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A New Graduate Space Science Course for Urban Elementary and Middle School Teachers at DePaul University in Chicago

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Abstract

This paper focuses on a new graduate space science course for urban elementary and middle school teachers. The course combines science content with pedagogy and classroom applications and is co-taught by a university science faculty member and a K- 12 science teacher. We found that teachers who try to bring space science to their classrooms face a number of challenges. These include lack of content knowledge, low expectation of the students' behavior and cognitive abilities, lack of administrative support, regimentation and structure of teaching set up by the schools, and lack of time during the school day to learn from each other and share questions about science and teaching. We found that because we addressed these challenges as part of the course, many teachers were able to overcome them.

1. INTRODUCTION

During the spring and fall quarters of 2002, DePaul University offered a new space science course specifically designed for in-service elementary and middle school teachers. In both quarters, the course was run as a pilot in the NSF-funded Chicago Urban Systemic Program (CUSP). In the spring, curriculum and classroom activities were designed primarily for grades K-5, and in the fall primarily for grades 6-8 (see Note 1). The course was co-taught by a faculty member in DePaul University's Scientific Data Analysis and Visualization Program and a science teacher at Walter Payton College Preparatory High School (the authors of this paper). We had two primary goals:

1. To deepen the space science content knowledge of the participating teachers
2. To enable them to teach space science to elementary and middle school students using sound pedagogy and age-appropriate classroom activities

In both quarters, the course met once a week at Walter Payton College Preparatory High School for three hours over a period of 10 weeks, with an additional half-day field trip to Yerkes Observatory. Enrollment information about each class is found in Tables 1 and 2.

Table 1. Enrollment by grade level

Semester	Total	Regular classroom teacher K-3	Regular classroom teacher 5-6	Science teacher departmental 6-8	High school teacher 9-12	Pull out teacher K-12
Spring 2002	16	3	5	6	0	2
Fall 2002	18	0	0	13	3	2

Table 2. Type of teaching position

Semester	Total	Regular classroom teacher— teaching all science minutes	Regular classroom teacher — supporting lab teacher	Lab science teacher — departmental	Special education teacher — self contained	Bilingual teacher	Math teacher
Spring 2002	16	10	0	5	1	0	0
Fall 2002	18	5	1	8	2	1	1

Teachers had multiple reasons for enrolling in the class. Space science is part of the Chicago Academic Standards (Board of Education of the City of Chicago Public Schools 1997) for all elementary and middle school grade levels; many teachers had never taken any college-level space science classes before and felt unprepared to teach this subject. Another reason for enrolling was to receive credit for the Illinois Middle School Science Endorsement. Finally, some of the teachers were already quite experienced in teaching space science. They felt that the subject was engaging and inspiring to their students and were looking for ideas on how to teach it in new ways; they also wanted to exchange experiences with like-minded colleagues.

Teacher comfort level with space science and their conceptual knowledge of the field were assessed at the beginning of the courses through pre-tests. Test performances varied widely, as could be expected from the diverse backgrounds and motivations described in the previous paragraph. However, over the course of the quarter, we observed significant progress in virtually all participants, which was also clearly evident in the post-tests administered on the last day of class.

2. INTEGRATING SCIENCE, PEDAGOGY, AND CLASSROOM APPLICATIONS

The traditional introductory science courses at DePaul and other colleges and universities typically are designed for undergraduate nonscience majors and frequently do not meet the specific needs of teachers. On the other hand, space science educator workshops offered by science museums, NASA, and other organizations are often focused solely on classroom activities. More advanced subjects that challenge the teachers as adult learners are rarely addressed. In contrast, the National Science Education Standards call for professional development to focus on pedagogical content knowledge that integrates knowledge of science, learning, pedagogy, and students (NRC 1996). Thus, our plan for the new course was to combine current and relevant space science content with applied pedagogy, practical classroom applications, and opportunities to reflect on student thinking and learning.

