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ABSTRACT

Due to the technological power and high status science is given in our society, educational reform efforts will continue to focus on science education. However, the purpose of science education for a multicultural society remains problematic. The implications of using social constructivism as a referent for science education is discussed, acknowledging that scientific knowledge, as all knowledge, is a cultural and sociohistorical construct. The position that social constructivism provides a theoretical base for creating multicultural science education is at odds with the view of science held by most science teachers. This case study follows two experienced middle school science teachers and shows how successful teachers change "good" teaching practices to make them "good" for all their students. One teacher participated in a four-year institute on multicultural science, while the other teacher revised his teaching practice primarily through his own trial and error experience. Participant observation methods were used to examine the salient features of transforming science education into multicultural science. A complex interplay between the nature of science and a pedagogical focus on the ability of the student versus content emerges as a precept differentiating the teacher's transformation of their science classroom and instruction. (Contains 33 references.) (Author)

Headlong into Inside Out: The Process of Becoming an Effective Multicultural Science Teacher

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Abstract

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Due to the technological power and high status science is given in our society, educational reform efforts will continue to focus on science education. However, the purpose of science education for a multicultural society remains problematic. The implications of using social constructivism as a referent for science education is discussed, acknowledging that scientific knowledge, as all knowledge, is a cultural and sociohistorical construct. The position that social constructivism provides a theoretical base for creating multicultural science education is at odds with the view of science held by most science teachers. This case study follows two experienced middle school science teachers focusing on how successful teachers change "good" teaching practices to make them "good" for all their students. One teacher participated in a four-year institute on multicultural science, while the other teacher revised his teaching practice primarily through his own trial and error. Participant observation methods are used to examine the salient features of transforming science education into multicultural science. A complex interplay between the nature of science and a pedagogical focus on the ability of the student versus content emerges as a precept differentiating the teacher's transformation of their science classroom and instruction.

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Headlong into Inside Out:

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What Would Multicultural Science Education Look Like?

The rationale supporting science education reform appears deceptively clear: our collective future depends on providing high quality science education for all students. Among the better known science education reform efforts, Project 2061 (AAAS, 1989, p. 3) states this need succinctly.

> Scientific literacy - which embraces science, mathematics, and technology- has emerged as a central goal of education. Yet the fact is that general scientific literacy eludes us in the United States... Reform is needed because the nation has not yet acted decisively enough in preparing young people, especially the minority child on whom the nation's future is coming to depend, for a world that continues to change radically to the rapid growth of scientific knowledge and technological power.

Bringing about such reform efforts, however, is a complex undertaking. Not only is there little agreement about *how* to educate a diverse population in science, but the *purpose* of "science education for all" is also debated. The methods employed to provide high standards of excellence to fill the science pipeline are not necessarily the same methods needed to meet the needs of a diverse student population. As Atwater (1993) warns, "multiculturalists suspect the pipeline itself". To provide quality science education for all children in our multicultural society calls for questions that run deeper than access, de-tracking, and bi-lingual classes. These questions beg the larger issue.

If science education reform efforts do not address major assumptions about the nature of science and the construction of knowledge, the changes that result will only be superficial. What must be incorporated into the restructuring discourse is a critical examination of the "perceived demarcations of western science, based on claims of objectivity, rationality, and progressiveness" (Harding, 1994, p. 307) in light of a more socially constructed conception of knowledge. In order to re-design science education that would enable our children to live productively and equitably in a scientific age, I believe it must be acknowledged and embraced that scientific knowledge, as all knowledge, is a cultural construct. Science education reform premised upon this view of science requires changes in content, pedagogy, teacher's roles, and the culture of schools. Changes of this magnitude require a new template.

The Role of Social Constructivism in Multicultural Science

Fundamental problems emerge in the science classroom when multicultural education is superimposed upon the science curriculum. Many of the underpinnings of the major science education reform efforts are based on various understandings of constructivism whereas "traditional teaching and learning strategies in science have developed from objectivist assumptions about knowledge" (Shymansky & Kyle, 1992, p. 761). The world view through the lens of objectivism sees knowledge as something definite and "out there" to be found. The majority of science teachers have experienced science and science education in the objectivist tradition, and teach science in their own classrooms with the same view. Objectivism leaves little room for alternative or multiple perceptions of reality, a basic premise of multicultural education.

Social constructivism as a referent for science education has wide ranging implications for change. Fundamental shifts must occur in our conception of knowledge such that "knowledge takes on the character of a process of knowing" (Lave, 1988, p. 175). O'Loughlin (1992, p. 811) further asserts that the greatest challenge we face is "to find a way to step outside our own cultural blinders to think of coming to know as a sociohistorically and culturally constituted dialogical process of meaning making." This is in direct opposition to objectivism. According to Driver, et. al. (1994, p. 11) an "empirical study of the natural world will not reveal scientific knowledge because scientific knowledge is discursive in nature." An additional feature that supports the appropriation of social constructivism as a base for restructuring science education that is multicultural is that it explicitly addresses issues of status and power in the educational process. Classrooms operating with an objectivist framework will perpetuate core inconsistencies with both multicultural education and social constructivism: the belief that knowledge can be transmitted from knower to receiver; strictly adhering to textbooks; and heavy reliance upon lectures. Reforming science education along a social reconstructivist perspective changes the role of the teacher, and the very nature of the *purpose* of teaching science. O'Loughlin (1992, p. 816) explains the implications of such a change in science education.

> Science teachers, therefore, face the simultaneous challenges of validating their students' personal ways of knowing, introducing them to the powerful speech genres of conventional science, equipping them with an understanding of the fundamentally socioculturally constituted ways of knowing that underlie science so that the process of doing science is demystified and they do not feel compelled to defer to the intrinsically authoritative power of the received view.

