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ABSTRACT

A new interdisciplinary science and mathematics course for preservice elementary/special education teachers at LaSalle University (Pennsylvania) is examined. "Explorations in Science and Mathematics" was designed to develop core skills, critical thinking and communication, understanding of math and science as real-life activities, confidence in the subject matter, and metacognitive awareness of the learning processes involved. During the pilot semester, a constant comparison method was used to identify topics studied, engagement, beliefs and attitudes about mathematics and science throughout the course, comprehension of course content, and connections drawn to future teaching. Primary sources of data were interviews with faculty, notes and records from the course planning process, course documents, comprehensive portfolios of all student course work, and focus group interviews with students conducted at the end of the semester. Categories of Silence (knowing in action), Received Knowing, Subjective Knowing, Procedural Knowing, and Constructed Knowing from "Women's Ways of Knowing" became important in the construction of rubrics. Students who did well tended toward Procedural (connected) and Subjective ways of knowing. Discrepancies between faculty and student expectations indicate that pre-existing negative student attitudes are more resistant to change than the literature on teaching reform initiatives indicates. (Includes 3 tables and 17 references.) (LH)

ACTIVE AND ENGAGED?
LESSONS FROM AN INTERDISCIPLINARY AND COLLABORATIVE COLLEGE MATHEMATICS AND SCIENCE COURSE FOR PRESERVICE TEACHERS

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Context of Study

Science and mathematics education has been an area of national concern and activity for over a decade, beginning with the publication of *A Nation at Risk* (National Commission on Excellence in Education, 1983). During this wave of reform, the focus has shifted from producing more scientists and engineers to developing basic scientific and mathematical literacy in all students (Rutherford & Ahlgren, 1989; National Research Council, 1996). The preparation of elementary teachers is a critical component (Sykes, 1992). Many students' attitudes and conceptual understandings are formed in elementary grades. A cyclical pattern has developed in which the students who go on to become teachers have been poorly prepared in their own schooling (Coble & Koballa, 1996). They generally avoid math and science during their pre-service training and are poorly prepared to teach those subjects, producing another round of poorly prepared students to become teachers, and so on.

With the foundation of its Institute for the Advancement of Mathematics and Science Teaching in 1994, La Salle University committed itself to improvement in mathematics and science teaching, K-16 . During planning for this interdepartmental program, university faculty identified an intervention with pre-service elementary teachers as an area that could yield great benefits for large numbers of students, and focused their efforts on revising La Salle's elementary/special education major's science and mathematics preparation. In this paper, we examine and report on a new integrated science and mathematics course for pre-service, elementary/special education teachers. Explorations in Science and Mathematics (IMS 160) was developed by a team of education, science, and mathematics faculty over a two-year period with the following goals in mind:

- Provide students who are preparing to teach elementary school with a core of scientific and mathematical concepts and skills
- Develop skills in critical thinking and communication
- Develop understanding of mathematics and science as real-life activities

- Overcome existing math and science anxieties
- Develop metacognitive awareness of mathematics and science learning processes

The course was designed in accord with research that suggests that learning requires students to actively construct their own understanding of concepts and relate those concepts to their real-life experience (Brooks and Brooks, 1993; Nolan and Francis, 1982; Zemelman, Daniels, and Hyde, 1993), that this can be done through close mentoring by more knowledgeable teachers as well as through peer interaction (Rogoff, 1984; Rogoff & Gardner, 1984; Tobias, 1992; Vygotsky, 1978), and that science, in particular, requires students to actively engage in inquiry confronting their own naive theories (American Association for the Advancement of Science, 1993; Gardner, 1991; National Research Council, 1996). Active and personal approaches have also been shown to increase the success of women in science and mathematics (Belenky, Clinchy, Goldberger, & Tarule, 1986; Tobias, 1990), an important consideration for our predominately female population of pre-service teachers.

In this paper, we will:

- Describe the course structure, teaching methodology, and content as it has evolved.
- Analyze course assignments and expectations and identify the important issues and dilemmas faced by faculty teaching the IMS 160 course.
- Evaluate students' engagement with course activities, students' beliefs and attitudes about mathematics and science across the course, students' comprehension of course content, and connections drawn by students to their future teaching.
- Use the data analysis to suggest assessment rubrics that address both student and teacher issues and make visible faculty expectations and views of knowledge.

The IMS 160 Course

IMS 160 was offered for the first time in the fall of 1995. The pilot section was taught by four faculty, a chemist, a physicist, a geologist, and a biologist. The course met twice a week for three-hour sessions to enable active investigation. Of the five goals listed above, developing positive attitudes toward math and science was considered one of the most immediate needs. Everyone involved in planning and implementing the course believed that a curriculum based on the students' levels of understanding and a teaching methodology employing active or hands-on learning approaches would be sufficient to help turn around the students' views of math and science and themselves as math and science learners. In light of this, the course was presented as a series of investigations into a selection of scientific and mathematical topics including estimation, motion and forces, states and compositions of matter, and life-cycles. Meta-topics included measurement, methods and modes of scientific and mathematical inquiry, data analysis and presentation, dimensional analysis, and linear and non-linear relationships. This material represented a sampling of the full curriculum, which was implemented when the course was expanded to a full year.

The course was structured into a series of topical units; initial investigations completed by the students provided the opportunity to review basic skills. As the semester progressed, the investigations included more complex problems. The course began with ice-breaking activities that had students using their powers of observation and logic and with an autobiographical essay reflecting on a past experience with math or science that was significant to each student. Throughout the course, students were asked to reflect on their class activities in a daily journal and they were asked to write a weekly essay on science or mathematics in their lives. Each day, students participated in several activities, usually part of an ongoing investigation. In addition to setting up and running experiments, class time was used to discuss experimental results and analysis. The twelve students in the class worked primarily in teams of four. As students worked, the faculty circulated among them, monitoring progress and facilitating discussion and investigation through open-ended questioning.

Faculty worked as a team throughout the semester and all were present and active in the classroom nearly all of the time. In class, they made a specific point of trying not to answer questions, but to guide students to ways of finding the answers for themselves. All students were encouraged to offer their perspectives in discussions and multiple approaches to problems were explicitly encouraged. About halfway through the course, a field trip to a stream to make observations and pose questions followed by experiments with laboratory stream tables to attempt to answer a few of those questions introduced students to the elements of planning, controlling, simplifying, and modeling that are central to scientific investigation. During the last half of the course, in addition to their class work and discussions, students cared for and observed plants and animals in the classroom and groups of students conducted research projects outside of class that involved experimentally investigating some aspect of science or mathematics of their choice. Each group of students worked with one of the faculty as a mentor during this project. At the end of the semester, students reported what they had learned to the rest of the class.