For example, one of the fundamental concepts in stellar astronomy (and discussed in the course) is the life cycle of stars. Introductory astronomy courses offered by physics or astronomy departments typically include a discussion of stellar structure, hydrostatic equilibrium, mass-luminosity relation, nuclear fusion reactions, the equivalence of mass and energy, and a discussion of the end stages of stellar evolution. On the other hand, typical educator workshops on the life cycle of stars may include a brief discussion of how long stars of different masses live, how they generate energy, and what happens after their energy source runs out. However, the bulk of the time is spent on classroom activities. While such activities are very important for the teachers, their understanding of the subject remains shallow. This makes it very difficult for them to engage their students in active exploration, thinking, and learning. In contrast, our course connected advanced science topics with K-8 science and pedagogy concepts, classroom applications, and reflections on student thinking.

Prior to the session, the teachers were assigned readings (e.g., book chapters and articles from *Sky & Telescope*, *Astronomy* magazine, and so on) on science questions related to the life cycle of stars, such as "How do stars form?" "How can we know what happens inside of stars?" "How does nuclear fusion work, and why does it generate energy?" and "What happens when the energy source runs out?" This was followed by a content lecture and discussion.

Because the new content was designed to challenge teachers as adult learners, it generally went well beyond the K-8 level. Thus, the second component was a discussion of related K-8 curriculum topics (colors, sizes, and masses of stars; transfer of energy; seasons; the Sun as a star; electromagnetic spectrum), which allowed the teachers to connect to the classroom their new knowledge of the life cycle of stars. The third component was a discussion of pedagogical questions related to these topics, which frequently included readings from the science education research literature. We addressed questions such as "What are typical student misconceptions about these topics?" "How do we uncover and address them, and avoid creating new ones?" and "At what age are students developmentally ready to understand these topics?" Finally, we worked through elementary and middle school classroom activities, such as those in the Great Exploration in Math and Science (GEMS) guide *The Real Reasons for the Seasons* (Gould, Willard, & Pompea 2000); *Earth, Moon, and Stars* (Sneider 1994); *Invisible Universe* (Pompea & Gould 2002); *ARIES: Astronomy-Based Physical Science, Exploring Earth in Motion* (Grossman, Shapiro, & Ward 2000); Full Option Science System (FOSS) *Solar Energy* (Lawrence Hall of Science 2000) and

Planetary Science (Lawrence Hall of Science 2001); and NASA *Imagine the Universe!* (Laboratory for High Energy Astrophysics at NASA/Goddard Space Flight Center 1997-2002). Teachers also tested these activities with their own students and discussed their experiences in one of the later sessions. Student work and audio recordings from the teachers' classrooms provided valuable data that formed the basis for our discussions about student thinking and learning and also gave us important feedback on how well the teachers were able to put into practice what they learned in our course.

2.1 Opportunity for Unstructured Discussion

Every week, the classes met for a single three-hour session. Because the teachers already had a long day of teaching behind them, we needed to allow for an extended break in the middle of the class (15 to 25 minutes). We soon realized that some very interesting science and teaching discussions took place during these breaks. The teachers explained to us that one of the reasons they used their breaks to "talk shop" was that they rarely had the chance to engage in informal conversations among colleagues during their busy workday. Due to their heavy teaching loads, teachers often work in isolation and do not get the opportunity learn from each other and share questions about science and teaching, an issue that has been identified previously (see National Center for Education Statistics 1997). These informal discussions had many positive outcomes that we couldn't possibly have achieved in structured lessons. For example, some groups of teachers from different schools decided to organize joint portable planetarium sessions and field trips for their students. They exchanged lesson plans and teaching tips and learned about grant and workshop opportunities. The teachers formed professional communities from which they would benefit long after the completion of the course.

3. SUCCESSES AND CHALLENGES—SOME CONCRETE EXAMPLES

Every teacher in the class was required to test at least one classroom activity, bring back student work, report on their experience (both orally and in written form), and lead a discussion in class. Although it was sometimes difficult for them to fit a space science lesson into their teaching schedules, applying what they learned in class while the course was still going on proved to be very valuable. It made it easy for them to get help from the instructors and colleagues during the design phase of their lessons and get feedback afterwards. It also gave the instructors insight into how the teachers applied the course materials, what worked well, and what the challenges were.

