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Integrating Math and Science Instruction: Developmental Considerations

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ABSTRACT:

A relatively simple request of my preservice elementary methods students to integrate their science and mathematics instructional design tasks evoked an enormous range of strategies, images, frustrations and discussion in my class. Clearly I had touched a sensitive chord. Such passion undoubtedly has foundational roots, but these students were not articulating the causes for these effects, nor could they address the praxis, or the theoretical foundations for their practice. My study looks at the issues of integration between mathematics and science education. I then review the images and justifications for integration put forth by preservice teachers in light of these foundational issues. I end with inferences about the diversity of schema represented by this data and suggestions for a constructivist response in my elementary science and mathematics methods courses.

INTRODUCTION:

The commonalities between scientific and mathematical thought are thoroughly acknowledged in the literature. Both mathematics and science educational reform movements promote the building of connections across the disciplines.

> The alliance between science and mathematics has a long history, dating back centuries. Science provides mathematics with interesting problems to investigate, and mathematics provides science with powerful tools to use in analyzing data. ... they are part of the same endeavor (F.J. Rutherford & A. Ahlgren, 1990, pp.16-17).

> Since mathematics is both the language of science and a science of patterns, the special links between mathematics and science are far more than just those between theory and applications. ... Firmer school ties between science and mathematics should especially help student's grasp of both fields (National Research Council, 1990).

> ...since so much mathematics developed in response to scientific questions, and since science is completely dependent upon mathematics throughout (Tinker, 1991 Fall).

Many other authors list common skills, concepts, and strategies among both disciplines (Gallagher, 1979; Berlin & White, 1991; House, 1990; Kuobaa, 1989). Still, arguments regarding integration continue.

At issue in this paper is not the question of whether or not the instruction of science and mathematics should be integrated, nor is it intended to propose a judgment on the relative value of different approaches to integration. Rather, I attempt to refine my sensitivity to the schema of integration that preservice teachers bring to my methods courses. With this knowledge I hope to better address their needs as they continue to construct functional schema to inform their practice.

OVERVIEW OF ISSUES AND ARGUMENTS IN INTEGRATED SCIENCE AND MATHEMATICS INSTRUCTION

Brown (1977) proposes a classification system of arguments for an integrated science curriculum that applies equally to the issues of science and mathematics integration. Her system divides the arguments into: (a) outcomes demanded by society, (b) resource constraints, (c) political constraints, (d) conditions for effective learning, (e) conditions for effective teaching, and (f) constraints imposed by the subjects. A look at her reasoning and more recent arguments from this perspective has helped me to frame the historical, theoretical, and philosophical factors that might be driving the beliefs and practices of my preservice teachers.

A) Outcomes demanded by society

Brown (1977) points out that our increasing reliance upon technology requires that we not only provide trained scientists, but also a political leadership and a general public informed on scientific matters (p.43). Howson and Kahane suggest that mathematics instruction serves four purposes: The mathematics needed for everyday life, the mathematics needed for intelligent citizenship, the mathematics needed for your vocation or profession, and mathematics as a part of total human culture (Howson & Kahane, 1988). Similar assessments have been made among science educators (Rutherford & Ahlgren, 1990). We often find, however, that the driving force of instructional choices in the two disciplines is the teaching of those skills and concepts that will be immediately usable by the students in their current studies.

Instructional decisions require that we consider not only the knowledge (skills and concepts) our students should acquire, but also modes of thought and the ability to recognize whether a question is capable of being modeled, or being treated mathematically (Howson & Kahane, 1988). Howson insists that computers now allow the general population to manipulate mathematical concepts without the gatekeeping effect of calculation skills, so conceptual understandings should become more widespread in the disciplines. Some common mathematical modes of thought deemed important for citizenry and applications in the sciences include "the ability to reason from data, to handle probabilistic situations, to plan and optimize and to understand something of modeling; to a lesser extent, to think algorithmically, and discretely as well" (Howson & Kahane, 1988, p.34).