This course is being offered again in the 1996-1997 school year. This time we are offering two sections, each with nineteen students enrolled and three faculty instead of four on the teaching team. As described later in the discussion, the course has evolved in response to both student and faculty concerns over some of the issues raised in this paper, however, the basic approach of hands-on interdisciplinary instruction remains the same. The profile of student and faculty responses that we describe below has also remained essentially the same.

The Study of the Pilot IMS 160 Course

Describing teaching and learning in the IMS 160 course means that we will be talking about an ever changing entity. We have investigated teaching and learning during the pilot semester (fall, 1995) in detail using qualitative and interpretive methods. We explored teaching through structured faculty interviews and analysis of course materials. We looked at evidence of student learning by closely examining the written products produced by students and comparing these with transcripts of in-depth, focus group interviews conducted at the end of the pilot semester. We used a constant comparison method of analysis to identify topics that were studied, student engagement with course activities, student beliefs and attitudes about mathematics and science across the course, student comprehension of course content, and connections drawn by students to their future teaching. We then used the data to develop assessment rubrics. It is our intention that these rubrics will be available in the future to faculty to guide them as they analyze the level of a student's participation and learning. The rubrics should be useful for helping faculty identify what students are doing, what it means in terms of the course and student learning, and what the next level of achievement would look like for a given student.

Data Sources

The primary sources of data were interviews with faculty who have taught the course, notes and records from the course planning process, course documents, comprehensive portfolios of all student work generated during the course, and focus group interviews with students conducted at the end of the semester. Units of analysis included both the individual student and the group as well as individual activities and "unit studies" within the curriculum.

Data Analysis

Faculty interviews, handouts for assignments and class activities, and faculty responses to student work were examined and analyzed to uncover expectations for student engagement and the ways of knowing which were valued or expected by faculty[1]. This analysis of teaching and expectations prepared us to explore the matches and mismatches between faculty expectations and student performance or expectations.

In addition to looking at teaching, we also looked closely at artifacts of student learning. Each student portfolio was read several times. These portfolios included the Scientific Autobiography, Science in the World Around Us journals, daily class summaries, data collected

[1] During our analysis of the student data, we discovered many connections between our data and the *Women's Ways of Knowing* theory. The ideas about ways of knowing that we drew upon in our analysis of faculty data is explained more fully in the description of the analysis of student data.

during class investigations, and observations from the caring for plant and animal experiences. The portfolios, faculty assessments, and student grades were used to rank students as either strong, average, or weak in terms of their engagement and learning. One student each from the strong, average, and weak levels were selected as being typical, and their portfolios were charted and analyzed in full.

In addition, the assignments for written work were divided into two broad categories based on features of the assignment. These were *personal narrative writing* and *class work based explanations of learning*. Personal narrative assignments primarily addressed issues of student experience and beliefs about math and science in their lives. These assignments included the Scientific Autobiography and Science in the World Around Us during the pilot semester. Class-work based explanations of learning primarily communicated the process, results, interpretations of student investigations, as well as the learning that resulted. In the pilot semester, these included daily summaries of class investigations and the caring for plants and animals assignment. These broad categories of assignments were used in our analysis of the student portfolios as well.

Each piece of writing was analyzed and charted by primary topic addressed, engagement, affect/beliefs, accuracy of content addressed, and connections to the student's future teaching. Topics of investigation provided the framework within which students' reactions to activities could be compared. Indicators of engagement include statements where students talk about specific ideas, how these ideas are similar to or different from their prior understanding of the topic, and changes in their thinking based on the experience of the course. Students were deemed to be engaged to the extent they wrote about specific ideas, personalized the knowledge, identified discrepancies between the new knowledge and their previous thinking, made connections, self-reflections, or analogies to other knowledge, or raised and pursued questions that came out of the investigation or writing. In statements of affect or beliefs, students either talked about what they believed mathematics or science to be, or about themselves as learners or doers of mathematics or science. Evaluation of student content learning included review of student work on the mid-term and final exams as well as analysis of the entire portfolio for accuracy of statements about scientific concepts investigated and the scientific quality of questions raised. Indicators of connections to future teaching included students' statements about what they would do in their classrooms when they were teachers. These were often linked to statements of affect or belief.

The analysis of the portfolio data was then compared with what each student said about the course and her learning during the end of the semester focus group interview. As the data analysis progressed, we were struck by the resonance between the statements of the IMS students in their autobiographies, portfolios, and interviews and the theory of knowing developed by Belenky, Clinchy, Goldberger, and Tarule in *Women's Ways of Knowing* (1986). Their categories of Silence (knowing in action), Received Knowing, Subjective Knowing, Procedural Knowing, and Constructed Knowing as reviewed by Stanton (1996) provide another set of lenses through which we understood the students' engagement (Table 1). These categories became important elements in the construction of the rubrics.

It is important to note that in working with the epistemological categories from *Women's Ways of Knowing*, we do not use them as a developmental hierarchy (Goldberger, 1996) nor reify them as labels (Stanton, 1996). Rather, we see their power as lenses for uncovering matches and mismatches among the ways of knowing used or reported by the students and those valued by the instructors and embedded within course activities.

Results from Analysis of Faculty and Course Data

The expectations of the four faculty members who taught the pilot course were investigated by reviewing assignment handouts from the course and by interviews with faculty members regarding their sense of the purpose of each assignment, their criteria for assessing a quality assignment, their sense of how easy or difficult it was to assess these assignments, and their sense of students' approaches to and possible stumbling blocks in completing the assignments. The assignments reviewed are the same ones selected to evaluate student outcomes:

Table 1

Women's Ways of Knowing

Silence (knowing-in-action)
Knowledge: Gets knowledge through concrete experience, not words
Mind: Sees self as "deaf and dumb" with little ability to think
Mode: Survives by obedience to powerful, punitive Authority
Voice: Little awareness of the power of language for sharing thoughts, insights and so on

Received knowing
Knowledge: Knowledge received from Authorities
Mind: Sees self as capable/efficient learner; soaks up information
Mode: Good listener; remembers and reproduces knowledge; seeks/invents strategies for remembering
Voice: Intent on listening; seldom speaks up or gives opinion

Subjective knowing
Knowledge: Springs from inner sources; legitimate ideas need to feel right; analysis may destroy knowledge
Mind: Own opinions are unique, valued; fascinated with exploring different points of view; not concerned about correspondence between own truth and external reality
Mode: Listens to inner voice for the truth that's right for her
Voice: Speaks from her feelings/experience, with heart; journals; listens and needs others to listen, without judging

Procedural knowing
Knowledge: Recognizes different frameworks, realms of knowledge; realizes positive role of analysis, other procedures for evaluating, creating knowledge
Mind: Aims to see world as it "really is"--suspicious of unexamined subjective knowledge
Mode: (Separate): logic, analysis, debate
(Connected) empathy, collaboration, careful listening
Voice: (Separate): aims for accuracy, precision; modulates voice to fit standards of logic or discipline
(Connected): aims for dialogue where self and other are clearly and accurately understood, even where different

Constructed knowing
Knowledge: Integrates strengths of previous positions; systems of thought can be examined, shaped, and shared
Mind: Full two-way dialogue with both heart and mind; seeks truth through questioning and dialogue
Mode: Integration of separate and connected modes
Voice: Adept at marshaling/critiquing arguments as well as empathetic listening and understanding; speaks/listens with confidence, balance, and care

(From: Stanton, A., 1996).

personal narratives (Autobiography and Science in the World Around Us) and class work-based writing (daily journals, plant and animal observations, and in-class essay exams).

