# We Have Lift Off! Integrating Space Science and Mathematics in Elementary Classrooms

Jacqueline Leonard Department of Curriculum, Instruction and Technology in Education, Temple University, 1301 Cecil B. Moore Ave., Philadelphia, PA 19122, jleo@temple.edu

James E. Oakley Strath Haven High School, Wallingford-Swarthmore School District, Wallingforn, PA 19086, joakley@wssd.org

## ABSTRACT

This paper examines the results of a two-year study of preservice teachers' development of self-efficacy. Specifically, we explain how 2 of our original 12 preservice teachers implemented an activity from the Earth Links Project and present data describing how it impacted their self-efficacy. These two prospective teachers elected to do a space science lesson called Alka Rockets with students during their field experience. The purpose of the lesson was to help younger students understand physical changes and older students understand the principles of Newton's Third Law. Both preservice teachers and students used the scientific method and learned the importance of observation and random trials. These prospective teachers also used the video Apollo 13 to reinforce the mathematical concepts of place value and numeracy. Most importantly, they learned how to improve their instruction in space science by reflecting on their practice.

## INTRODUCTION

Prescribed science and mathematics programs that leave no room for teacher input and student creativity can rob children of discovering just how fun and exciting these subjects can be. Finding the time and place for students to investigate science and learn mathematics in innovative ways is a daunting challenge. However, the integration of science and mathematics allows teachers and students the flexibility to participate in investigations, simulations, and inquiry, as well as address issues of time management that teachers face.

The purpose of this paper is to share an integrated space science and mathematics lesson taught by two preservice teachers who participated in a two-year research study. We examined 12 elementary preservice teachers' science efficacy before and after intervention. Efficacy beliefs have tremendous influence over the course of action an individual may take, the amount of effort he/she will expend, how long he/she will persevere when challenged, how much stress he/she will experience, and the level of success he/she will reach (Bandura, 1997). Self-efficacy is defined as the perceived judgment that an individual conceptualizes regarding his or her capacity to perform (teach) in a particular setting or situation" (Wilson, 1996, p. 53). The interventions included workshops that modeled teaching science inquiry, a six-week teacher internship in an after-school program, and focus groups. Preservice teachers were also simultaneously enrolled in mathematics and science methods classes while they were involved in the internship. Thus, they received inquiry-based guidance in more than one context.

This paper focuses on teaching a space science lesson called "Alka Rockets" and describes the teaching of two preservice teachers of second and sixth-grade students, respectively. The lesson was field-tested and implemented with elementary children in Philadelphia in the fall of 2004. The preservice teachers were participants in the Earth Links Project, which was supported by the National Science Foundation. The goals of the project were to help preservice teachers inspire and motivate children to learn science and mathematics as well as improve their pedagogy. We wanted students to consider careers in aerospace, geoscience, and engineering because one of the major goals of the project was to increase students' awareness of geoscience and their access to Earth science curriculum and scientists. Moreover, the project provided exciting opportunities for preservice teachers to learn space and earth science content and deliver it in both informal and formal classroom settings. Prior to describing the lesson and teaching episodes, we link the lesson to science and mathematics standards.

## SCIENCE STANDARDS

National Science Education Standards (1996) suggest teachers engage students in inquiry-based science. According to Teaching Standard A, inquiry refers to student activities in which they develop understanding and knowledge of scientific ideas including an understanding of how scientists study the world. Moreover, inquiry involves asking questions, making observations, examining alternative sources of information, reviewing what is known in light of evidence, using tools to gather, analyze, and interpret data, making predictions, drawing conclusions, and communicating the results. In addition to inquiry, prospective teachers guided and facilitated learning physical and space science (Teaching Standard B). Specifically, the lesson addresses properties and changes of properties in matter (Grade 5-8, Content Standard B) and the Earth in the solar system (Earth and Space Science Standard).

## MATHEMATICS STANDARDS

The mathematics Standards (NCTM, 2000) addressed in the lesson included: numbers and operations (students used numbers and made reasonable estimates), geometry (students made a three-dimensional figure), measurement (students measured amounts of solids and liquids as well as time and distance), data analysis (students analyzed data about duration of flight compared to amount of Alka-Seltzer), problem solving (students adjusted the materials to test different outcomes), reasoning and proof (students made predictions and tested the outcomes), communication (mathematical thinking and learning were clearly conveyed in the lesson), and connections (mathematics was connected to space science).