The central role that the teacher plays in science education reform is implicit, but poorly articulated. While science education reformers continue to look for resolutions, science teachers are in the classrooms educating our children. Teachers are often left to their own devices to make sense of "sweeping changes" and implement them in ways they feel are both practical and will benefit the children in their care.

The majority of science teachers in the field today did not receive instruction in multicultural education as part of their teacher certification requirements and are under-prepared to modify their curriculum and teaching practice in light of the current multicultural and social constructivist reform efforts. Inservice programs are generally viewed as a primary vehicle to relay new strategies and techniques from the research base to the practitioner. Based on what is known from the small number of inservice programs designed to bridge the cultural gap between teachers and diverse student populations, results are not promising (Redman, 1977; Washington, 1981; Grant & Grant, 1986; Watson & Roberts, 1988; Haberman & Post, 1990; Sleeter, 1992).

It is not merely the effectiveness of multicultural in-service programs that is less than encouraging, but inservice programs in general. Whereas the national annual cost of in-service education was over two billion dollars more than a decade ago (Gage, 1984) and is surely much higher today, the results remain questionable (Waxman, 1986). Traditional school inservice activities provided by teacher educators are often one-shot and are known to have little effect on what actually happens in the classroom (Parkay, 1986). Coupling these dismal results with the realization that the nature of science itself is at issue, reform efforts to provide high quality science education for all students may seem to be a remote possibility.

This research deals with a program that undertook the challenge of unpacking science education and the implications of what such science would look like in a multicultural classroom. Since 1990, I have been the director of a multicultural science institute, working with inservice science teachers from two midwestern urban school districts. The concept of the institute was to invite science teachers to rethink how and why they teach science the way they do, and how they might change the nature of their science instruction in view of three major tenets: education that is multicultural and social reconstructivist (Sleeter and Grant, 1994); science as a process, known as the 3P's: problem posing, problem solving, and peer persuasion (Peterson and Jungck, 1988); and cooperative learning (Johnson, et. al., 1988).

The case study includes two teachers, Tom, who adapted his science teaching working primarily from his own experience and informally with a small group of his peers, and Margaret, who attended the multicultural science institute for four years. Tom and Margaret, both experienced science teachers of more that twenty years, are regarded as excellent science teachers by their colleagues and administrators. In the lengthy course of their science teaching careers, they have experienced many different educational trends, and seen critical education issues wax and wane. Even more importantly, Tom and Margaret have experienced a personal need to change their science teaching based on the "different kinds of students" presently in their classrooms. How they have perceived these different kinds of students, including their abilities, strengths and weaknesses, has been an important aspect of how Margaret and Tom have modified the nature of the science instruction they now provide.

Using the participant observation methodology (Spradley, 1972; 1979; 1980) I have spent over 50 hours observing, interviewing and collaborating in each teacher's classroom. Classroom visits consist of an entire morning or afternoon block. Segments of classroom interaction are audio tape recorded, and later transcribed by a third party. Classroom visits are followed by either a formal, audio taped interview, or spontaneous conversation which is immediately written into my field journal. Additional information that allows me to triangulate data include student interviews, texts, lesson plans, tests, student handouts, and lab notebooks.

There are three major players in this case study, Tom, Margaret, and myself. Tom and Margaret are trying to change how their classrooms operate while at the same time, maintain dignity and sanity in a profession that is currently viewed as the scapegoat for our nation's problems. I, as the researcher, am trying to juggle multiple lenses. One kind of lens is that of the teachers, gaining insight into their view of science. The other lens is my own particular view of a "could be" world based on research that I have come to believe offers a theoretical base for multicultural science education.

I believe that in order for a teacher, such as Margaret, to seek out continuing education courses on multicultural education, she must be predisposed to change for some reason. The reasons may be as varied as: personal dissatisfaction with teaching; viewing change as a part of professional growth; desire to learn about a particular pedagogical technique; desire to learn more about students' needs; or interest in interacting with other teachings facing similar challenges. The way this predisposition to change was played out with Margaret and Tom is one of many differences in the way they each approach science teaching. An additional complexity is the way in which this collaborative research developed along two paths, each characterized by a different relationship between researcher and participant. Margaret, whom I have known for four years during her involvement with the institute, was eager to read her transcripts, and commented frequently about her own development. Tom accepted transcripts graciously, but more as a matter of protocol, showing little if any indication that he either read them, or cared to use them as a tool for learning and reflection. As time went on, the result of this different "welcoming" of the opportunity to grow professionally (within the context of this research) widened into two distinct interaction styles between researcher and participant.

Tom and Margaret's teaching and classrooms are described in the following sections. It is critical to emphasize that both classrooms are places where students are engaged in hands-on lessons, working together in groups and pairs, and being provided with current science information. The teacher's years of experience have fine-tuned their sensitivity and concern towards the students in their classrooms. Both classrooms "look" good, (i.e. active, hands-on). However, Tom and Margaret have re-shaped their classrooms based on different understandings such that the *purpose* of science education is different. The telling of their stories is to begin a search for the foundation of what makes an effective multicultural science classroom. The criteria for this search was formulated during a pilot study in which Tom and Margaret self-identified the factors defining their change process (Wachtel, 1995). Based on the findings of the pilot study, I have chosen to focus on the way the teachers perceive the nature of science, and abilities and needs of their students.

Tom's Story

Tom, a veteran teacher of 29 years, teaches 8th grade middle school physical science at Parkside school. With a double major in physics and math, Tom has taught at Parkside all of his teaching career. Early on, he began teaching math, but "two years of math bored me to death in the sense that it was too routine." Even though he pursued a master's degree in math, he opted to switch to teaching science when the opportunity arose. Tom is adept at locating and taking advantage of university resources to enrich his science background, including courses in engineering, physics, astronomy and biology.

