and university professor were blurred. Teachers often described themselves as students or learners, both during the summer experiences and in their own classrooms during the academic year. As these roles were recast, one teacher compared her sensitivity to students to a newly understood "adult sensitivity" required when trying to extend classroom reform efforts to teachers not originally involved in the collaborative:

> We were always making adjustments for individual learning styles [of pupils] and unfortunately we hadn't made any adjustments for individual teaching styles.

Another teacher describes a new empathy for her students, gained as a result of her own experience as a learner:

> I run my classroom in a group setting, and I don't think I ever fully understood how some kids really felt sitting in a group setting when they couldn't accomplish a task until I got involved with this project and actually had to work with five other people. I think that some valuable lessons have been learned [among the teachers].

One university faculty member who is an expert in curriculum development described a readjustment of his usual consultant role to that of "listener" and "reinforcer." He found that teachers who had already invested much time and energy in developing a particular curriculum framework sought his support and gentle guidance regarding new adaptations rather than his expert opinion on curriculum planning and development.

Teacher Empowerment

Teachers involved in the collaborative now find themselves responsible for more than one group of students in one subject area. Teachers are connecting with each other and becoming more involved in the issues that they and their schools face. The teachers see themselves as having more of a stake. They no longer look at things as, "Well, there's nothing that I can do about it anyway." Instead they have begun to see that they have a voice, that they have important contributions to make to the school, and it matters to them what happens.

> I guess because we don't seem to have much direction from the administration and we haven't sometimes self-directed ourselves, we have all kinds of conflicts. The assistant principal couldn't seem to schedule back-to-back classes or common students. So we worked through that. You find a way to get around that.

Teachers feel empowered by the group and by their successes. They also are aware of the tensions empowerment and success can create.

> ...now we've got a movement toward these directions in school that's a grassroots movement. Not just this group of teachers (but) other teachers in the building too. But there's been a strain because of success in the things that have happened, for this movement seems to be having an effect on administration in terms of restructuring. I mean, how far that's actually going remains to be seen.

One teacher credits the "Change Game," a school change simulation in which teachers and university faculty adopt various roles, with helping her see that individuals and schools could be at different stages, but that they were all in the midst of change.

Student Empowerment

Students are reaping the benefits of teachers who are empowered to change and bring about change. Students see the cooperative challenge that their instructors provide. They know that the textbook is no longer the only guiding principle in the class; they know that there is something more going on. Each student is involved in his or her learning and the learning of others. For example, students at one site completed an interdisciplinary activity involving a "scientific census" of a forest plot and an aesthetic journal-writing exercise. The science teacher, who describes himself as "not very aesthetic," reports a change in students' behavior and his own reaction to it:

> I had a dozen kids, at least, say: "Could you please save me some time before we leave...I haven't finished my English activity yet." I've been teaching in that school going on 25 years, and I have never had a student ask me if they could have science time to do any activity never mind English!

Success stories are being shared. Teachers are empowering students. Students are empowering teachers.

> I mean we have the gamut of kids and to see them gel as a group has been amazing. We had a student, on his own, write a grant to the United States Department of Agriculture. He brought it in. I said, "Go for it." We

> got a notice yesterday that said we got $300 from the USDA for the proposal. Unbelievable!

Conditions of Change.

What factors contribute to teachers feeling that they are influencing and directing the change that is occurring around them?

Our data support findings by others such as Barth, Moore Johnson, Fullan, Sarason and others in identifying the elements needed for teachers to become agents of change. Common elements include: recognition and acceptance of the challenge; energy; confidence in oneself and the group; support; time; self-efficacy; "having a stake" in the process and outcomes; openness to new ideas and research; willingness to take a risk; willingness to fail; willingness and ability to revise; and the ability to recognize and celebrate failures and successes. These elements are in common with those described by Moore Johnson (1990) as necessary for a successful "teachers' workplace."

Educational change also forces a reordering of priorities and a translation of those priorities into action. In the Mathematics and Science Collaborative, the investigation of change itself has become a priority. Each participant, for example, is being challenged by this project to investigate new curricula and new teaching approaches. Whether creating an interdisciplinary unit on Orienteering, or incorporating new techniques for the use of manipulatives, teachers have a personal and collective investment in the creation of better programs for their students.

> We are putting a tremendous amount, a lot, of personal energy into this project, and have been for a long time. It takes so much wind out of you. You know you got to have time for family, for going to the bathroom, and eating and stuff like that.

Recognition of Growth and Change

The benefits to the teachers of becoming chroniclers and researchers within their own classrooms as change takes place becomes clearer over time. Continuing collaboration and ongoing feedback based on MSC data collection has had a positive effect on teacher growth and on teachers' interest in continuing to grow. As one teacher said:

> ...we didn't see the change, I think, until other people started to tell us that they saw significant differences in the product that the students were producing.