Howson and Kahane provide an excellent example of the level of knowledge that professionals might need:

> ...in the course of his [sic] professional life an engineer will rarely have to solve a mathematical problem, but he will frequently have to recognize whether a question confronting him is capable, or not, of being modeled, of being treated mathematically. As in any other science, the important thing for him is to know enough mathematics to be able to consult a mathematician and to derive the most benefit from this. The consequence of this is that in the choice of subjects to be taught one must think not only of mathematical modes of thought but of the large range of knowledge required to permit a professional to know what might be mathematically tractable (Howson & Kahane, 1988).

(B) Resource constraints

Arguments regarding resource constraints tend to focus on time, curriculum resource materials, and successful teachers modeling effective practices. A large number of curriculum projects provide models for integration, suggesting more widespread acceptance of the validity of integration. Brown (1977), Blum & Niss (1991) and Berlin (1991) provide a thorough list of these projects. The time issues include concerns that integrated courses might result in disparate groups of students requiring the same resources at the same time in a limited school setting, or alternatively, that integration can provide a way of avoiding unnecessary duplication of learning experiences that are common to the various disciplines (Brown, 1977, p. 47). Blum and Niss (1991) report that many mathematics educators express concerns that integrating mathematics and science would require forcing the science into what they perceive as an already crowded curriculum.

(C) Political constraints

The political constraints are especially difficult to separate from other categories. Authority structures within educational institutions (departments and their department heads, centralized assessment systems) interfere with integrative attempts. The purposes of schooling are also of a political origin and relate to the question of whose culture will be transmitted. Both of these issues are also a result of isolationist pressures as discussed in Section F (Constraints imposed by the subject).

(D) Conditions for effective learning

Pedagogical arguments for integrated science and mathematics instruction range from motivational (students will find it easier to attend to the instruction and will therefore be more likely to master the concepts) to applicational (learning how to call upon the concepts and skills of both disciplines in context better prepares students to carry out these processes in the real world).

Traditionally, mathematical educators have included applications at the end of otherwise purist lessons (adding application questions at the end of math lessons, or vise-versa) for a number of pedagogical reasons: developing creative and problem solving capacities using math (suggesting that this might not follow from mastering pure mathematics but requires some degree of preparation and training); preparing students to recognize, understand, analyze, and assess math applications that suggest solutions to socially significant problems; to establish a rich picture of mathematics as a science and as a field of activity in society and culture; and that these applications assist students in acquiring, learning and keeping mathematical concepts and methods (Blum & Niss, 1991).

Concerns exist about the gatekeeping effects of integrational issues. Some claim that the new approaches to science education have provided new avenues of mathematical applications for children (now relying on less demanding mathematical theory and skills). For example, the heavier emphasis on inquiry approaches in which students investigate personal hypotheses activates math in ways that are more easily accessible to the majority of students. On the other side of this argument are those that warn that routine math tasks such as calculations are more predictable for students (especially during testing) and less demanding than the cognitive processes required of integrated demands. Therefore integration might actually create more barriers for full public education (Blum & Niss, 1991).

Cultural transmission arguments, which also play a large role in gatekeeping effects, will be discussed in Section F (Constraints imposed by the subject).

(E) Conditions for effective teaching

Brown (1977) refers to the "hostile attitudes of teachers who have specialised training in separate science subjects" (p.55) and also the reports of some teachers that integrated teaching rewards their broader interests. It is interesting to note that in one study "practicing science teachers indicated they taught topics in an integrated fashion significantly more often than did the practicing mathematics teachers" (Lehman & McDonald, 1988, p.647). This suggests greater comfort with the issues among science educators. (However, those authors contend that science teachers' perceptions that they integrate might not be a reliable indicator that they actually provide effective instruction for both disciplines.)