Our analysis revealed a fairly consistent pattern of expectations across the assignments in the course. In the personal narrative assignments, faculty generally held few specific expectations for format and expected to see a variety of approaches and attitudes. In contrast, faculty had well-formed expectations for content and intellectual activity. All of the faculty expected students to use these assignments to become aware of their own personal experiences and the experiences of others. Faculty expected that the Science in the World Around Us assignments would function as an outlet for curiosity or creativity on the part of students. Faculty expected students to extend what they had learned to new situations and evaluate presentations of course concepts in the media and other sources. Two faculty expressed the expectation that students should write with correct style and should follow directions. Faculty also saw both personal narrative assignments as tools for assessment and information gathering about learning by both the faculty and the students. The autobiography was expected to bring attitudes and feelings out into the open at the beginning of class and give students a sense of common ground. They were also intended to give faculty information on student attitudes and concerns and form the groundwork for the rest of the semester.

Faculty reported a number of consistent student responses and stumbling blocks for these assignments. Faculty felt that students generally did not seem to perceive that these assignments were useful and found them a burden. Faculty felt that this perception contributed to student complaints about the amount of work required in the course. Faculty noted that many of the students limited the content of their Science in the World Around Us writing to comfortable topics and often offered little more than summaries of their sources. In the faculty's view, students generally had difficulty relating their Science in the World Around Us sources to other science or math materials or experiences. A few students had mechanical problems with their writing.

In terms of the Women's Ways of Knowing categories, the faculty expectations for the personal narrative assignments asked students to demonstrate either a connected, procedural way of knowing or a constructed knowing (See Table 1). Faculty expected that the students would see the analysis and systematic evaluation of their everyday experiences and self-selected readings as important ways to increase their knowledge of mathematics and science. In addition, they expected that students would see the importance of "seeking truth through questioning," establishing a "dialogue where self and other are clearly and accurately understood," and collaboration based upon careful listening to others (Stanton, 1996).

Faculty had generally similar reactions to the class work-based assignments. These included the daily journal assignment and caring for plants and animals assignment, as well as two in-class examinations. In these assignments, faculty again expected students to follow directions and to write clearly and correctly. More importantly, faculty expected students to be able to draw together class activities, prior experiences, and readings to develop and then critique new understandings. Faculty also expected students to look for patterns, draw connections between different things they had learned, and even to express joy or wonder, or to take a chance. In the daily journals, faculty expected students to show evidence of thought about their class experiences, to use writing to create knowledge by connecting class experiences and readings with their own thinking, and to engage in questioning instead of accepting what was read or heard. The idea was also expressed that these assignments should function as a foundation for succeeding classes. In addition to reflections and connections with the course content, the daily journals were seen as a way to continue the process of monitoring and exploring students attitudes about math and science through the semester. The exams were seen as a more objective activity. Extension and connection were important objectives and students were also expected to demonstrate their ability to use correctly the techniques presented in class.

The faculty sensed that students reacted to the daily journals in much the same way they reacted to the Science in the World Around Us assignments and with many of the same stumbling blocks. They seemed to put in only enough effort to put words on the page and primarily provided narrative summaries rather than analysis. When faculty started giving daily feedback on these journals as a way of clarifying expectations the level of reflection improved, but only to the extent that some students would pose questions. There was rarely any attempt to answer those questions and the questions were primarily queries for information (Why...), rather than testings of understanding (What if...). It was the unanimous sense of the faculty that students did not understand the rationale for doing the daily journals and found them burdensome. Some faculty also felt students took a lackadaisical approach or lacked willingness to engage in the assignments, probably as a result of the lack of perceived benefit and lack of understanding of the goals of the assignment. Faculty sensed that the assignments were too vague to the students and that the students needed some concrete examples. Faculty felt that the exams were clearest and least frustrating to the students. Although there were strong differences of opinion among faculty about the utility of tests in this course, faculty sensed that the students accepted the exams more readily than some of the other assignments.

In terms of the Women's Ways of Knowing categories, the faculty expectations for the class based explanation assignments asked for students to demonstrate either a separate, procedural way of knowing or a constructed knowing. For these assignments accuracy in observations, data recording, and written presentation as well as questioning, forming a logical (scientific) argument, and making careful considered (balanced) judgments were expected.

Assessment and grading were the most difficult issues facing the faculty who designed and taught this course. Faculty found the daily journal and the Science in the World Around Us to be difficult to evaluate. All faculty were more comfortable with exams and with the autobiography, the former because of their well-defined expectations and the latter because grades were not assigned. Students were asked to comment on each others autobiographies and one faculty member noted that students provided only positive comments to each other. This behavior was a precursor to a lack of questioning in class and in any of the class-based activities. One of the faculty also commented on the difficulty of providing critical feedback without eroding the confidence that faculty were trying to develop in the students. Faculty found grading particularly difficult when several faculty reviewed an assignment and had to arrive at a consensus grade. Although faculty shared a common point of view in what they saw as important in nearly all of the assignments, they often differed on the weight that should be given to different aspects of their criteria.

Results from Analysis of Student Data

Twelve students enrolled in the IMS 160 course during the semester of the study. Of the twelve, 3 (Sarah, Janice, and Karen) were classified as strong students, 3 (Kim, Jennifer, and Patrice) as average, and 6 (Sheila, Maria, Nicole, Melissa, Ellen, and Susan) as weak, based on student performance, analysis of portfolios, and faculty rankings. Of the students in each group, Janice's, Patrice's, and Sheila's portfolios were selected for the in-depth analysis.

Janice:

The pattern that emerges from the analysis of Janice's work is that she was fully engaged in most aspects of the course, except perhaps in the raising of her mealworms which she described during the interview as "boring." She described herself as not confident at the beginning of the class and worried about her ability to learn the content of "chemistry, biology, and physics which is just a bad thing for me." She also was concerned that she might feel intimidated by the instructors. Instead of being intimidated, she found that she was comfortable with the format of the investigations and liked not having a textbook most of the time, although there were times when she would have found a text useful as a reference book. She also liked the discussions that were woven throughout their investigations. She found it especially helpful in coming to understand what had happened when different groups' investigations led to different results.