Tom sees himself as a lifelong learner in science: "I don't think I'll ever stop learning. As long as they send me [course information] that sounds interesting, I'll sign up for it." Other professional involvement includes participation in the district science curricula studies, and collaborative curricula development efforts with other district's science departments. Even though Tom claims that he often learns "just for fun", there is a direct connection between what Tom decides to involve himself in, and the applicability of a particular view of what is valuable for his science teaching.

Tom values organization and order: of his time; his lesson plans; and his classroom. His room is arranged with lab tables forming four rows, divided in the middle with an aisle. Each group of two tables seats four students. The two students at a table are lab partners. The west side of the room has large windows extending nearly the length of the room. The front teaching desk is lengthened by an additional table used to lay out lab equipment. A storage cabinet in front contains rocket parts and samples of student-made rockets. The back of the room has a sink with a huge test tube rack hung above it. Throughout the year the room decor remained pretty much the same: a poster of Einstein; a large student-made kite; a decade of pictures of the class trip to Washington, D.C. (that Tom chaperones yearly); and a prominently posted lesson plan in which each day that passes gets crossed out with a large red X.

Tides of Change

During the nearly three decades of Tom's science teaching career, he has seen many changes occur in science education in general, and in his school in particular. One of the earliest and most significant changes that Tom speaks about is the change from a junior high structure to that of a middle school philosophy. In the 1970's, "people were brought in for a few weeks to train us in the new ways, everything from Piaget to living skills." This transition in the focus on teaching and learning was prompted by a structural change in the school. It was the kind of top-down change over which Tom didn't have much choice. However, Tom accepted the change, and grew professionally. The process of switching over to a middle school philosophy helped Tom to begin to modify and reflect on his own science teaching. According to the "experts" brought in to "retrain", Tom learned that more emphasis should be placed on the student and less on the subject.

> The thing that impressed me the most was the idea I shouldn't get so upset about the curriculum because most of the time there's a good percentage who aren't listening. What you're doing is you're treating the kid at where he's at and trying to bring him along and help him mature and, at the same time, teach him some science. So, we did many more labs. (11/7/94)

An equally significant impetus for change stemmed from Tom's own personal desire to renew his spark in teaching. "I had been teaching science for a long, long time and when you do anything for a long, long time, it gets dull." Instead of "changing jobs, or something else," Tom looked for a new way to frame his science teaching. The spark that Tom needed was found through his participation in a summer science experience with "some of the brightest teachers in the state." What affected Tom most about his summer science experience was gaining a new insight on how to teach science differently.

> It was the idea that you can have fun and teach science. You don't have to lecture all the time. That a lot of things you do that they consider lecture, the kids forget right away. But if you give something they can touch, they can feel, they can measure, they can hold, they can do the basic thing of science research, observation, they remember it longer. And, if you do something that's hands-on, they remember the skill, not necessarily the information as long, but they can use that same skill later on in life. We laboriously do five part lab reports. Not for the sake of doing them...but it prepares them for always looking at problems in a five part system. (11/7/94)

Science and Learning by Doing

Science, for Tom, is "an organized body of knowledge." Information is gathered primarily through observation, and observations are governed by the scientific method. Science for the most part is a logical, systematic progression of thought. Although Tom recognizes some limitations to science, he believes that the scientific method has relevant application to personal and social problems, such as "why mom is grumpy in the morning." The process of science in Tom's perspective goes like this: Adherence to "correct or approved" procedures result in information. Accumulation and verification of this information results in scientific knowledge (NOSS 11/94). It is this view of science, one based on the scientific method yielding information, that is the cornerstone of the science that goes on in Tom's classes. It is therefore necessary to understand how this view of science meshes with Tom's view of how student's learn.

Tom relies heavily on lab activities for three primary reasons: 1) students enjoy "doing", and science should be fun; 2) students learn better and remember longer by doing rather that just hearing or reading; and 3) scientific knowledge is conveyed via the procedures of science. In other words, students learn by doing, and learning by doing fits well with Tom's view of teaching science. Tom self-described his science teaching by the following: "Hopefully there will be a lot of hands-on. A lot of discovery by themselves. I'll be more in the background not in the foreground as much. I'm more of a "guider" channeling kids into different things that they never thought about."

The best way to describe how science is conveyed in Tom's room is to describe a typical lab activity. On lab days, Tom dons a white lab coat, giving him the look of a "scientist". Nearly the entire class period of a lab is structured so that students come in the door, receive a few details or instructions, and begin to work on the day's lab in groups of twos. A common labs entail primarily observation of a phenomena, such as freezing point of various solutions. These observations may go on for 30 minutes or more, with students taking temperatures every 15-30 seconds. The data is plotted in the student's lab notebook. Individual data is put on the overhead projector at the end of the hour. Tom will note how close individual plot points are to the correct answer. Students must complete the five-part lab write up as homework, which is generally due the next day. Due to the hurried pace of completing a lab in one period, there is a marked lack of discussion about how the lab exercise fits into a scientific concept, why there were data discrepancies, or opportunities for related student questions. Over a 90 day period between October and February, roughly 50% of student-teacher days were formal labs. 20% of the time was devoted to reviewing, tests and quizzes. The remaining time was divided almost equally between activities and teacher-directed demonstrations and introductions to new material.

Tom distinguishes between labs and "activities" on the basis of whether or not a formal, five part write-up is required (based on the scientific method known as PHEOC: problem, hypothesis, experiment, observation and conclusion). "Activities are something that I don't think is important that it should be in their notebook to look back on forever and ever." Generally, labs are modified from the textbook, for example, "freezing and melting point" and "density of a gas". The textbook provides a picture of the set-up, explicit directions, in addition to examples of graphing, relevant and mathematical formulas. Textbook questions following a lab focus on quantities, mathematical relationships and procedure. In comparison, the activities in Tom's classes are more open-ended, including: a five-day project culminating in a report on a scientist or inventor; bridge building; and air car construction.