(F) Constraints imposed by the subjects

Are science and mathematics indeed separate disciplines or are they unified? Taylor traces the historical precedents for unity and isolation between the two disciplines. In summary, he describes how Euclidean geometry developed as an ally to the developing Newtonian model of the physical universe. The unity and apparent certainty of scientific and mathematical thought resulted in a belief that they were uncovering the given laws of the universe. The advent of non-Euclidean geometries resulted in a separation of the two disciplines. Mathematics was now used to explain the physical phenomena (in contrast to revealing the unity of the two disciplines in the eyes of God). Math then began its development as a means for logical reasoning, completely separable from the context of science (P.C.S. Taylor, personal communication, July 5, 1993).

Regardless of the cause, the two disciplines have now evolved with important historical, philosophical, and methodological differences. Some claim that integration would distort the clarity and aesthetic purity of both disciplines. When one discipline is used as the organizing framework for instruction, the other often is de-emphasized or distorted to an unacceptable degree. (Blum and Niss, 1991).

Others emphasize that although the disciplines might remain separate, they share common skills. Gallagher categorizes the basic skills common to both disciplines as: reading prose, acquiring information, interpreting information, going beyond information, and problem solving (Gallagher, 1979, p.558). More recently, science educators have emphasized the development of process skills which are either indistinguishable from mathematical skills or require mathematical reasoning (measurement, classification, graphing, analyzing and interpreting data, identifying variables). Many acknowledge that scientific concepts are entirely dependent upon such mathematical relationships such as proportional reasoning, exponential growth and understandings of rate. Indeed, the major curriculum reform efforts in the United States promote the unified nature of the two fields as reflected in the initial quotations of this paper.

Some consider the two disciplines as separate, with mathematics acting as a tool in service to other disciplines. Howson and Kahane (1988) investigate the reactions of educators to the notion of mathematics as a service subject.

> It is a striking fact that non-mathematicians - even more than most mathematicians - insist on the power and value of a mathematical mode of thought.... Let us mention, however, the reservation expressed by Tonnelat: 'Mathematical thinking is a good servant, but a bad master'...(Howson & Kahane, 1988, p.9).

These statements perhaps expose a relative imbalance in the appreciation of mathematics as a service subject, with more mathematicians focusing on their discipline as something to aspire to with a clean academic agenda (or decontextualized).

Related to the topic of unification among the disciplines is our awareness of diverse ways of knowing in science and mathematics. The issue of hegemony is deeply interwoven into the curriculum decisionmaking process, authoritative structures in schools, and definitions of disciplinary boundaries. Our choice of starting points for instruction (integrated or pure?) and the respect we pay towards the historical antecedents of the disciplines partially answer the question of "Whose culture are we transmitting through our instruction?" We can look at several incidences in which mathematics and scientific thought emerged as a unified subject (Newtonian physical laws of the universe and Euclidean geometry; indigenous peoples' development of mathematical processes to assist them in making sense of and utilizing their natural environment) and see instances where the two disciplines were developed socially as constructs to explain natural phenomena. If we later look upon the way these revelations are taught, they are transmitted as given truths, not as processes for developing shared meanings. This subtle shift in interpretation can lead to a profound difference in the implied purpose of schooling. Students take away one of two messages: 1) mathematics and science are powerful tools that I must master in order to join the dominant power structure, or 2) I use and develop mathematical and scientific reasonings in many forms in order to explain the universe to my satisfaction. My discoveries are of value to myself and possibly to others (including those in the dominant power positions). Consequently, whether or not a teacher integrates the disciplines, how s/he chooses to integrate, and his or her beliefs about the nature of the disciplines create a hidden message for students about the accessibility of these disciplines as tools for different cultures (gatekeeping issues).

On a different note, Kuobaa points out that although the language of science and mathematics includes common terms, the rigorous interpretation and application of those terms is indeed very different. For instance, mathematicians consider a "constant" a term which includes no variables, while scientists prefer to think of holding some variables constant as they manipulate others. She provides an interesting list of terms that should be considered as educators combine the language of the two disciplines (Kuobaa, 1989).

(G) Other issues

Although they are most certainly permanent features of modern classrooms, computer use still generates controversy in education. Support for computer usage is strong:

> MBL (microcomputer based lab) interfaces..."can be used for computations and data analysis, allowing students to be theorists,, and to move between theory-building and experimenting with ease. In such situations, there is no distinction between mathematics and science"(Tinker, 1991 Fall, p.22).