Overall, she saw the course as giving her "basic" knowledge about scientific topics and giving her a base to continue her own learning. In her interview she said,

> I think what it gave me personally is more of a basic science. Because some of the stuff we went over, like about atoms even, I didn't understand at all. Just the other day we did the heating thing. We did why a liquid turns to steam and what happens and all that kind of stuff. I could never have explained that to a little kid. I would have been like that's what happens. But now I think it gave more of a base to work off of.

Systematic analysis of Janice's work in her portfolio reveals that she engaged all aspects of the course with a personal commitment. She believed that her view of herself as competent or incompetent would have an impact on what she would learn. In her references to what she as a teacher should provide for children, she often focused on helping the children have the confidence to learn.

Personal Narrative Writing

In her personal narrative writing, Janice took the personal seriously. Her autobiography was about three important influences on the way she approaches math learning. She wrote about her parents and the way that her relationship with them has supported her in learning math, an elementary teacher who told her she would never be good at math, and her work tutoring a third-grade boy. She chose to write in a highly personal voice talking about her beliefs about people, "I am a firm believer that if you are told something long enough, you start to believe what people say." She contrasted her approach to helping Marcellus and being supportive to him with the way Miss Edison had treated her. Janice did not include any content information in her autobiography.

Janice approached the Science in the World Around Us journals from a similar personal perspective. She chose events from her everyday life to write about in a personal and speculative way. Janice discussed scientific content in all but one of her Science in the World Around Us assignments. These discussion took the form of a narrative of real or fictional events surrounding scientific phenomena. In addition to her personal descriptions of these events, Janice sometimes related them to other experiences from the IMS class or from her past, and in about half, she briefly described her understanding of underlying principles. These understandings were usually from her pre-existing knowledge and many were only partly correct. In a number of cases she expressed disbelief or skepticism about the events she was describing, generally without regard to whether the events were factual or fictional.

In the latter part of the semester, Janice's Science in the World Around Us entries contained questions rather than explanations. She raised many questions but seldom attempted to answer any of them or to pursue additional resources. For example, in one journal she wrote about how when she changed toothpaste brands, she noticed that the new one burned her tongue. She listed the ingredients in the toothpaste she used, wrote about her dentist's recommendation to brush her tongue, and compared the reaction of her tongue to the reaction her skin has to a new soap. She wondered why switching products (either soap or toothpaste) might have this effect on her skin and why all products are not safe for all people's skin. This journal, however, does not go beyond wondering what caused the burning sensation. She does not, for example, try to find out which ingredient might have caused the reaction. She concludes by saying, "I don't understand this at all. Maybe I should use all natural products."

Janice made few connections to teaching in these journals. In her first journal, Janice had written about watching a young boy watch a squirrel. In her speculation about what he was doing, Janice noted that she believed that children need time to explore things without being forced to. In another journal, she wrote about the importance of having animals in the classroom for children to study.

Class Work Based Explanations of Learning

Janice's work on the class work based explanations of learning combined discussion of the substance of the investigations with a discussion of how she felt about the work and what it meant to her. Janice regularly completed her class summaries. She wrote about the major topics addressed in each class by focusing on the content material and on the events in class that led to discoveries. She listed the questions she and her group addressed, included descriptions of what she learned and insights she came to during class discussions, often included data from the investigations, made connections to readings, other events, or what she had previously learned, and raised questions or pointed our areas where she may have been confused in her understanding. Almost all of her entries had a good level of detail and there was a noticeable increase in the amount of quantitative detail and in the level of analysis of experiments in class. After observing falling balls one day, she wrote:

> The only thing I don't understand is if this is true, that the weight is not a factor [in how fast a ball falls], then why does a book fall faster than a piece of paper? I wonder if you crumpled the paper into a ball if it would fall at the same speed as the book. I should try this.

She challenged her own understandings and also explanations given by the faculty in following entries, although she didn't always have confidence in herself. After one of these entries, she asked "IS THIS RIGHT?" She also referred to metacognitive content in a number of her entries.

The caring for plants and animals assignment was one area where Janice showed less engagement. She was forthright in her explanation of why. She was not excited about caring for mealworms. Although she was not excited about the project, Janice and her partner presented a plan for caring for their mealworms that was based on thorough and effective research including talking to a teacher who kept mealworms in class. Once they actually had the mealworms, their initial descriptions were entirely qualitative with descriptions of color and sketches of worms that show no detail other than the outlines. Janice's feelings about the "disgusting" worms clearly did not inspire lengthy or careful observation. Their plant sketches were also schematic, though they did take some data about height. By the end of the semester, however, Janice's observations of both the mealworms and plants were more detailed. She also speculated about why some of her mealworms were yellow and others were black, why at one point all of the mealworms appeared to be dead, and what the life cycle of a meal worm is. She also noted what she did not understand about the life cycle of the meal worm.

In terms of her beliefs about mathematics and science, the class summaries included little in the way of direct comments. One of the few examples of beliefs or affect was when she again commented that animals are valuable learning tools for children. In terms of connections to teaching, her one direct comment was when discussing the Brownian motion demonstration which she had very much enjoyed. She said that using the demonstration with kids would help them develop and understanding of the concept much more than reading about it in a book would.

Using Stanton's summary of the Women's Ways of Knowing framework (see Table 1) to look at both Janice's view of herself as a mathematics and science learner and her work in the portfolio leads to seeing her as using predominately a Procedural way of knowing and in terms of mode and voice preferring a connected stance. She shows a respect for knowledge in mathematics and science and sees herself as creating knowledge through her investigations. She enjoyed the collaborative approach used in the course and was interested in dialogue with her peers and in understanding why they came up with different results to some of their investigations. She believed that there were procedural differences that could be used to explain differing results.

Patrice:

The pattern that emerges from the analysis of Patrice's work is that her engagement in the course was more distanced than Janice's. In the autobiography, journals, and "Science in the World Around Us," she wrote in general terms and used few specific details. During the interview, she acknowledged that she did not always put in the kind of time and thought that the projects and writing required. From her perspective, it was a matter of time. She mentioned that she felt rushed on several of the projects. She found it difficult to settle on topics and then ran out of time before she was able to complete the work. She would have preferred to have fewer assignments and to have done more with each.