## THE ALKA ROCKET LESSON

Lesson plans for making the rockets may be found in Mission Mathematics K-6 (NCTM/NASA, 1997) and at the following Internet sites: http://www.spacegrant.hawaii.edu/class_acts/AlkaRocketTe.html and http://lunar.arc.nasa.gov/education/activities/active4.htm.

This lesson was selected because the materials were easy to obtain, the science concepts could easily be taught, and the excitement it elicited from both preservice teachers and children was exhilarating. It allowed the children to express their creativity in designing their own rockets. It also provided a forum for them to learn about the importance of space science and mathematics.

The following materials are needed to implement the Alka Rocket lesson: empty film canisters, 5 x 8 index cards, crayons or colored pencils, thick clear tape, bottle or tap water, safety glasses and lots of Alka-Seltzer. Film canisters were obtained free of charge at local camera shops and drugstores that processed 35-mm film. Safety glasses may be purchased from a local hardware store at minimal cost.

Two preservice teachers' Alka Rocket lessons are presented as examples of inquiry-based teaching. Although each of the preservice teachers taught the same lesson, each teaching episode was different because they worked with students in different grades and school settings. Millicent taught a second-grade class in suburban Philadelphia, and Fred taught a sixth-grade class in the city of Philadelphia (both names are pseudonyms). The lesson may be divided into four phases: Background Knowledge, Making the Rockets, Launching the Rockets, and Understanding the Data. Vignettes from each of the classrooms are used to document the teaching and learning that took place in these phases.

## BACKGROUND KNOWLEDGE

At the outset, the preservice teachers showed students a 10-minute clip of the video Apollo 13 (Universal City Studios, 1995). The following teaching episode describes the teaching and learning that took place in Fred's sixth-grade classroom:

### Fred's Lesson

*Vignette 1*

Fred: Has anyone seen the movie Apollo 13?
Student 1: I have.
Fred: You've seen it? Okay. It's a good movie. What I'm going to do is show you a bit of a clip from that so you can see what really happens. It's very accurate…how the shuttle lifts off, you know, how it gets into space. I'm going to show you about a ten-minute clip of it so you can see how shuttles launch into space. Okay.
[Plays Apollo 13 clip.]
Fred: Why do you think [the engineers] are stepping on them [astronauts]?
Student 2: To buckle them up.
Fred: That's part of it. They've got to be so tight in there. [Movie plays.] You see all the checks and balances they have to go through to make sure everything works properly. All the checks and re-checks and triple-checks…
[End of clip.]
Fred: There you got a little taste of how a rocket works. Now, what was the time it took them to get from the launch pad up into space?
Student 3: Ten seconds.
Fred: Ten seconds? Not quite.
Student 4: It was 12.3...
Student 5: Twelve point thirty-four.
Fred: Very good! Twelve what? Twelve seconds? Twelve hours? Twelve…
Student 4: Twelve minutes.
Fred: Very good, 12 minutes. Now, think about that. Think about the sheer speed of that. I can't get from this school to Grant and the Boulevard in 12 minutes. But they were able to get from the United States, Earth to outer space in about 12 minutes. That's pretty cool, when you think about it. You know, the average car goes like 60 miles an hour if you're on a good day. Think about that. Think about the sheer speed of that, the sheer force they had to go through to get there in 12 minutes.
Student 3: That's fast.

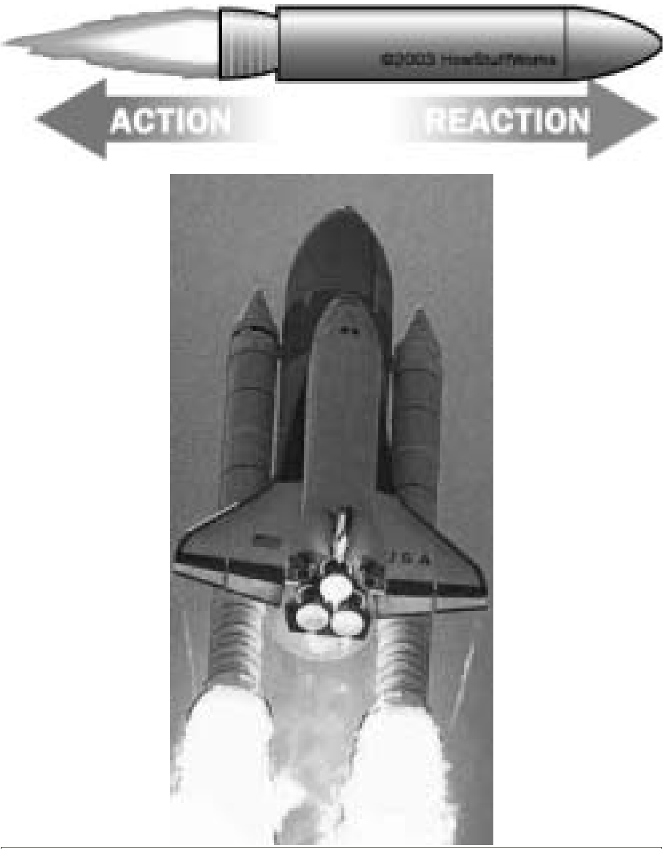
Not only does the movie provide an example of what a lift off is, but teachers can use the video to engage students in discourse about time, rate, and speed. Students' conceptualizing about how fast a spaceship can travel is evident as Fred helped them to visualize moving from Earth to outer space in 12.34 minutes. Fred went further in depth to help students understand exactly how the rocket traveled so quickly.