> ...technology can blast through the barrier between science and mathematics...This technology will cause us to rethink our pedagogy (Berger in Berlin & White, 1991, p.6).

> New possibilities: the use of the computer allows one to illustrate concepts and methods, to experiment, to assist memory and replace technical virtuosity, to adapt learning to the potential and rhythm of an individual student (Howson & Kahane, 1988).

Mathematics integration/modeling is dependent upon computers and computer skills as computers now allow access to mathematical thought without the gatekeeping of computation (Stella, Logo, statistical and graphing packages). However, some still tout the dangers of the emphasis on computers and modeling:

> ... arithmetic and geometry skills may atrophy; the devaluation of routine skills ... will make mathematics instruction more demanding for all students and too demanding for some of them; software packages emphasize recipe-like modeling and reduce critical analysis; computers deter some students and teachers from the mathematical problems to the technological problems (which would not exist without computers) (Blum & Niss, 1991).

SUMMARY OF THE ISSUES FROM A TEACHER'S PERSPECTIVE

The above summary of the issues in integration highlight several points that might affect teachers' decisions on integrated instructional planning:

A) To what end are they addressing instruction: the creation of scientists and mathematicians, policy makers, or informed publics? Should instruction shift from teaching skills towards helping students to manipulate and understand the concepts?

B) Will the schools support a shift to integrated instruction with materials and time?

C) Will the institutional structure accommodate integration (in terms of organization, power, and assessment)?

D) Are they attending to gatekeeping issues for their students?

E) Have they been exposed to effective examples of integration to facilitate this new instructional style? Do they feel competent to address both mathematics and science simultaneously?

F) Is there a body of knowledge that they need to transmit? Do the disciplines require similar or complimentary modes of thought? Is it appropriate to think of mathematics as a service subject? Should they or shouldn't they integrate?

TYPES OF INTEGRATION:

It is now useful to look at the variety of types of integration in light of the above issues. The following classification system, modified from Blum and Niss (1991) will be used throughout this paper:

Two-Discipline Instructional Strategies: teaching the basics of each discipline separately, with opportunities and motivation to integrate following as a separate instructional item.

This approach allows for the historically separate organization of the discipline to be maintained without avoiding the call to develop integration skills for future application by students. It reinforces the cultural transmission of western science and mathematics as a purpose of schooling, and it assumes that students should master culturally agreed-upon skills and concepts as a given. The application opportunities likewise risk becoming exercises instead of problem-solving opportunities. Gallagher promotes a variation on this approach: "... we hope to show how the two subjects may be used to enhance the development of basic skills common to them while each subject retains its own identity and organization"(Gallagher, 1979)

Thematic Instructional Strategies: using motivating images or themes to encourage students to attend to mathematical or scientific academic tasks.

A common practice among elementary teachers involves picking a theme, such as pumpkins or dinosaurs, and capitalizing on the students' inherent interest in the phenomena. Instructional reliance upon the theme might range from posting mathematical quizzes on dinosaur pictures to using the theme as the basis for developing the simple process skills of classification and graphing or developing numeracy. Word problems might include references to the theme. This approach makes little reference to the salient issues in science and mathematics integration as discussed earlier. Teachers perceive of this strategy as a classroom management decision, one that promotes "on-task" behavior while covering two required disciplines in half the time. The heavy emphasis on process skill development is often not provided in the context of an investigation of phenomena or concepts, reflecting the purist approach once again, that skills should first be perfected out of context. The subtle message is again that science and mathematics consist of sets of skills (possibly related) and concepts, the attainment of which will benefit all students.

Parallel Instructional Strategies: organizing curriculum so that teachers can begin with one discipline, invoke the use of another discipline as its relevance surfaces, and switch to instruction of the second discipline.