Although overall Patrice's engagement with the course was uneven, there is evidence to suggest that it is likely she was more engaged during class time than through her written work. During the interview she told one story where she had made direct use of her experience in the course in her field work for an education class. In addition, she reflected on how the IMS course experience and her field work came together to give her ideas for ways she would teach the same topic in her own classroom. Patrice said,

> In my field experience, this class really came in helpful at one point. Because I was in a fifth-grade class, and they were learning vertebrates and invertebrates. And I just happened to be there once a week and it happened to be on a day where they were learning metamorphosis. None of the kids were really paying attention. Their teacher really wasn't the best, and he really didn't go into many things or give them any examples like a caterpillar. He said like a caterpillar goes into a cocoon and becomes a butterfly. For our project, me and Sarah, were given little caterpillar larva, and we had to take care of them until they turned into butterflies. We had to do observations. We saw the entire process. And I had a group of kids, and they had just taken a test on it and they did horrible. None of them even knew what half the stuff was. It just happened that my butterflies the day before that the caterpillars emerged from the cocoon and had turned into butterflies. So I got to use that and I think that would definitely be a project that I would use. Even if I just sit it in the class and have the kids journal about it. Like everyday sat aside, if I'm teaching that, every single day have them observe for five minutes what they see differently in the terrarium and keep it in a journal. I think they could learn the concept much better.

Overall, two issues emerge as central in Patrice's thinking about what worked for her in the course. First, is the importance of what she calls "hands-on" experience. She is clear that she learns more when she sees things for herself as opposed to reading about them in books. She enjoyed both field trips (to the stream and to the Franklin Institute) as well as what she called "the experiments" (the daily investigations) and would have liked more individual projects like her whale project. The second issue was the relationships that she developed with the four instructors. Throughout her group's interview, she mentions individual instructors by name and talks about the importance of what they did to help her.

Personal Narrative

In her personal narratives, Patrice usually wrote about connections between teaching and learning. She wrote about experiences with science themes, but focused on how useful they could be in teaching rather than on the science content. Her autobiography was about her early love of science and the way that changed when she had a bad biology teacher. She claimed that the bad biology class was one of the reasons she decided to become a teacher rather than a marine biologist. It is also clear from both her autobiography and her Science in the World Around Us journals that she believes science teaching should be "hands-on" and fun, although she never clearly specifies in the autobiography what either of these concepts mean to her. In addition, almost all of her narrative writing, including large portions of her autobiography was focused on students with somewhat impersonal discussions of how “they” learn, what she wants “them” to experience, and how experiences will make it easier for “children” to learn.

In her Science in the World Around Us journals, Patrice wrote about connections she made to current courses (Religion and English), a television program about wild animals and articles from magazines and newspapers. She talked about why she found each topic interesting. In the case of the religion class, Patrice wrote about how the IMS field trip made it easier for her to relate to the professor's comparison of the path of Taoism to the path of a stream, although she does not question apparent inconsistencies between the professor's comments and what was seen on the field trip. She also wrote about how many of these programs or articles might be used to stimulate curiosity in elementary school children. For example, for one *National Geographic* article about squirrels, she wrote about one of her favorite grade school science projects, feeding and watching birds. She then said, that she thinks children would find a similar project feeding, watching, and recording their observations about squirrels to be "fascinating."

Class Work Based Explanations of Learning

Patrice's approach to the Class Work Based Explanations of Learning differed from her approach to the Personal Narratives. At the beginning of the semester, she seldom made connections to what she might do as a teacher. Rather, she usually summarized in general terms the process used by her group as they worked on their investigations. She seldom presented any data or raised additional questions. She did describe her expectations and her relevant prior experiences and she sometimes tried to predict the outcomes of experiments. She was strongly committed to these prior experiences and, in one case, she led her group in revising the experiments in order to produce the expected results. Unexpected results were seen as failures to be rationalized, "...we feel that for the first time dealing with anything like this we did not do that bad." After discussing experimental design for stream table experiments, Patrice wrote "We're not too sure that if we were given an experiment dealing with a completely different subject topic we could use anything we learned from our stream experiment." Patrice was clearly not drawing connections between topics and the lack of prior experience in each specific topic was seen as a handicap. As seen above, Patrice's voice in these journals is almost always plural.

Later in the course, her daily summaries started to contain more connections to teaching and evaluations of her own learning. In one entry, she talked about learning about "constructivism" in one of her education courses and how the IMS course was the only example she could think of for this approach in her own experience. She also began to make connections to what she would do as a teacher and mentioned adding several of the investigations to her "bag of tricks." In one case where she clearly understands a concept that had been illustrated in several related ways, she writes "This is definitely a demonstration I would use in my teaching career. It's amazing that connections can be made so clearly." At other times, she reports similar feelings whereas her summaries do not suggest that she has learned the concepts.

In writing about her projects caring for pea plants and butterfly larvae, her approach was much less personal. In this set of writings, she stayed with describing her plants and animals and making some predictions about what would happen to them. In the most interesting of these observations, Patrice describes her decision to release the butterflies because she could not bear to see another one die. She sees releasing them as giving them "at least some chance of survival." While not a researched or rational response, it was more personal than most of her other writing about her work for class.

Using Stanton's summary of the Women's Ways of Knowing framework (see Table 1) to look at both Patrice's view of herself as a mathematics and science learner and her work in the portfolio leads to seeing her as most often using a Subjective way of knowing. She likes learning for herself through her own activity, is interested in different points of view, and speaks from her feelings and experience. She is not particularly interested in analysis of data or details; rather she learns from doing what feels right.

Sheila:

The pattern that emerges from the analysis of Sheila's work is that she showed little engagement in most aspects of the course. She described herself as often lost during class discussions which as a result she described as "too in-depth" and off the central topic. In response to Karen's comment that a lot of things were left up in the air but what they covered they had covered completely, Sheila said,

> Too completely sometimes. Like one time we had a discussion, I don't know what it was, the bird analogies ... The same topic went off on a tangent for like fifty minutes. After we were done, I don't think anybody understood what we were talking about.

During the interview Sheila mainly commented on procedural aspects of the course rather than talking about content or what she learned in any specific terms. Her comment on the organization of the class and her disappointment that the teachers did not function as authorities who knew exactly what they were going to do at all times is also revealing.

> Another thing that bothered me too was organization of the class itself, because each day they would come in and say we aren't quite sure what we want to do today, but ... They'd just go like day-by-day with what they wanted to do. And if they had like a syllabus it would have been so much better at the beginning of the semester. Like before we were writing journals, but we weren't doing them for every class. Then all of a sudden they said we had to do it for every class. That is added work we have to do that we weren't expecting. All of a sudden all of this work came to us, and we couldn't handle it. We just had so much work at the end of the class, and I don't understand.