Three major challenges were made manifest by the two classes. All three have been identified previously in the literature as issues that impede learning across disciplines and grade levels. The first was the teachers' comfort level with the science content, the second was the teachers' low expectations of their students' performance, and the third was the lack of support from the school administrations.

3.1 Teachers' Comfort Level with Their Knowledge of Space Science Content

Although most of the teachers were able to comprehend the new concepts introduced in class, they often did not feel that they understood the big picture well enough to guide their students in inquiry-based lessons and get them to think deeply, ask questions, and engage in discussions. It has been well documented that the lack of confidence in their own knowledge of science discourages many teachers from teaching the subject, especially in an era when reading scores are used as a measurement of teaching and learning (Abell & Roth 1992; Akerson 2001; Atwater, Gardener, & Kight 1991; Tilgner 1990; Tobin, Briscoe, & Holman 1990). We addressed this issue by giving the teachers the chance to grapple with the content through lectures, readings, discussions, small group activities, and by frequently putting new content into the larger context. We also encouraged them to ask big picture questions, such as "Why do we study the invisible parts of the electromagnetic if our goal is to understand how stars form?" and "Why do we ask our students to do an experiment with waves on a slinky if we want them to understand light and color?" Over time, teachers became more willing to approach new topics with their students. This was especially apparent with those who brought to their own classrooms their experiences as students in our course. They would eagerly share the activities with their students, often returning with questions that were generated in their own classrooms as teachers and students worked through the activities that the teacher had tried the week before. Both students and teachers were experiencing the thrill of discovery. By enjoying this experience with their students, teachers were beginning to lose the fear of science that had prevented them from substantial science teaching.

3.2 Teacher Expectations of Student Performance

The second major roadblock that we identified in our course was the belief held by some of the teachers that space science is too difficult for their students. This is an example of the well-known phenomenon that teachers' low expectations of student cognitive ability and behavior leads to low student performance (Bamburg 1994; Good 1987; Tauber 1997). This issue was particularly important for the special education teachers in our course. After the first few sessions, one special education teacher of profoundly handicapped high school students explained to us that he didn't think he would be able to use any of the course content with his students. His lessons focused primarily on the life skills that his students needed to function in everyday life, and learning about the universe was something he didn't think his students would be capable of. However, he did consent to try a lesson in his classroom because it was a requirement of the course. He started by showing his students pictures of the planets from a NASA lithograph set. To his surprise, the students became very interested, and over the next two weeks of discussion and planning with his working group, he added several components to his lesson. When it came time for his presentation, he shared the fun the students had experienced as they explored each of the planets and what they might bring on an imaginary planetary trip. As a final project, the students built mobiles of planets and galaxies, to which each student was able to contribute according to his or her mental and physical ability. At the end of the course, this teacher was planning a field trip to the local planetarium for his students. The joy this teacher experienced while watching his students have a meaningful learning experience with space science content allowed him to abandon the idea that his students were unable to share the excitement of science and space exploration. Exposing the students to difficult science content allowed them to perform on a higher level. In turn, the teachers' low expectations of his students' cognitive ability changed as he saw them rise to the challenge of a new content area he would have never thought of presenting before.

The course didn't change every teacher, however. In his article, "Pedagogy of Poverty Versus Good Teaching," Haberman (1991) describes an unwritten script often followed by teachers and students in urban schools that suppresses good teaching and learning. Because of low expectations of student cognitive ability and behavior, teachers avoid challenging students intellectually and give them routine work. In return, students award teachers with good behavior. Both students and teachers are conditioned to behave and think in a way that allows this pedagogy to continue. This behavior became evident with some of the teachers who took our course. For example, one of the teachers had available to him at his school a space science activity kit that we used in our classes. Several other teachers had tested this kit with their students and wanted their schools to buy it, but found that the kits were prohibitively expensive. To our surprise, even though the teacher in question thought that the activities in the kit were well designed, he had never used it and was not planning on using it in the future. He believed that the materials would just get broken if he let his students work with them. His school wouldn't be able to replace broken parts, so his distrust in the students prevented him from using the materials at all. Even class discussions with experienced teachers who shared their methods of classroom management and use of hands-on materials couldn't change his mind. In spite of the fact that these other teachers had the same type of student population, he remained convinced that his inner city students were not capable of behaving in a way that would allow the use of expensive materials. Even though he was not enjoying his teaching experience, the risk of changing his teaching style appeared too great. He felt that the little control he did have would be lost. His low expectations of the students prevented them from experiencing the joy of discovery and denied him the joy of teaching for learning.