Labs are used as the primary method of conveying scientific information in Tom's classroom. Lecturing as a method of communicating information has fallen out of favor with Tom, and that disfavor has been reinforced by his encounters with other science teachers and administrators. From a teacher's perspective (and an administrator's), the outward appearance of a lab activity is good, in that students are actively engaged in "doing science". There is an interesting irony between what Tom deems is "important to remember for ever and ever" (i.e. formal labs) and the lower value of learning placed on open-ended activities. The irony is even more evident when compared to Tom's strong belief that science should be fun. Whereas students proceed through the labs, they are indeed doing, but not necessarily thinking or understanding. It is still a transmission approach to learning, albeit the mode of transmission has shifted from the teacher as lecturer, to the lab activity as bearer of scientific information.

An Evolutionary View of Tom's Students

The evolution of how Tom perceived his students went through about three major phases. Each of these phases is connected to the changes in Tom's perception of the needs and abilities of his students. In the early years of Tom's teaching, students functioned as individual receivers of knowledge. That was during the time that he lectured and emphasized memorization more.

> We used to have them go do research on each element. It used to be a lot of work and a lot of memory type things. We used to spend time diagramming, you know the shelf and where the electrons popped in, and the SPDF sub-shelves... Over two periods we just drilled these kids. It became more difficult over time as kids didn't go home and memorize them, they didn't have anybody at home. They didn't do the flashcards that we suggested. It got to the point that you were just beating yourself against the wall. I went and made flashcards, and I gave extra credit or candy to try to stimulate... I think that is when we started to pull back on it. (12/5/94)

At this juncture Tom acknowledged that memorization was no longer an effective learning method with his students, and questioned the value of the information conveyed via this method. "The comprehension wasn't there. And they really didn't need it. They didn't need it in that depth."

The following phase dealt with group work. But this too became problematic as time went on, primarily due to student abilities to work together and negative parental feedback.

> A lot of kids coming out of the elementary school were group-project oriented. They would carefully pick partners and each contribute so much... It became more and more difficult to get some kids into a project group because they were not picking the low-end kid. And you had to go around and beg somebody to take their group, knowing well that the group may not get as much work out of them as they should. Or, you would have four or five low-end, non-workers pick each other and then do nothing and blame each other almost to the point of having a fist fight...It came to the point where you were getting parent complaints of "How could you, as a teacher, allow this person to be in my son or daughter's work group?" The quality of the

> projects was going down, the grades were going down. Time and effort just changed. So, now any kind of a group work that we do the maximum number of people will be two. (12/5/94)

The "boss and bossee" student relationship, Tom's present method of fostering inter-student relationships, evolved after the group work was abandoned. Labs are often discussed in terms of duties and tasks. The two students seated at a lab table are lab partners. It is Tom's hope that the two share the duties. However, he has noted over time that the situation usually falls out into unequal sharing.

> If they learn to share the duties, things go quicker and smoother. It they don't share the duties, it usually comes down to one will be the boss and the other the bossee...They tend to have a feeling that one person in the two will know what they're doing or assume the responsibility. I've found that even if you put two rather low students together, one will assume the responsibility of being the leader and one the follower...It forces them to have to be aware they have to think on their own because they may be put with a partner who doesn't. (12/1/94)

The boss/bossee relationship is an example of Tom's understanding of how students may work social relationships out for themselves. Rather than devoting class time to discuss effective group work, Tom has adapted to the student's mode of interaction. Tom states that he "takes kids where they are at" but does not actively intercede to foster the development of their social skills. His rationalization of where his students are at, (i.e. the "thirteen or fourteen year old mind in there that is going bananas on hormonal changes") sets the tone for his own tolerance level. "You expect certain minimal behaviors from all kids. There are some that cannot meet even those."

How Do I Reach Them?

An area that Tom specifically mentioned he would like to work on regarding his professional growth is learning about how to deal with different kinds of students. His frustration with students who are "angry", "rebellious", or "will work 110% against doing something that I want" has grown over the years as student diversity has increased. "They may be coming from an environment where they just moved out of [large urban city] and anything we say or do is basically nothing, water off a duck's back, because they have seen it all and done it all and have been into drugs, been into alcohol and you know, you're just you up there talking." (2/22/95) Although Tom recognizes a need to reach his changing student population, he is equally skeptical that resources available will be of any substantial use to his particular needs.

> We have had one, maybe two hours of inservice over two years where people will come in and talk to you about the differences in kids. But somehow the hour always goes by before they get down to anything that as a teacher you would say is concrete, that you could put your hands on. They'll tell you what doesn't work. Give you some examples that will help? They don't have those. They need to come up with a video tape, techniques, a list, a chart, a folder, a handout. What are things other people have tried successfully? I'm not so sure you could find it, that would be worth what your are looking for as a teacher. How do I reach African American's in chemistry? Or physical science? Or whatever... You try to relate to where they are coming from, but I'll be the least important thing in their day. But beyond that, what works best for teaching? Is it a lot of repetition? I don't know. Is it modifying the expectations but giving them more so they can reinforce it? That is the type of thing we are very deficient on. The whole school. I think the whole system. (2/22/95)

Tom feels he has learned as much as he has about dealing with diverse students by his own trial and error. He is not afraid to keep trying new and different techniques, as long as the student puts forth some effort. However, the immediate plan that Tom has for continued professional development includes the refinement of a lab to produce esters. As far as dealing with students with diverse needs and abilities, Tom and the rest of the science staff are continuing to work with the special education staff to "balance the number" of special needs students in any one class.