It is interesting to note that it appears this was Sheila's opinion and was not necessarily shared by the other students. The next speaker, Nicole, disagreed and called the course "pretty organized" considering how new the course was. Others picked up on Nicole's conclusion and then shifted the conversation.

Sheila's only story about learning reveals that she did not develop any new strategies or approaches to independent learning or thinking things through prior to trying things out. She told the story of one of her gerbils,

> We had to take care of these animals and these plants. We, me and Jennifer, my partner, were in charge of these two gerbils and I learned a lot about gerbils. Because we had like permission to take them home in our dorms because we had to feed and water them and everything. So I take him out, right, I kept hold of his tail because I didn't want him to get loose. He was really jumpy and they will like fly anywhere. So, I was like holding on to his tail. All of a sudden part of the tail comes off. Gerbil running around and I'm holding a piece of the tail of my gerbil. I was like going hysterical because I had no idea that that was normal. They grow their tails back. But I was hysterical, I had no idea, so that's something I learned.

Sheila summed up what this story meant to her by saying, "It's something I learned. And teachers always have animals and plants in their classroom. Always expect the unexpected." From this example, and her constant references to being confused or "dumbfounded" by the mysteries of science in her journals, it is clear that Sheila does not see herself as someone who learns through systematic inquiry or reading. She doesn't say for example, "That as a teacher she would need to do her homework and learn about what the animal needs before bringing it into her classroom."

Personal Narrative

In her personal narratives, Sheila often revealed confused or superficial thinking. Her writing was not clear. In her autobiography, she wrote about why she became an elementary/special education major. She talked about children who are born with "deformities" and went on to explain that through her experience as a buddy to handicapped teenagers while in high school, she had learned to respect "handicapped individuals as human beings." She linked the causes of their deformities to what we can learn from science. A number of statements in her autobiography suggest that Sheila has an idea of science very different from her instructors. She seems to see science as a subjective field in which ideas are judged by what feels right or "makes sense."

In her Science in the World Around Us journals, Sheila usually summarized her understanding of the content of her selections. Her selections usually related to children; for example, she often wrote about "Kids Talk"[2] questions taken from the *Philadelphia Inquirer*, but she did not go on to make connections to what she might do as a teacher. It is also important to note that her writing was not accurate and she often misused the concepts she wrote about. In one entry she said that she believed, "that how a teacher demonstrates concepts depends on how easily a child will grasp the information."

When Sheila does ask questions in her Science in the World Around us entries, she sees the answers to those questions as intuitive at a level that she is incapable of achieving. In one entry she is "dumbfounded" by the idea that she is standing on two-hundred million year old rocks, but never questions that information or how it was derived. In another she asks a series of questions about snow, freezing rain, rain, and their respective colors, but never follows up on instructors' comments. In many of her entries she recounts ideas that come from authorities. In

2 "Kids Talk" is a weekly feature which answers children's questions about science and nature.

one she hears a doctor on the television news say that going outside in winter without a hat or with wet hair does not cause colds. She responds that she now tells people that colds don't come from that. Although she seems to readily accept information from external sources, some of those ideas were never internalized. A week before the end of the course she writes that the formation of stars is "just another one of the scientific mysteries (for myself) of the universe" just a few sentences after she had summarized the explanations given by experts in the Kid's Talk column.

Class Work Based Explanations of Learning

Sheila's approach to the Class Work Based Explanations of Learning revealed similar confusion and inaccuracies. She wrote in general terms, never providing any data to support her observations. She mainly reported the work she and her group did. She also wrote about interactions with teachers and told what they explained that helped her group. Unfortunately, her comments were often inaccurate as when she wrote about how Dave helped her group with the concept of viscosity and how to measure it. She then went on to equate density and viscosity. In another entry, she says that she will agree with Nancy's explanation, although she is not sure why.

In her entries, Sheila only learns content from direct observation, She wrote, for example, "water pressure varies all the time" after trying to measure flow rates for a homework assignment. She poses questions about these observations, but does not seek to answer them. She seems confused about how to learn content, asking "Is there a deeper science to know to understand this [varying water pressure]?" Her reflections contain references to "amazing" concepts and "tremendous" effects in experiments, and lack any evidence of forethought or prediction. "We never really anticipated anything" she writes about the stream table experiments. Although many such claims are plural, other group members' writings suggest they did in fact engage in these activities publicly and privately and that Sheila was unaware of their thinking or ideas.

Later in the course, her writing contained summaries of concepts discussed in class. When she personally identifies things she had learned, they were words, definitions, or restatements of faculty summaries at the close of class discussions. Connections between classes were absent, even when related applications of the same concept were separated by only a few days. She also wrote about extensions of concepts (such as how crystals grown in space might differ from those grown in class) as annoying tangents. In one class, she asked a question about a personal incident related to the experiment underway, but seemed bewildered and annoyed that the instructors followed up on it, using a substantial block of time to elicit and clarify the underlying concepts. Sheila's main concern in her journal was that "we didn't get to finish the experiment".

Her portfolio has very little writing about her projects caring for bean plants and gerbils. Clearly, she and her partner Jennifer divided up the task of keeping logs for the project. Sheila wrote about the bean plants. She kept a simple log of this work. She gave the date and a few words to describe the state of the bean plant on that date. She did even less writing about the gerbils; she included Jennifer's log of the gerbil project without comment.

Again, using Stanton's summary of the Women's Ways of Knowing framework (see Table 1) to look at both Sheila's view of herself as a mathematics and science learner and her work in the portfolio leads to seeing her as using Silence (knowing in action) as her approach to the course. The word "dumbfounded" was what she often used to express her feelings during the course. She seldom used words to express her learning although she claimed to have learned a lot through her own activity. She found the course confusing, especially since the faculty did not assume the role of punitive authorities who would tell her when she was wrong.

Summary of Results of Analysis of Student Data

Exploring the student data in general for overall themes and connections leads us to two generalizations. There were a variety of ways of knowing expressed by the students. Those students who did well in the course tended toward Procedural (connected) and Subjective ways of knowing. Those who did less well tended to approach math and science from either a stance of Silence or Received knowing. Table 2 presents an overview of the predominant stance(s) used by students as revealed through analysis of their autobiographies and focus group interviews.[3]

In addition to the differences in the student views of knowledge and ways of knowing, one important overall comment related to the amount of work faculty expected from them. Almost every student mentioned that the faculty expected too much work. The six hours of class time plus homework was considered too much. In many of the comments, students seemed to be saying that they thought all that should be expected of them was to work during the six hours they were in class. In terms of outcomes, those students who were most bothered by the homework were the students who by and large were weak in the judgment of the faculty. In addition, many of the weaker students commented that they were unhappy about the inconvenience of having to care for plants and animals on the weekend. They also expressed the most resentment toward having to read a "whole book."