This approach resembles a highly organized "curriculum dance" in which the two disciplines receive equal and individual coverage, but the connections between the disciplines are emphasized. The curriculum coordination demands are high for this model. Although it does not attempt to maintain the uniqueness of each discipline, it guarantees curriculum attention to the basic skills and concepts that each discipline deems important for transmission. Rebecca Corwin (1993) suggests one way of planning for instruction using this approach which allows students to indicate their interests and readiness for themes around which to organize or web the curriculum. Her approach provides for more responsiveness to student readiness, but maintains the transmission of externally approved skills and concepts.

Project Instructional Strategies: beginning with a problem or challenge to develop and test a hypothesis, followed by instruction in mathematics and science skills to effectively address the initial project.

This approach is highly recommended by a the TERC group in Massachusetts and the numerous e-mail, data-gathering curriculum options that are springing up around the country such as National Geographic KidsNetwork:

> By focusing on the goal of thoughtful student participation in original work, we tap mathematics and science for inspiration, a strategy which we hope brings to education the excitement of discovery that motivates students to become engaged... What we are saying, then, is that projects, when they encourage thoughtful student exploration, neatly integrate mathematics and science. This is not too surprising, since many projects are based on interesting situations which require a quantitative understanding of cause and effect, that is, they require a mathematical treatment of science topics (Tinker, 1991 Fall).

These strategies can range from teacher-posed problems/hypotheses to student generated issues (as in the more social-action oriented STS approaches). Both the science and mathematics instruction then lies in service to the initial project, a curriculum decision that requires flexibility. Teachers must free themselves from initial preconceptions of the required bodies of knowledge to cover in each discipline. Students gain more (sometimes total) control over the skills and concepts that they learn. The application takes the lead. Most of these lessons involve a degree of mathematical modeling, a process common to both science and mathematics. It is through modeling that we blend the quantitative aspects of mathematics with the contextual aspects of science (Berlin & White, 1991).

> Modeling or model building is the entire process leading from the original real problem situation to a mathematical model (Blum & Niss, 1991).

> Making predictions, finding and testing apparent regularities, and building and using models to portray complex realities are far more important mathematical skills than those small pieces we often consider vital, such as knowing a small set of arithmetic truths (Corwin, 1993).

Fully-Integrated Instructional Strategies: same as above, but science and mathematics are never addressed as separate subjects or skills.

This approach is but an extreme variation on the prior strategy, but the implications of the differences are important. One working group at the Wingspread Conference for the School Science and Mathematics

Association suggested that a definition of integration should include: "Integration infuses mathematical methods in science and scientific methods into mathematics such that (it) becomes indistinguishable as to whether it is mathematics or science" (Berlin & White, 1991).

REALITY TESTING: HOW DO PRESERVICE TEACHERS ADDRESS THESE ISSUES?

Few of my preservice teacher education students were cognizant of the factors affecting their images, beliefs, or skills related to science and mathematics integration. Out of curiosity, I posed an introductory request at the beginning of my elementary science and mathematics methods course: *"What is your idea of an ideally integrated science and mathematics unit? Describe the unit and why you like it."* The results were extremely varied. In some instances it was obvious that the students were responding to many of the issues listed above. Other issues surfaced as well. A summary of the responses and the implications of those responses follows.

Lack of images

Let us first look at the preservice teachers who were totally frustrated with the task. Four of the 21 respondents expressed frustration to various levels as reflected in the following quotes:

> I don't know if this is integrated, because right now I have no glue [sic] as to what integrating math and science is.
>
> I wish you were asking this question a few weeks into this course so I could feel like I have something to say.

These preservice teachers seem to be entering the experience with no images, no schema, on which to construct their practices of integrated instruction. If their cooperating teachers were modeling integrated lessons, they were not perceiving the lessons as integrated. In one case, a preservice teacher even presented one of her teacher's "integrated instructional tasks" as a non-lesson:

> The lessons I've seen when observing weren't really lessons, they were done in center activities that students did on their own.

Although this is an extreme example, this perception that lessons require a tight locus of control residing in the teacher is reflected loosely throughout the responses.