Margaret's Story

Margaret has taught middle school for 22 years, and the past seven teaching 8th grade physical science have been at her current school, Prairie View. Prairie View has the highest percentage of diverse and low income students of the middle schools in the moderate sized urban school district (based on number of student's receiving free lunch). She is involved in numerous professional organizations, and considers herself politicaliy active. Most of her teaching had been in a white, middle class setting until her move to Prairie View. In her former teaching settings, her traditional, objectivist view of science had served her well. But, the dramatic change in the student body at Prairie View had motivated her to look for help. She committed herself to participating in a two-year multicultural science institute, a commitment that required nearly 400 hours of her time. After the first two-year cycle, Margaret returned to the institute for an additional two years to mentor new teachers. Thus, her total involvement in the multicultural science institute spans four years, in the capacity as both a participant and a teacher mentor.

A series of events at Prairie View came together to set the scene for change for Margaret. A particularly demoralizing year had preceded her involvement in the institute. Violence, suspension rates, poor academic achievement, all contributed to Prairie View's reputation as being the "armpit" of schools. In the year preceding her participation in the institute, Prairie View had more than its share of negative media. She had just begun to be interested in cooperative learning, and was looking for ways to try it in her classes. In addition, the entire Prairie View staff had been required to attend an inservice on multicultural awareness. She vividly described this scenario with bitterness that has lingered for years. Margaret said the presenters immediately put the entire staff on the defensive, and personally attacked individual teachers for "racist behaviors". She swore she would never quietly sit back and let herself become attacked for being a racist teacher again. If she ever attended another "multicultural workshop" she demanded it must address a positive route for her to change and improve her science teaching. It was against this backdrop that Margaret came to the institute.

There are several key aspects that make Margaret's struggle to create multicultural science a promising one. She wishes to make her classes "cooperative", "safe" and "inclusionary". What is driving these changes above all else is her student-centered vision of teaching. She realizes that in order for students to learn, they must "make a huge investment in themselves" (9/25/94). Margaret has moved herself to the point where she assumes the responsibility to teach science to all her students. Instead of pulling back and abdicating teaching to special education teachers, Margaret has begun the challenge of restructuring the way she teaches to provide a wide spectrum of learning opportunities for all her students. In addition, Margaret is wrestling with "letting go"; moving from an objectivist view of knowledge to a more student-centered view. She has a view of science that, although may not strictly be labeled "constructivist", contains significant facets of the model.

These Kids Can Do Science

At first glance one would peg Margaret's classroom as a typical middle school science room in many senses: hamster cages, plants, hummingbird mobile, glassware, balances, and boxes and boxes of all the necessary stuff to do hands-on science stacked to the ceiling. There is a Martin Luther King poster next to Einstein's. When the students begin to come in, one gets a glimpse of the personal concern Margaret shares with her students. She isn't barricaded behind her desk awaiting the signal from a bell. She is at the door making conversation, greeting her students.

There is generally no sharp line separating when the casual conversation ends, and the science begins. Margaret engages with her students in the highlights of the day, including: pointers for registering for high school classes; "Science Day Away"; tallies of the hamster-naming election; the weather over the weekend; and insuring that her students know that "aunts, uncles, brothers, sisters, all your family is welcome to just come on in the door to Family Night." One principle of multicultural education that Margaret has incorporated into her science teaching is the central role that the family plays in education. She more fully recognizes the importance of family in many cultures, and uses it as a bridge to reach more of her diverse students.

It is this view of students, as members of a family, that underpins the way science is done. Students are knowing, caring, intelligent young people, who respect those who see their potential, and foster it. She does not ask or expect that the student's shut off their way of knowing and interacting to "do science". Instead, she invites their lives into the process of doing science. Her definition of science reveals some evolution from a reliance on objectivity to a more constructivist stance.

> [Science] is one of many ways we have in our culture to find answers to questions. It's the most organized problem-solving methodology that we have in our modern society. But, not the only way. People would argue that religion, etcetera would be another way of solving problems. But, this is the only one that's formalized and quantitative. I look at science as a way of finding out answers to questions, solving problems. Students like working with their own curiosity and answering questions that they really want to know answers to, not something that you want them to know the answers to. (5/28/94)

Margaret has talked about her difficulties in catching her teaching techniques up to her changing views and beliefs. As dissatisfaction with traditional science teaching grew, she needed to re-tool her teaching techniques. Lab activities in which the purpose was "confirmation of fact" began to lose favor in that they were no longer suited to her view of science, or her view of the abilities and needs of her students. However, letting go of an objectivist perspective has been a long process.

> I taught all that IPS [Introductory Physical Science textbook] stuff for a long time and then there's a few experiments that still remain in my curriculum that came from that. But, I don't teach them the way they were designed to be taught. If you look in the old teacher's guide, there's a data table in there and the kids measure x and then they calculate these numbers and then they come up with a percent, and you put them on a histogram. And, boom! That's it. It's all cookbook stuff. I did that for years. And, I always found that the kids had a terrible time trying to figure out how much air, space, and sand. When I came here, I was still doing it the same way. I changed it to a cooperative learning lesson. But, it still wasn't good. So

then, I had some students a few years ago that got real assertive with me about it and said, "Yeah, but you don't have to do it this way, Mrs. M. Here's an even easier way to figure this out." And, I was very resistant to that. I said, "No. It works, but it's not mathematically correct." I looked at, and I looked at the students' work and I looked at it. And, these two girls convinced me. I went, "Oh yeah. That is easier." So, now when I do it with kids, I don't give them a set of directions and I don't give them a data table. And, I just say, "Here's the problem. You figure out a solution. What materials do you want?" And, there's a lot of different solutions. And, let them take a little bit more time, let them struggle with it, and in the end, they own the knowledge. They can all do it. (11/15/94)

The science curriculum has undergone many changes in the past four years. Although she told me that her students don't know what the 3P's are, Margaret is working on the problem-posing and peer persuasion components She says she was caught in the middle P (problem solving) and never got out of it before. An interesting example of how she interprets problem posing was revealed in a discussion with her students about science. The previous week they had talked about falsifying data. As a follow-up discussion, Margaret ventured with her students into the parameters of science:

There are some kinds of problems that scientists don't try to find answers to because it doesn't fall in the realm of science. Can you think of any questions or problems that scientists might not even tackle? There's something that they call unanswerable questions. Scientists don't tackle unanswerable questions. What would an unanswerable question be? A question that's been around for a long time that I don't think we'll ever find the answer to. It's tough, questions for which there are no answers. Or do you think science can find the answers to any question? (9/16/94)

The conversation that ensued invited an intriguing array of student's perspectives ranging from the origin of life, to "what number is infinity?" Traditional lab activities ("coming from the old IPS text") still comprise a fair share of the curriculum. But, Margaret has recently placed more emphasis on trying to make the subject more relevant to the lives of her students. In introducing an experiment on salt and ice, Margaret initiated a discussion about the effects of salt on winter roads, environmental problems with salt run-off, and the social trade-offs of sanding roads versus salting. Students posed their own hypotheses as to what happens with salt and ice, which ranged from "causing friction", to "breaking up the water". After discussion and problem posing, student volunteers were quite excited to go outside and gather up snow to begin their "own experiment".

Creating Inclusionary Science

It is an essential point to keep in mind that Margaret was recognized as an outstanding teacher long before her involvement in the institute. Further, the institute is only part of her professional development, which also includes leadership roles in state-wide science programs and science teacher organizations. What then, can be said about the changes that are a result of her participation in the multicultural science institute? To begin to answer that question, Margaret shared her lens for change with me.

> I feel more comfortable working with all the different kinds of kids I have. I think before [the institute] the only group I felt even a little bit knowledgeable dealing with might have been females. But, I feel very strongly that I have a better handle on how to work with particularly African American kids to get them to be more successful... I think the sensitivity was always there to the point where I wasn't really teaching them because I didn't know their needs. Now, I go "Okay. This kid is going to learn"... I think what I was doing before was pretty close to benign neglect. Now, I'm much more assertive. I call mom or dad. I make opportunities for them to learn. The changes I made for those students were changes I made across the board. It's been good for all of them. (6/29/94)

When the role as teacher was more clearly defined in Margaret's perspective, she accepted the responsibility to teach all her students. She still works with special education staff, and uses all the special resources the school has to meet the needs of her most challenging students. But, an interesting turn of events has transpired. Instead of the special education teachers being responsible for special students, Margaret is often seen in ad hoc conferences offering the special education teachers strategies. In many cases, Margaret works better with her exceptional needs students than special education teachers do, and consequently all the learning disabled students have been assigned to her. She is continually experimenting with ways to structure her classes to be more "inclusionary".

> But the problem for me, is being more purposeful in making sure there are lots of different ways in my class for kids of all different kinds of talents to succeed... We have a very wide spread in our classes. The word inclusive applies to having all of them included in the learning process. They're not just sitting and listening, and kind of bumping along, and having the responsibility for their learning taken on by some LD resource teacher or something like that. It's our responsibility as a classroom teacher to make sure that every child has an opportunity to learn. And I think that when we first started mainstreaming kids, we still felt the main responsibility for the learning for these kids belonged to the resource teachers. I think that's changing over. And I think that's the difference between mainstreaming and inclusionary practices. (9/13/94)

There are several ways that Margaret has changed the structure of her classes to be inclusionary. Many of her projects and quizzes have been revised to allow students to demonstrate what they know, based on alternative assessment strategies. She continually changes her old "lab practicals" so that the quizzes emphasize learning processes more. A particular quiz she was pleased with dealt with measurement. The quiz consisted of steps to pour and mix specified amounts of colored water in test tubes resulting in color changes. The classroom atmosphere was atypical of a quiz mode. There were "ohhs and ahhs". All students were able to produce results indicated by a color change. With the introduction of rubrics assessment one year ago, she further enables the "wide spread" in her classes to push a little further.

> The truth of the matter is that every single kid in every single class will stretch themselves if they know what direction to go. And this [rubrics] makes it more specific to them, and so they do! (9/13/94)

Fostering A Cooperative Environment

The expectation of the institute was that cooperative learning would be an integral feature of a multicultural classroom. One of the initial reasons Margaret gave for joining the institute was to learn more about cooperative learning. Implementing a truly cooperative learning environment is one of her on-going searches, "My level of using cooperative groups in my science classes is not as high as I would have hoped it would be." (10/5/94) But, after four years of experimenting with various combinations and strategies, her definition of "cooperative learning" has become her own.

> For a couple of years I used it a lot and loved it. And then, all of a sudden, students just got really, really turned off to cooperative groups. You know, they weren't really cooperative groups, it was just "I do my job, you do your job by yourself." It was hard to find assignments where they were really interdependent. The traditional Johnson and Johnson cooperative groups didn't work for me. They were being cooperative grouped to death. They hated it. So, I faked it so that I had cooperative expectations, but I stopped assigning those roles. Now it's the task of the group to figure out who's going to do what, assign tasks and everybody should be busy all the time. If somebody takes longer than somebody else, then you have to chip in. I no longer have all those little tasks like readers and gophers and all that stuff. (10/5/94)

A cooperative environment implies that the teacher learns along side of, and with her students. For Margaret, this means letting students inform the teacher of what works, and what doesn't. As I came for a visit near the end of the first six weeks, Margaret was waving a stack of papers at me. She told me that I might be interested in some student "data". The stack of papers were student evaluations of the first six weeks. Done in a typical Margaret fashion (i.e. pragmatic and to the point) the papers were folded into four boxes. In each box, students were asked to write what they thought about the following: 1) favorite activity; 2) view of the classroom rules, 3) what helps me the most; 4) grade you give the teacher. She was thoroughly lambasted for the rule banning gum chewing (even though it was a joint-venture decision). One of the most prevalent comments students made was the way in which they were given so many opportunities to know what the expectations were, and then to be able to fulfill them. Some of these specific strategies included Margaret's on-going development and refinement of rubrics, catch-up time (called Heinz time), quiz bowls, checklists, and the chance to re-do assignments and lab reports.