Conclusions

Faculty and students in the fall 1995 IMS 160 pilot came to the course with very different expectations for student engagement and learning. Faculty, while aware that students would most likely have negative attitudes and low opinions of themselves as math and science learners, expected that addressing these student issues early in the semester through the autobiographies and discussions coupled with providing a supportive, yet challenging, active learning environment would lead to high levels of engagement, thinking, questioning, and learning. Students expected to engage in "hands-on" activities while in class, talk about them, and have few requirements beyond the classroom. These differing expectations created tensions between faculty and students and made assessment of students highly problematic for faculty.

[3]Work on the three case studies revealed that for each student the autobiographies in combination with the interviews provided a good sense of the students preferred ways of knowing. In addition, each student's identified stance was checked against statements in her portfolio to verify the preference.

Table 2

Summary of Analysis of Student 'Ways of Knowing' in IMS 160 Class

Name	Rank by Faculty	Comments from Autobiography & Focus Group Interview	WWK[4] Stance
Janice	High	• likes hearing results from everyone, even when different from her group's • likes not having a text (most of the time) • gained confidence in self as math learner through teaching young boy having trouble	Procedural knowing--connected
Sarah	High	• teacher's approach to having students think through answers for themselves before even yes or no from him was helpful • curiosity stimulated and motivated by techniques that were hands-on • liked working in groups; made learning easier • knows now can teach herself	Procedural knowing--connected & Subjective knowing
Karen	High	• teacher has great impact on whether or not students learn math or science • course cleared up a lot of things about science that were not clear from earlier education • came out with "deep understanding" that will come in handy when want to relate this information to kids	Procedural knowing--connected
Patrice	Average	• values hands-on experiences; learns more when sees for herself • liked doing experiments and individual project • high school science ruined her--everything read, memorize, test--never got to see how anything worked or watch it take place	Subjective knowing
Jennifer	Average	• fear of math is very real in hard subjects (algebra and chemistry) fear took over and confidence was gone • teachers didn't give answers--she moaned and complained about that--but thinks she learned a lot • casual atmosphere was good for such an intimidating subject matter • had a hard time accepting different results from different groups--had to learn to accept that her results weren't wrong, just different	Silence (math)/ Received knowing
Kim	Average	• needs good teachers to explain and let students try after understand • usually did well in science courses • liked student/teacher ratio--each group always had someone to explain a question • often finds answers to questions in books	Received knowing

[4]WWK refers to *Women's Ways of Knowing.* In this case the Stance is Stanton's summary of the theory.

Name	Rank by Faculty	Comments from Autobiography & Focus Group Interview	WWK Stance
Sheila	Weak	• class organization bothers her, does not have syllabus (authority) to tell what to do when • sees science as "mysterious" • often sees self as "dumbfounded" • learns through own action, i.e. gerbil tail came off when holding it	Silence
Maria	Weak	• believes science and technology have not led to effective cancer cure--may be better off not treating • it was really good how they let us take "it" (course content) any way we wanted to • doing experiments may look fun and interesting, but they aren't really easy--learned off them (teachers) from doing	Subjective knowing
Nicole	Weak	• doing math means getting the right answers • projects and labs are needed because get students more involved in what they are studying • course was good to a point, but frustrated because questions weren't "totally" answered • will always remember this class because it was so different	Received knowing (began to move away from stance during interview)
Melissa	Weak	• sees self as having special abilities in math because can add restaurant bills faster than other waitresses who use calculators • not sure if it's right to say that calculators are quicker than the human mind • they gave us a basis for it, but we did most of stuff ourselves--taught ourselves • experiments easy in class; analysis too hard--couldn't raise other questions	Received knowing & Subjective knowing
Ellen	Weak	• learning depends on the quality of the teacher • chemistry has more math and less [sic.] boring facts than biology • is type of person who needs to know everything--exactly what happened and what that is going to do • chose project that would be easier to do research for than her real interest that would have meant going to a museum	Received knowing
Susan	Weak	• class was definitely on the students' levels because students did everything themselves • math and science teachers should be sensitive to students (like her) who are having a hard time • different groups got different answers--had different groups so could see where went wrong	Silence & Subjective knowing

Examination of the data revealed that only three of twelve students were consistently engaged with the material in ways that were close to what faculty expected, three others were occasionally engaged, and the remaining six showed little personal connection with any of the material. These discrepancies between faculty expectations and student engagement created a fundamental conflict for instructors. They were torn between providing a supportive environment (a course goal) and providing realistic feedback related to their perception of students' lack of engagement and follow-through. These findings present an important challenge to course designers and faculty. In the final section of the paper, we will suggest ways to address these discrepancies.

We also found that in the buzz of activity during class, it was difficult for faculty to consistently address student misconceptions. Students often did not accept the challenge to go beyond what they thought they knew and clarify discrepant findings, even when the findings came out of self-selected and self-designed investigations and the students wrote in their journals that they thought that they should try learn more about the discrepancies.

On the more positive side, our experiences seem to support findings from other research on science and mathematics learning. Those students who were actively engaged clearly learned more content than their less engaged peers. One challenge as we work to expand this course from one semester to two is to develop strategies for increasing the number of students engaged with the material so that we can increase the learning that occurs in the course. Increasing engagement may also help narrow the existing gap, seen clearly in focus interviews, between faculty and student expectations regarding workload and productivity.

As noted above, the course is being offered as a full-year course this year. A number of changes were made to address some of the issues identified by the faculty who taught the pilot section. The biggest changes were the addition of a weekly mathematically focused "Problem of the Week" and changes in the structure of the written work to eliminate the daily journals in favor of an in-class feedback form, replace the unconstrained weekly Science in the World Around Us with a bi-weekly assignment in which uniform reading or viewing material was assigned, and augment the portfolio with a series of three Unit Summaries, in which students explain their understandings of the key concepts in a topic and relate those concepts to their in-class activities. Despite these changes, and perhaps in some measure because of them, preliminary review of course materials and student evaluations suggest that the level of student engagement remains relatively low, and that frustration and negative attitudes toward math and science were more prevalent than in the pilot semester. In addition, assessment continues to be a major issue among faculty who struggle to assign meaningful grades to students written work.

Addressing the Problems

It is clear from the data from both faculty and students that IMS 160 changed the rules of teaching and learning. In addition to requiring class time for the active learning approaches and investigations, the ways of knowing expected were much more intellectually complex than in a traditional, college, non-major, introductory science course. For faculty, the challenges were in communicating these expectations to the students, providing guidance for students to transform their understandings, and assessing student work using these new expectations. In their assessments faculty needed to figure out where the student was in her understanding of herself as a mathematics and science learner and her understanding of the mathematical or scientific concepts explored in class and find ways to move the student to higher levels of understanding. For their part, students needed to approach the course with an open mind and with the recognition that what they would learn would be well worth the time invested.