A continuum from initial skepticism to action and risk-taking, to a sense of self-efficacy arose over time. As one spokesperson summed it up after reviewing data collected among participants at her school:

> If you look in the journals it is conflict, controversy, its -- you know --What are we doing here? What are we going to do? So here's Year One. Year Two is becoming like this: ...last night we had our science/math fair and some wonderful things came out, and we had a meeting where we were discussing the science math fair. Not all the teams were there. I go, 'okay, 8 out of 11 are doing it. That's good. That's good stuff taking place'...the quality of the display was much better than in the past...And what can we do better? Year Three we are looking at huger goals.

The process of moving along this continuum comes about through teachers feeling that they have ownership of the change, that change is not something that is happening to them but instead is something that is happening *because* of them. It then follows that teachers are also willing to assume the risks associated with change. They are able to move from a limited view of education and their teaching to a more encompassing view that encourages reflection, questioning and inquiry. Teachers thus empowered through belief and action are more likely to be effective in institutionalizing change. Their new approaches become an integral part of the way a school functions.

The heart of this matter is the teacher's self concept and sense of efficacy. How does the teacher see herself in the classroom? in the school setting? Does the teacher feel as if she is effective and successful or does she feel that behind every door is another person ready to challenge her position and criticize her actions? Are the students viewed as passive absorbers of knowledge or are

they seen as questing for an understanding of the world around them? Is the teacher a learner practicing the tools of the trade and refining his talents along the way or is the teacher a person who requires the student to do exercises that the teacher would not do himself? Recognition by teachers of changes in beliefs and actions is an area for further investigation in this study.

The MSC Community of Learners

The MSC program has been successful due, in part, to the fact that a community of learners has been established. All members of the collaborative are learning from each other. No one person is considered an expert in everything. Each person has valuable contributions to make to the education of the community. A climate has been established that allows teachers and university professors to engage in the examination of education at the four schools in a manner that is encouraging and reflective, not threatening or intrusive.

> I found that the biggest key to this project is that we have been put into the role of learners. And we are saying, "We don't know. We've never done it this way before."

The community of learners removes an individual teacher or a team of teachers from the feeling that they are the only ones experiencing difficulty.

> These other people have felt the same things and that to me has been important because sometimes I feel as if I am out in left field. I feel as if I am there by myself, you know? But it is nice to hear that other people are having the same kind of struggles.

Products of Change

One of the driving forces for effective change is the achievement of meaningful products. The development of these products and the reflection upon them allows teachers to see the growth and change that has occurred within their program or sphere of influence. This recognition of outward change can lead to an individual's personal understanding of the change that has taken place

within herself. Participants are able to take credit for their investment in the program that led to the change that they are seeing.

Student products are particularly important to teachers because they are the literal, tangible translations of teaching in which students and teachers alike can take pride. This product-oriented aspect of teacher research and change is rewarding because the teacher is able to stand back and see the growth that has been brought about by the innovations implemented. The teacher is often able to accept the second-hand praise of a product more easily than direct praise of teaching from an administrator, colleague, or parent.

> We found that there were phenomenal differences in the quality of student work during the science fair as indicated by the people that came in and judged our science fair. It was a graphing activity that carried over into the science classroom. Where they (the students) then looked at these same graphs and said, "How could this fit my data or my working with things?" So that was real helpful.

Another product of change are the teacher-created portfolios from participants at each school site. The purpose of the portfolios was left up to the discretion of the teachers at each site. The process of the portfolio development was, in many ways, more important than the final products. In reviewing journal entries, minutes of meetings, student work, etc. in order to develop the portfolio, teachers became reflective and more cognizant of change.

> I think we were so involved we didn't see the change until we looked back.

> I think all of us have changed. I think if we -- if everyone -- went back and read things that we had written before compared to what we write now, I think that we would all see vast differences.

> I mean working on this portfolio has made me feel good about what we are doing in our school and what we are doing with this project.

The positive reflective benefits of the portfolio development process will continue to have lasting effects on the teachers and their programs. As they

understand better the role that this process has played for them, they will be able to more quickly grasp the intricacies of making this process work for their students. The community of learners begins to encompass the entire school. The application of these concepts is just beginning as a result of the MSC project.

Conclusion

Adolescents, teachers, professors, alternative assessments, national standards, integrated curricula, are wound together in a collaborative approach that enables participants to see their connections to substantive changes that have occurred in a variety of areas. Full implementation and institutionalization of these changes will take time, but the high level of commitment among participants is a key factor for future success. The formula used by the Mathematics and Science Collaborative to bring about change is a process in itself that has changed over the course of the project to better serve the needs of the participants. The direction was determined by consensus as a community of learners. The information was attained, approached, reflected upon, and re-defined as a community of learners, each individual contributing his or her particular expertise. The shared goal was to improve mathematics and science education. Products reflecting success have been developed, reviewed, revised, and implemented. Continued success requires a flexible adaptation of the collaborative model which positively influences the workplace of teachers and enhances their sense of self-efficacy. One participant's comment encompasses those of many and bodes well for the future.

> "I am a firm believer now that if you want to do something, you can do it."

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