Margaret's conception of herself as a teacher is defined in large part by what her students need. Numerous conversations indicated that her rationale for curricular decisions are largely based on her perceived needs of the students, "determinations are made based on what we think the kids are going to be interested in learning." (5/28/94) In particular, content decisions are made from factors such as: "when students can get outside"; "they come in itching to burn something at the beginning of the year"; and a survey where students indicate what they would like to learn or do in science. The content of science is viewed as merely a vehicle for a "skills thread".

> There are certain things we want our eighth graders to know when they get out. We definitely want them to know how to measure in volume, and mass, and length accurately. And, to have a little bit of an understanding of the mathematical concepts of density [ ] to have some experience dealing with problems and hypothesis, and accurate data collection and interpretation of data. So we have a skills thread that runs through the eighth grade. But the content thread, who cares? As long as kids are liking what they're doing. (5/28/94)

The role of a teacher in such a classroom is multi-faceted. Margaret sees herself as a co-learner. "I have to change things often so that I am really learning with them. If I lose that enthusiasm, it doesn't work." (1/31/95)

My role can change depending upon what kind of an activity they're doing. So, I'm really a facilitator on a day like today. This is all stuff that we've prepared for, so I'm just kind of facilitating and keeping an eye on things to make sure that everything is safe in the room. And, I'm talking about scientifically safe. I don't think there's any big issue of emotional safety in there today, but, you know, you have to make sure that one lab partner isn't getting too aggressive with another one or something. I'm much more comfortable in that role than I am in what a lot of people would think is a traditional role of a teacher as a sort of fact-giver. (10/5/94)

Headlong into Inside Out

Among various scientific communities, a debate takes place about whether evolution proceeds at a gradual and steady pace, or is "punctuated", proceeding by series of steady state, and then dramatic change. Margaret's process of becoming a more effective multicultural science teacher has moments of each evolutionary view. Through some periods Margaret comforted herself with little changes, and even going back to some "solid science" of her former teaching style. The changes in her perception of the "the scientific method" is one example.

Traditionally, the scientific method is written in a five part system (PHEOC). In an objectivist view, PHEOC defines how science is done. At the beginning of the school year Margaret took special care to draw out the PHEOC method in a circular fashion, emphasizing to her students the looping nature of questions and answers. This indicated a more open, cycling vision of science, a vision of science that does not necessarily search for some predetermined knowledge and become fact. She stopped short, however, of giving ownership of the questions to students. It is interesting that after four years of the institute's work with the 3P's, she used the 3P's only in our discussions, not with her students. The content of experiments were still largely framed by Margaret, but she encouraged students to question pieces of what she has framed. Her view of students as adolescents permitted her to feel comfortable that this was the right balance.

> Problem posing is a tough one at this age level. I haven't done as much of the beginning to the end research type of thing with my students as I sometimes think I should. But then, I go "Well, come on now. These kids are only thirteen and fourteen years old." I mean, this is only a piece of their science education. (4/28/94)

In addition to her perceived constraints of the abilities of her students so early in their science careers, other factors restricted her from letting go and turning over more ownership of the construction of scientific knowledge to the students. Management issues, time, space and money were a major concern.

> It's really a tough one to have kids doing real open-ended research because when they pose a problem, do you have the space to take care of that? It's money at the right time and the right place that's accessible. If you've got a hundred kids, and they're all doing their own research, and they need stuff to do it properly, there's the limiting factor. Where does all that stuff go? I can't go any place else with my kids. It's like any other thing, it's money, space, and time. (4/28/94)

This perturbation phase lasted nearly a year. Margaret sensed that open-ended investigations would promote the kind of science that fit her evolving view of a multicultural science classroom. Yet, according to Margaret, money, space and time were real obstacles. When the variables and outcome of a lab experiment are pre-determined, money, space and time were not seen as insurmountable obstacles. It was the "unknown" requirements of an open-ended, student-centered project that caused Margaret to hold on to a certain degree of authority over the direction of a lab experience. To change from an objectivist view of science to one in which students create scientific knowledge with the collaboration of their teacher, was a quantum leap. But then, one day in early spring, a great spurt of "punctuated evolution" took place with her announcement, "I'd like to change my whole curriculum." A summary of the conversation that ensued gives the reader some sense of Margaret's "headlong" jump into changing her teaching "inside out".

There's always something different about the way I'm presenting it or maybe some little management thing that I'll change, but that's not important. I think that there's another major step that I have to make. We had a long discussion about kids doing original research in class and I really didn't think I could do that with my students because there's not enough space, financial support and not enough time. I think it was very specifically those three things that was keeping me from doing problem posing, problem solving, and problem persuasion. And, I've been thinking a lot about that since then. I thought about it a lot during the summer and I've been thinking about it this year. And, I am going to get into a little research with kids next year. I applied for one of the [proposal name] and I'm feeling real strongly that we're going to be accepted into the program. I think that will give us an option, one option for kids to do some original research.

I: Are you thinking of this for a special class? At one point, you had mentioned something like this for your advanced or gifted and talented.

I probably won't have a TAG [talented and gifted] assignment to my job next year. And that means that I'll have to do this research with my [regular science] classes. Isn't that too bad? [laughs] I think I'm ready to give it a shot.

I: Okay, so space, time, and money were your impediments. How are you feeling now about those?