3.3 Administrative Support for Teaching Innovation

A third major stumbling block was the regimentation and structure of teaching already set up by each school, and the lack of support for innovative change by the principal and administration, an issue that has been well documented (Blasé & Blasé 2001; Cosemius 1999; DuFour 2001). For example, one teacher was very nervous about the classroom projects because she taught science only once a week. Her students saw a science lab teacher for the rest of their science class time, so she had to coordinate her lessons with the content covered in the lab. Because she didn't consider herself the science teacher, she usually just read the textbook during her lessons. She was also very wary of how her principal would react to any deviation from the normal structure of her class. Because teachers in our course were required to implement at least one lesson (it was an important part of their grade), she got to the point where she wanted to drop the course. Several other teachers expressed similar concerns. We stressed to these teachers that they had permission to push the usual boundaries, since this course was part of a program sponsored by the school district. The teacher in question did stay in our course and tried a lesson about the difference between local time and standard time in her class. By chance, her principal chose that period to visit her class unannounced. The loud discussions as groups of students tried to figure out at what time local noon occurs in Chicago presented a chaotic environment. To her amazement, the principal loved the activity. He thought it was great that students were engaged with this new idea and that they were using mathematics in a science setting. As this teacher shared her experience with our class and read from her students' journals, it was evident that student and teacher learning had taken place, and that both teacher and students were excited about having figured it out on their own. By the end of the course, the teacher decided to use grant money to obtain new space science materials for her classroom, and her principal was encouraging other teachers at her school to take our course as well. This example shows that by encouraging teachers to stretch the boundaries of their environment, and by providing a support structure through the school administration (e.g., by coordinating a program with the school district or principal), teaching can change and can give rise to new experiences that result in better learning.

4. CONCLUSIONS

We have designed a new professional development course in space science for K-8 teachers. The course is part of the Chicago Urban Systemic Program and is co-taught by a university science faculty member and K-12 science teacher. It combines science content with pedagogy, classroom applications, and reflections on student thinking.

We found that teachers in Chicago face many challenges when they try to bring space science content into their classrooms. Three challenges, previously identified in the science education research literature, were manifest in our classes: teacher comfort with science content; low expectations of students' cognitive ability and behavior, especially in inner city settings; and support from school administrations for innovative change. To overcome these challenges, it is crucial to address them as part of the professional development course. New science content alone is simply not sufficient to change teaching and classroom practices, however interesting and exciting it may be. Long-held beliefs that are passed down through the teaching ranks and inhibit new ideas for teaching have to be addressed. Teachers have to come to believe that their students are capable of learning, even if they themselves are not completely comfortable with the science content. Teachers must have time to try out new activities and have support available as they bring the activities back to their classrooms. The opportunity to grapple with the scientific concepts in a variety of ways prior to bringing them to the classroom allows the teachers to overcome their fear of science. Teachers need to feel free and encouraged to take the risks associated with changing their teaching styles, and need support to deal with the reactions and behaviors of their students, their fellow teachers, and administration. Teachers also need unstructured discussion time to "talk shop" with other teachers, because in their professional lives they rarely have the chance to network and exchange ideas. This is especially true for newer teachers. We built time for unstructured discussion directly into every class period. However, in other situations it may be possible and desirable to create such opportunities outside of class or through Internet tools such as online chats and discussion lists. Making classroom applications of new science content and pedagogy a requirement may pose scheduling problems for some teachers, but it is our experience that interaction between learning, applying, discussing, and reflecting can change science teaching for the better.

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Notes

Note 1: Our plans for the spring course had to be adjusted somewhat because half of the students who enrolled were teachers for grades 6-8 . This was less of an issue in the fall course because the three high school teachers who enrolled were special education and bilingual teachers (see Tables 1 and 2).

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