*Vignette 2*

Fred: That was a pretty cool video. I'm going to show you some facts about rocket ships and whatnot. Just take one and pass them around. At the bottom of the rocket we have the action. What would the action be?
Student 1: Fire
Fred: Fire, fuel burning, fire. And then towards the front of the rocket, you see the word reaction. What would the reaction be?
Student 2: That's when the fuel has the reaction making it turbo.
Fred: Turbo… what do you mean by turbo? If there's fire and fuel burning at the bottom, what's happening to the entire rocket? What's happening to the rocket, if there's fuel burning at the bottom? What's that turbo effect that you were talking about?
Student 3: Speed?
Fred:Speed! It's going, it's going whoosh. So in order… There's a law, and as you go into high school, and you get into physics class you will learn Newton's Third Law. For every action there's a reaction. So you get this fuel burning at the bottom, it's propelling, it's pushing up. So what's happening to the rocket? What's the fuel doing to the rocket ship?
Student 4: It's making it move.

In Vignette 2, Fred helps his students understand Newton's Third Law: for every action there is a reaction. He began by focusing on the action that took place as Apollo 13 lifted off. Through a series of questions, Fred helped his students understand how the action - the fuel in the engine - caused the rocket to react - take off into space. Mathematics is more evident in the following teaching episode as students examine the figure with the Orbiter on it (see Figure 1). Here, Fred also helped the students understand how much fuel it took to create the amount of force and energy needed for lift off.

*Vignette 3*




The Orbiter weighs 165,000 pounds empty.
The external tank weighs 78,100 pounds empty.
The two solid rocket boosters weigh 185,000 pounds empty each.
Each SRB holds 1.1 million pounds of fuel.
The external tank holds 143,000 gallons of liquid Oxygen (1,359,000 pounds) and 383,000 gallons of liquid hydrogen (226,000 pounds).
The whole vehicle -- shuttle, external tank, solid rocket booster casings and all the fuel -- has a total weight of 4.4 million pounds at launch.
4.4 million pounds to get 165,000 pounds in orbit is a pretty big difference.
To be fair, the Orbiter can also carry a 65,000 pound payload (up to 15 x 60 feet in size), but it is still a big difference. The fuel weighs almost 20 times more than the Orbiter!!!!!