Relative prevalence of images; Types of integrated lessons proposed

The types of integrated lessons proposed could be roughly categorized by the above-mentioned scheme. The breakdown was:

Two-Discipline:	1

Thematic	2
Parallel	5
Project (Experiment)	5
Project (STS)	1
Fully Integrated	5

Although the students were relatively equally balanced between early childhood (K-3) and intermediate levels in their practicum placement, few relied upon the more popular early childhood Thematic Approach. Those two that chose this approach seemed quite pleased with the degree of engagement (on-task behavior) resulting when their teachers modeled these activities, hence their focus appeared to be on management issues.

Only one preservice teacher proposed a relatively strict Two-Discipline Approach, expressing a strong image of some purist practices:

> In an actual classroom teaching experience, I would of course have a separate time for learning and exploring math skills. I have never seen a classroom (except kindergarten) where a set time hasn't been devoted exclusively to math concepts.

Five of the preservice teachers proposed lessons of the Parallel Approach. In only one of these the preservice teacher carefully matched the math skill with the science concept:

> For example, if I was teaching fractions in math, I would also teach during the day a science unit that required the students to use fractions - an experiment in which they had to combine measurements or the like.

Interestingly, this was also the only lesson which began with an emphasis on math. The others emphasized science and used math.

Eleven of the preservice teachers chose lesson types which provided a natural integration of science and mathematics from a project perspective. Many expressed a fairly sophisticated perception of the nature of the relationship between science and mathematical thought.

> The ideal integrated science math lessons should flow as in a real life situation, not do a science lesson and tack on a graph.

> An ideal unit which successfully combines math and science would involve a relationship to a project or activity that has real application possibilities - i.e. building or creating something that might work and demands problem solving or inquiry thinking.

Five of these eleven did not distinguish between the science and mathematical components of their lessons. Others struggled between the boundaries of the disciplines:

> If students had to build a science project, it could involve math. The problem I see is that the math would not be that difficult, but that would be fine with my class because they are horrible at math."

> The science part would be .... I would also think math would be part of their predictions and graphing, but they also had to count...

> ... by making scale representations of places like the solar system or places on the earth (though that may be geography).

All but one of the lessons (with the exception of the Fully Integrated lessons) were based upon a science lesson that used math, reflecting a tendency to view math as a service subject.

Overall, the proposed lessons reflect a skew towards slightly more sophisticated models of integration, in spite of the fact that less than half of the preservice teachers had cooperating teachers modeling any integration and only three of these sophisticated models grew from ideas presented by cooperating teachers.

Issues of cultural transmission

A predominant feature of the proposed lessons is the relative prominence of a locus of control within the teacher. I hesitate to call them teacher-driven topics, because indeed the preservice teachers were quite unaware of the factors driving them. They seem to be driven by a responsibility to pass on a given body of knowledge, with little responsibility to attend to individual students' unique needs to construct meanings about their present world. Of course, the nature of the question and the time frame for answering could factor into this omission, but this perception is reinforced by other interactions beyond this one task. Unsurprisingly, the five lessons that were Fully Integrated and the one Project (STS) Approach allowed the lessons to arise from student interest. However, even the preservice teacher who expressed the most extreme example of a Fully Integrated lesson revealed a nagging responsibility to the disciplines:

> How to actually facilitate this and still cover all the skills that need to be acquired is still a mystery to me.

The one preservice teacher who chose a topic that focused upon American Indian culture indicated that this culture used the process skills in the course of their daily lives. Not enough information was presented to indicate whether or not she was challenging the "western ownership and transmission" of these skills.