I really don't know, because I haven't thought about it hard enough yet. But, it's one of those things where I'm just going to sit down and say, "We're going to give this a shot and we're going to see how it comes out. Tell me what you want to do, and I'll do my best to help you get some information on whatever subject." And, guide these kids through a research project... I'm just feeling that if I'm really going to be able to get at with this kids what I want to, how does science work? I have to give them the opportunity to do original research. Otherwise, they're never going to know. They can model all these experiments in my class until the end of the year and they won't really know how science works until they come up with their own question and their own solutions. And, money? I will find money. I figured out money, heck with it! This is the kind of thing that you can go to a lot of places and you can find money. People would support original research that students do. Don't you think? And, if it doesn't work, kids will still learn a lot. It will probably make me a crazy person, but at least it won't be boring. So, I'm kind of looking forward to doing it with all my students and not having that TAG assignment next year, so I can give every kid a chance to do it.

What Can We Learn From Margaret and Tom?

The issue as to whether or not a teacher's view of science effects classroom instruction is still in debate. Would a multicultural perspective based on social constructivism improve science education for diverse students? While a limited number of early studies have stated that the teacher's view of science is not a factor in classroom instruction (Klopfer & Cooley, 1963), the most widely held current view is that the teacher's view of science plays a role, but is mediated by a host of other factors. In accordance with this perspective, some findings indicate that there is no significant relationship between teachers' understandings of the nature of science and classroom practice (Duschl & Wright, 1989; Lederman & Zeidler, 1987). Alternately, there is research stating a direct influence on classroom practice (Brickhouse, 1990; Gallagher, 1991). I contend that the changes Tom and Margaret have made in their science teaching stem directly from and continue to be framed by their view of science. The extent to which a teacher's view of science is mediated by factors such as curriculum constraints and administrative policies (Lederman, 1992; Brickhouse & Bodner, 1992) is of lesser consideration for experienced teachers, who, like Tom and Margaret, are often in leadership roles. Of greater significance is the teacher's conviction and belief in the ability and need of students to learn science.

Tom has a rather unshaken belief that science is determined by its procedures, and that when students carry out these procedures, understanding will result. Students who come from "non-traditional homes and lifestyles" are perceived as less capable of learning, and of needing, in-depth scientific concepts. The primary modification that Tom has made to adapt his teaching for these students is converting lecture material into lab experiences. This particular lab approach to teaching science has several shortcomings for many students, in particular those from diverse backgrounds. One negative result of Tom's changing the route of information dissemination from direct transmission to indirect transmission is that it increases the level of abstraction. The multitude of uncertainties inherent in middle school lab experiments (i.e. hurried pace, unskilled maneuvers, unsophisticated, outdated, and cumbersome equipment) all contribute to a masking of the information purported to be held in the lab. If learning by doing is the objective, what is truly learned? This version of the process approach to science distances students from an essential understanding that science is culturally and sociohistorically constructed. Students conduct lab after lab, and yet, do not gain the appreciation that they can do science. The science that they have done was somebody else's science. Only a few students in Tom's classes are able to unravel the mystery behind the lab, and feel that they themselves can create knowledge. Those students, who fall behind with the series of lab write-ups, rely on their partners answers and work, and are otherwise un-invested in the long, "laborious" series of manual tasks, are the very students that Tom had intended to better serve.

Margaret's view of science as "one of many ways we have in our culture to find answers to questions" opened her up to possibilities to move beyond objectivism. The conviction that "all kid's will stretch themselves" provides additional foundation for Margaret's gradual shift to restructuring an "inclusive" multicultural science classroom. Margaret's process of change can be visualized as a spiral, consisting of two interconnected strands: a view of science education; and a view of the abilities of students. During the last four to seven years (since she began teaching at Prairie View) Margaret has experienced a period of accelerated growth. This growth was spurred by her pulling together a variety of experiences (multicultural science institute, professional science organizations) and strengthened self-realization in herself as a responsible advocate for children from diverse backgrounds. As her understanding of multicultural issues grew, her teaching practices altered in response to her new understandings. At points in the spiral, her belief in the abilities of her students had not had enough reinforcement for her to fully implement some of the "new" teaching techniques. At other points, she felt convinced that her students were able to do "better" science, but she did not have the pedagogical skill to "pull it off". But, on a few occasions, the two strands joined, and she felt like she was giving her students "the best she could". After that brief and rewarding encounter, Margaret looked for another way to move up the spiral.

Working with Tom and Margaret revealed that addressing a teacher's view of the nature of science is a primary and first step in science education reform. Techniques and strategies, the "quick-fix" of many inservice programs, will not bring about the change required to provide our diverse student population with high quality science education. Teaching techniques and strategies must be framed by a perspective that values students' diverse ways of knowing. In order to develop such a framework, sustained reflective collaboration among science teachers and researchers is a promising path.

While the number of "minority" students continues to increase, the gap widens between the cultural and socioeconomic mismatch of science teachers. As pointed out earlier, inservice programs to assist science teachers in bridging this gap between cultures, class, and scientific world view, are few. This research supports the stance that the gap can be bridged. "Monocultural" teachers can be effective science teachers for multicultural classrooms. One of the determining factors of whether or not teachers can expect to make such a change in their teaching will depend on their view of knowledge. Ladson-Billings (1990a, 1990b, 1994) and Winfield (1986) contribute to the literature that is describing the complex art of teaching students of color. Among the factors that enable teachers to reach diverse students are: the teacher's conception of self and others; their interaction with students and community; and their view of knowledge. These successful teachers hold a view of knowledge that "is continuously recreated, recycling and shared by teachers and students. It is not static or unchanging" (Ladson-Billings, 1994, p. 81). The teachers in Ladson-

Billings' study hold fast to the belief all students can learn. Successful teachers then create a classroom where this belief is transformed into an everyday reality.

Because of the technological power and high status of science in our society, science education will continue to be a prominent component of educational reform. What would multicultural science education look like? This question depends on our collective resolve to ask: "Are we willing to seriously look at models other than objectivism to frame science education reform?" "Is there room in the discourse to openly criticize the role of objectivity and rationality in science?" "Are we able to discuss the implications of the purpose of science education based on social constructivism?"

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