We believe that the Women's Ways of Knowing categories provide several approaches to resolving the problems we have identified. These categories should be shared with the students at the beginning of the course and referred to across the course, especially during conferences and in evaluations. In addition, we have developed assessment rubrics (Hyerle, 1996) for the two major types of writing. These rubrics emerged from our analysis of the data and the Ways of Knowing categories. Table 3 presents the rubrics for personal narrative writing and for class-work based explanations of learning. These assessment rubrics should also be shared explicitly

Table 3: Assessment Rubrics

Assessment Rubric For Personal Narrative Writing

Level*	Mechanics	Content	Analysis	Connections/Extensions	Personal Reflection	Way of Knowing
Unacceptable	• assignment is incomplete or late without notification • writing contains many English errors (more than 3 per page)	• student does not address any of the science or math in the source material	• no discussion of data beyond description is present	• only the actual source material is described	• no personal thoughts or feelings about the activity are described	• student shows evidence of learning only through experience • student does not share own ideas or concepts
Minimal	• writing contains some English errors (2-3 per page) • all instructions are followed	• student discusses only personal feelings about the source materials	• data are compared with other personal/own group data	• current source material is linked to student's personal experience	• emotional reactions (pleasure, fear, joy, etc.) are described	• student shows evidence of learning from what is heard/read from others • student's assessment of other's ideas is absent or purely subjective
Participating	• assignment contains few English errors (no more than two per page) • student seeks assistance or guidance in response to problems or difficulties	• major ideas in source material are clearly identified	• student identifies assumptions in source material	• current source material is linked specifically to other activities in the course • at least one extension of the current material is described • student describes potential new activity to answer questions raised by this activity	• student recognizes own emotional response and describes possible reasons • student recognizes own learning as a result of activity	• student engages in dialog with others to understand others' ideas • student learns from analysis and logic as well as what is heard/read from others • student uses subjective and objective criteria to test own ideas or ideas of others
Highly Effective	• assignment is completed with originality/ creativity • assignment contains English errors (one or fewer per page) • student seeks assistance and guidance proactively	• different lines of evidence in support of and opposing the major ideas in the source material are clearly identified	• lines of evidence are evaluated for reliability and weighted • student chooses a position based on the weight of evidence	• student speculates on extensions that might exist for others outside of own experience	• thought processes used to interpret data are recognized and described • student analyzes own learning in context of the activity	• student uses evidence to analyze personal knowledge and ideas of others • student engages in dialog with self and others to establish, test, and share ideas • student's positions are balanced, thoughtful, and open to challenge

*Note: Each indicator at the lower level must be met before work can be judged to be at the higher level.

Assessment Rubric For Class Based Explanations of Learning

Level*	Doing the Assignment	Content	Analysis	Connections/Extensions	Personal Reflection	Way of Knowing
Unacceptable	• assignment is incomplete or late without notification • assignment is illegible or contains errors that interfere with meaning	• no observations or insights are described • discusses only process of class, no concepts are explained	• no discussion of data beyond description is present	• only the actual class activity is described	• no personal thoughts or feelings about the activity are described	• student shows evidence of learning only through experience • student does not share own ideas or concepts
Minimal	• assignment legible and is written so that meaning is clear • all instructions are followed	• personal/own group observations are described • data are largely qualitative • student reiterates class discussion of concepts • student's own explanation is absent or contains multiple errors/misconceptions	• data are compared with other personal/own group data	• current activity is linked to the overall theme of the unit	• emotional reactions (pleasure, fear, joy, etc.) are described	• student shows evidence of learning from what is heard from others • student's assessment of other's ideas is absent or purely subjective
Participating	• student seeks assistance or guidance in response to problems or difficulties	• all personal/own group quantitative data are tabulated • a synopsis of the observations of all groups is reported • relevant material in assigned readings is described • concepts explained in student's words with no more than one error	• quantitative data are graphed on appropriate axes • personal/group observations are compared to observations of others • class observations are compared to material in assigned readings • questions are posed about the activity	• current assignment is linked specifically to other assignments in the unit • at least one extension of the current activity is described • student describes potential new activity to answer questions raised by this activity	• student recognizes own emotional response and describes possible reasons • student recognizes own learning as a result of activity	• student engages in dialog with others to understand others' ideas • student learns from analysis and logic as well as what is heard from others • student uses subjective and objective criteria to test own ideas or ideas of others
Highly Effective	• assignment is completed with originality/ creativity • writing is notably clear and effective • student seeks assistance and guidance proactively	• detailed data from all groups is reported • additional information is reported from outside resources other than those assigned • concepts explained correctly and clearly in student's words	• graphs of data include uncertainty • best-fit lines are drawn through data • student carries out own investigation beyond scope of assignment to answer questions raised by this activity	• current assignment is linked to others in the course beyond the scope of the current unit of instruction • student speculates on extensions that might exist for others outside of own experience	• thought processes used to interpret data are recognized and described • student analyzes own learning in context of the activity	• student uses evidence to analyze personal knowledge and ideas of others • student engages in internal and external dialog to establish, test, and share ideas • student's position is balanced, thoughtful, and open to change

*Note: Each indicator at the lower level must be met before work can be judged to be at the higher level.

with students at the beginning of the semester. As the semester progresses, students should begin to use the rubrics for self-evaluation after faculty have commented on their written work.

Over time, the faculty will want to develop two additional rubrics. One will help faculty assess engagement during class activities and the other will address attitude or approach to the course. These rubrics will help faculty communicate their expectations and give students the information and direction they need to grow and progress in both their understanding of the content of the course and their understanding of themselves as math and science learners.

Our Work in Perspective

As colleges and universities move to reform undergraduate teacher preparation programs, similar mathematics and science courses are in widespread development. The discrepancies between faculty and student expectations that we found suggest that pre-existing negative student attitudes toward mathematics and science and toward themselves as mathematics and science learners are more resistant to change than the literature on teaching reform indicates. This poses a serious dilemma for faculty who desire to support the development of positive attitudes and who also want to hold students accountable for their learning. Our experience suggests that course designers and faculty should actively plan strategies to confront these persistent attitudes and behaviors.

The difficulties that faculty have encountered in this course and that we document here should not be construed as an argument for a return to a less active mode of teaching. It is painfully clear from these students' stories how inadequate such strategies have been for them. We believe that the learning of science and mathematics should be open to the widest possible audience. In our study, those students who did become engaged learned the material and enjoyed the experience, even in the face of weak backgrounds. Improving engagement through a dialog with students about expectations and ways of knowing may enable us to reach as many students as possible in any introductory science or mathematics course.

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