**Figure 1. Orbiter**

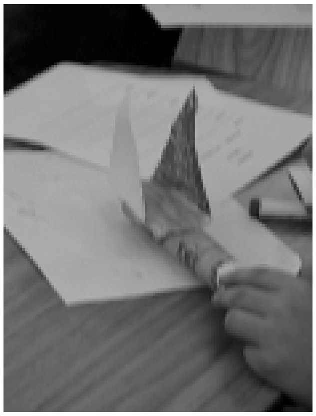
Fred: Here are some facts that I thought were pretty interesting. Okay, the Orbiter weighs 165,000 pounds. Now, what's the Orbiter? Anyone want to take a guess?
Student 2: The engine?
Fred: Not just the engine.
Student 6: The plane thing?
Fred: Good, the plane. That weighs, keep that in mind, 165,000 pounds empty. The external tank weighs 78,100 pounds empty. That's the red thing or the orange thing. The two solid rocket boosters weigh 185,000 pounds, empty. Do you want to say what they are?
Student 1: They're the solid rocket boosters.
Fred: Very good. Okay. Each SRB, or solid rocket booster, holds 1.1 million pounds of fuel. So if you have 1.1 million pounds of fuel in each booster, how much fuel are we carrying total in that booster and that booster?
Student 6: Two point two million.
Fred: Very good, 2.2 million pounds of fuel. Think about that, think about how much that is. I believe a hockey puck weighs a pound. I'm not sure, somewhere around a pound, anyway. So, that's like saying there's 2.2 million hockey pucks stored in this thing. That's a lot of hockey pucks. The external tank holds 143,000 gallons of liquid oxygen, which turns out to be 1.359 million pounds. So now, we've got our 1.1 million in here, correct? We've got 1.1 million in there. And we're going to add another 1.3 million pounds. How much fuel do we have? [Writes on board.]
Student 6: Three point six million.
Fred: Three point…
Student 2: Five million.
Fred: Three point five million. That's a lot, hm. That's a lot. Think about that. How long did we say the trip was, from Earth to outer space?
Student 2: Twelve minutes?
Fred: Twelve minutes. So roughly, we're looking at… I mean, it could deviate a little bit. It could be more, it could be less; it's not an exact number. We're just doing very rough math here. But, for 12 minutes for the rocket or space shuttle just to travel, 12 to 20 minutes let's say, you're going to expend 3.5 million pounds of fuel to get from Earth to outer space in 12 minutes. The average gas tank in the average car in the United States burns about… You can get about 21 miles per gallon. And you have to fill up about once a week. Your parents probably fill up once a week. This thing needs 3.5 million, you know, for 12 minutes. That's pretty astonishing.

The foregoing dialogue offers students a chance to begin to understand large numbers and exactly how much energy is required for a rocket to lift off and get into space. Fred used everyday things that students knew about, such as cars, gasoline, and hockey pucks, to help them understand how much the Orbiter weighed and why it required so much fuel to lift off. Providing this kind of background knowledge helped the students to understand the role of the Alka-Seltzer as the fuel needed to lift off the paper rockets they would make.

However, Fred's lesson shifts from guided inquiry to teaching by telling (Schifter and Fosnot, 1993). His lesson would have been more effective if the descriptions of time and distance came from the students. Fred might have encouraged the students to talk about how long it takes for them to get to school or might have created a list of things that takes about 12 minutes to do. In addition, the discussion about the weight of the fuel might have been more effective if the students provided the benchmarks for understanding what 1.1 million pounds of fuel might be. Students might accomplish this task by determining how many gallons of fuel an average car, Olympic-sized swimming pool, tanker truck or battleship holds and then they could determine how much fuel would be needed for the Orbiter.

## MAKING THE ROCKETS

After the students understood how the rocket worked, they designed their own rockets by making crayon or colored pencil designs on a 5 x 8 index card. Crayon and colored pencils are water resistant and will not bleed when the rocket gets wet. The card is then rolled into the




**Figures 2 and 3. Student makes Alka rocket.**

shape of a cylinder and taped around the Fuji film canister for the fuselage so that the canister's open end is left exposed. Next, older students used compasses to draw circles, cut the circles out, and slit the circles along the radii to make cones for the rockets' noses. They used trial and error to draw circles large enough to serve their purpose. An additional lesson on area of a circle could be used prior to this lesson to help older students determine exactly how long the radius needs to be to cover the diameter of the canister. Younger students may cut pre-drawn circles or use plastic compasses. Vocabulary words such as fuselage, nose, cone, cylinder, and radius were used to build students' understanding of these concepts. Finally, some students placed small triangular pieces on the fuselage for the rockets' wings (see Figures 2 and 3). Before making the rockets, Millicent explained to her second-grade students how the Alka-Seltzer rocket worked.

### Millicent's Lesson

*Vignette 4*

Millicent: But first, before we can make one [a rocket]…we're going to use what we know about changes. Who remembers when we did the experiment with water and Alka-Seltzer? Do you remember? What did we do?
Student 1: We put it in the water
Millicent: We put the Alka-Seltzer tablets in the water. And what happened?
Student 2:It all bubbled up!
Millicent: It all bubbled up? Did it get really fizzy really quick?
Student 3: Yeah!
Millicent: What was Alka-Seltzer?
Student 4: A solid.
Millicent: And what happened when the Alka-Seltzer and the water mixed together?
Student 5: It dissolved.
Millicent: But what happened? What did we get?
Student 5: It mixed up, and we got gas.
Millicent: Gas, right?
Student 5: Carbon-dioxide.
Millicent: Carbon-dioxide gas? So when we put the solid into the liquid, we got gas. That's the stuff we're going to use to power our rocket-ship. We're going to make them shoot into the air as far as we can. Do you think that would be a good idea?
Students: Yeah!