Generalizations from the data:

A few generalizations can be drawn from the above examples:

1) It seems that the personal schema of mathematics and science integrated instruction varies considerably among preservice teachers. The existence of prior images and models of successful teacher integrated practices is important as a foundation, but many of the most sophisticated examples in this sample did not arise from observations of master teachers. Most of the sample expressed positive opinions about the value of integration.
2) At the elementary level, none of the preservice teachers mentioned insufficient background in one of the disciplines as a detrimental factor (possibly because the level of knowledge required of them in these fields is quite manageable). However, it is not clear whether or not the authors of the more sophisticated examples were indeed more comfortable with the modes of reasoning in both mathematics and science, which could account for their emphasis on connections between the two.
3) These preservice teachers expressed little sense of personal control and responsibility for the information covered in the lessons. They held to the tenet that a body of knowledge exists that needs to be assimilated and that integration provides an effective means for delivering that information. Even those preservice teachers who provided student control over projects which naturally required an integrated experience questioned their responsibilities to the disciplines. One gets the sense that they are stepping over a forbidden fence, providing opportunities for their students to construct their understandings in accordance with their personal rhythms and schema, yet worrying about the damage they might be causing by neglecting to pass on some universal truths.
4) These preservice teachers are not focused upon diverse cultural ways of knowing. In fact, they do not mention the cultural influences which have shaped their own ways of knowing and teaching.

In short, these teachers held different schema, were willing to cross traditional boundaries between the disciplines, were undaunted by the issues of preparation and sufficient models, yet they were naive about hidden agendas which were governing their decisions regarding curriculum.

IMPLICATIONS FOR MY APPROACH TO INTEGRATED SCIENCE/MATHEMATICS METHODS

It is not the intent of this paper to propose that integration of mathematics and science instruction is inherently superior to more isolated approaches to the disciplines, but rather to investigate the underlying issues affecting preservice teachers' response to integrated task requests. This investigation has provided me with a greater sensitivity to the nature of the integration schemas that my preservice students bring with them as they begin designing and implementing lessons. If we hold loosely to constructivist tenets while teaching preservice teachers, we must admit that:

1. Teachers have ideas about teaching before any methods instruction (Lortie, 1975).
2. Teachers' preconceptions about teaching and learning are not easily changed (Hollingsworth, 1989; Shymansky, 1992 Spring).

Therefore, any integrated instructional challenge must allow for multiple entry points, opportunities for preservice teachers to work on their current schemas of integration rather than attempting to mimic one particular model. Opportunities should exist for them to develop comfort with their own model until an internal need to modify it surfaces.

It might follow that once we have identified the diversiy of schema for integration, we might reflect on the underlying causes of those schema. What epistemologies are driving the teacher's belief about connections between the disciplines? How do their methodologies communicate those beliefs?

Next, I might move on to discuss my own beliefs about integration. Do I (as the methods instructor) believe that the array of integration lesson types reflects a hierarchy of "sophistication" in integration? Is it a developmental sequence of stages through which all teachers will inevitably pass given the proper experiences and perspectives? Or is this diversity a result of the complex issues and belief systems that influence curriculum decision-making?

Finally, as a class we might investigate the issues of power within the institution that are perpetuated by these instrucitonal decisions. Are we striving to restructure the development of our students' understandings of these issues, or are we attempting to allow our students to develop parallel understandings of these issues?

CONCLUSIONS:

My interests in improving my approach to integrated science and mathematics methods for preservice teachers resulted in a review of the literature on the salient issues related to integrated instruction. A survey of my students' (preservice teachers) images of effective integration patterns revealed a diversity of images and a naivety about epistemologies and political factors influencing those images. As I pondered the instructional implications of this research, I found myself confronting the current dilemmas in constructivist thought: what is the positivist nature of knowledge (in this case, scientific and mathematical knowledge); which instructional strategies support a positivist's perspective (knowledge is passed on as a given truth) and which support a more complex critical constructivist's perspective (knowledge is socially constructed to create shared meanings, the "passing on" of this knowledge serves political purposes). In light of the above considerations, this research has helped me to develop the following guidelines for an integrated science and mathematics methods course for preservice teachers:

Science and mathematics methods instruction should first identify the diverse images of integration that the preservice teachers bring to the classroom. It should simultaneously support and challenge these schema by including multiple entry points, continuous reference to the history and philosophy of science and mathematics education from multicultural perspectives, and a dose of good-natured reflection as we learn to catch ourselves responding to historical pressures previously hidden from our perception.

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