From this teaching episode, students learned about chemical actions and reactions. The water and Alka-Seltzer reacted together to produce carbon-dioxide gas, which was used as the fuel to lift their rockets off into the air. The fact that this information came from one of the second-grade students was powerful. The teacher repeated the response but could have praised the student and elaborated on the chemical reaction a bit more. Nevertheless, students understood the process that was taking place because Millicent made connections to prior knowledge.

## LAUNCHING THE ROCKETS

Once the rockets were completed, the preservice teachers took the children outside into the schoolyard to launch them. This activity may also be done inside a gymnasium during inclement weather. Before the students tried to launch the rockets, they were given a pair of safety glasses to protect their eyes. Students were paired into groups with one rocket each, and the preservice teachers filled the fuel cells (film canister) halfway with water. Each student was given an Alka-Seltzer tablet to put into the open end of the canister. Then the students clicked the cap on, turned the canister upside down on the ground with the rocket pointing upward, and stepped back to watch what happened. On average, it took about 10 to 20 seconds for the Alka Rockets to blast off.

The students were very excited about the rockets. They conducted three to four trials to determine how high the rockets could go and how long they could stay in the air. To vary the activity, Alka-Seltzer tablets were broken into quarters and halves for some of the trials. A stop watch was used to record the flight times. The preservice teachers used stop watches to time how long several of the rockets stayed in the air. The average flight time was about five seconds. It was difficult to measure the height of the rockets because children were scattered around the playground, but estimates were made by comparing the distance to the height of a student, adult, or tree. However, the more accurate measure of flight time was used to analyze the data that was obtained outdoors. Figure 4 provides a data sheet that can be used to record the data. Vignette 5 reveals the students' excitement about this part of the activity.

*Vignette 5*

Millicent: Alright, good. Ready? Drop it in, everybody hear it click? Put it down. See, it doesn't take too long. Plenty of time to get out of the way. No excuses. Oh, it's starting to fizz, I can see it.
Students: Eight, seven, six, five, four, three, two, one, lift off! Wow! Oh!
Millicent: You guys can go find some space somewhere. Does everyone have their own personal space? Away from everybody else?
Students: Yeah.
Millicent: Did you put the lid on? You need to make it [the top] click.
Student 1: Wow!
Student 2: Yeah, that one went high!
Student 1: Wow!

| Trial | Amount of Water | Amount of Alka-Seltzer | Time |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

**Figure 4. Alka rocket data sheet.**

Student 3: Ms. Millicent, mine didn't go up in the air.
Millicent: That's because you didn't hear it click, did you? You know what, try again. Let me see. Get another one.
Student 4: That's because he put it the wrong way. He put the cap backwards.
Millicent: Oh, you did? Uh-oh.
Student 3: Hurry up, we have water. Okay, you do it.
Student 4: No, you're doing it.
Student 3: Okay, I'll do it.
Millicent: Everybody back up. Okay, let's see.
Students: Ten, nine, eight, seven, six, five, four, three, two, one, blastoff!

## UNDERSTANDING THE DATA

Students were given the opportunity to learn how to represent and interpret data. Older students experimented with the activity by varying the amount of water and Alka-Seltzer placed in the rocket. Students used one-quarter, one-half, one and two tablets with the same amount of water to determine how the size of the tablets affected the flight time. Trials were conducted with canisters that were one-quarter, one-half, and three-quarters full of water using one tablet. Younger students only varied the size of the Alka-Seltzer tablet. However, it is difficult to time the rocket because the entire event happened so quickly. If the stop watch is started when a "pop" is heard at lift off and stopped when the rocket begins to fall, more accurate measurements may be recorded. During the series of trials with the two classes of students previously described above, the recorded flight time typically ranged from 4 to 10 seconds. Back inside the classroom, students shared the experiences they had during the rocket launch. Using flight data, students found one tablet produced the longest flight. Students in Fred's class found half a canister of water produced longer flights. Too much or too little Alka-Seltzer resulted in shorter flight times.

Thus, the optimum ratio of water to Alka-Seltzer was discovered by conducting several trials, observing the flights, and analyzing data.

## TEACHER REFLECTIONS

Fred and Millicent were interviewed shortly after they implemented the Alka Rocket lesson with students. Some of the questions on the interview protocol were as follows: What problems did your students have learning the content? Did you ask open-ended or inquiry-based questions to elicit student discourse? What would you do differently, if you were to teach this lesson again? The prospective teachers had the following responses to these questions:

**1. What problems did your students have learning the content?**

Fred: The biggest thing I could probably see is the fact that students might not exactly realize the scope of what space is. I don't think they understand or understand fully how much we don't know about it and how big space is. They just can't conceptualize that in their mind. And also I didn't think they really realized the amount of technology, and fuel, and force that it really takes to get a rocket ship into space. That's something that I wanted to stress upon, that it takes millions of pounds of fuel to get a hundred-thousand-pound rocket ship into space. So I don't think they fully realized this until this lesson.
Millicent: For some of them, I think it was hard to grasp the liquid, water, solid idea. But for the most part they didn't have a problem.

**2. Did you ask open-ended or inquiry-based questions to elicit student discourse?**

Fred: Yeah, one of the keys, especially in a special education environment, is you have to keep that active learning window open. It's key to have active learning in an environment such as that. So it's important that I not only stand up in front of the students and give them information but also that they feel free and comfortable to ask me questions. After watching this video, I definitely believe that we had that open kind of classroom, where they were free to ask questions. It wasn't just me lecturing.
Millicent: I think so.

**3. What would you do differently, if you were to teach this lesson again?**

Fred: Now that I am reflecting on my teaching, I believe I spent too much time with the actual construction of the rockets. If I had to change anything, taking into consideration it's a special education environment and the kids need structure, I don't think I gave them enough structure during that time. I think I should have set more clear-cut time frame limits to the actual constructing of it. So if I were to redo this, which I probably would, I would definitely look at that. Give them…ten minutes, fifteen minutes to do this.… I took too much time on that and not enough time outside actually experimenting with the rockets.
Millicent: I would prepare more for each lesson. There were times when I had questions about the lesson.

It is evident from the interviews that Fred was much more reflective than Millicent. Even when the interviewer probed to get specific information from Millicent about the inquiry-based aspect of her teaching, she gave the same response: "I think so." This response may imply that after the study, she was still unclear about what inquiry-based teaching was. However, she exhibited a high level of inquiry-based teaching during her microteaching lesson as measured by the Science Teaching Inquiry Rubric (STIR) (Beerer and Bodzin, 2003). Both Fred and Millicent had an average STIR rating of 3.33 on a four-point scale. Furthermore, the difference in grade levels may have influenced different kinds of reflection for each of these preservice teachers. Simple concepts about change were taught in Millicent's class. Her response indicates that she was not sure how well her early childhood students grasped the concept. Fred went more into depth in his lesson, connecting Newton's Third Law and Apollo 13 to the tasks students would do next (i.e. making the rockets and recording data about the blastoff). Finally, both of the preservice teachers reflected and focused on what they could have done differently to enhance their science lessons. Millicent stated that she wanted to improve her content knowledge while Fred wanted to add more structure to his lesson so that there would be more time for the experiment. These reflections, though brief, indicate the preservice teachers' critical reflection of their content knowledge and pedagogy.

## SUMMARY

The "Alka Rocket" lesson is recommended to teachers of elementary students in grades two through six. It is motivational for teachers and students, allowing them to use their own creativity rather than only participate in prescribed programs that have a tendency to deskill (Fullan, 2000). In addition, it provides children with a venue to explore their curiosity and to investigate questions they may have about rockets and space travel while emphasizing the importance of science inquiry.

The prospective teachers who participated in the Alka Rocket lesson learned as much as the students. Students learned about Newton's Third Law of Motion. They were able to verbalize that chemical changes brought about by the carbon-dioxide gas formed when Alka-Seltzer dissolved in water caused their rockets to fly as high as 10 or 12 feet into the air. Furthermore, students observed the force of gravity as the rockets fell back down to Earth. Using mathematics in context, helped students to estimate heights, calculate flight times, and experience how brief a few seconds can be. Most importantly, students learned that science and mathematics can be enjoyable and exciting. Students will remember what they have learned long after a lesson has been taught when the lesson is innovative, motivating, and applicable to the concepts learned.

The objectives of the Earth Links Project were to improve preservice teachers' self-efficacy and their ability to teach inquiry-based science. After the intervention, Millicent's (94 to 99) and Fred's (97 to 102) self-efficacy score (maximum of 115) improved on the pre-post survey (Science Teacher Self-Efficacy Belief Instrument (STEBI) (Enochs and Riggs, 1990). Furthermore, they experienced for themselves the richness of teaching inquiry-based lessons (Leonard, 2002). Our work is ongoing. Providing prospective teachers with practical experiences is important in helping them to develop the knowledge needed to implement hands-on activities and engage children in scientific inquiry. In this era of high accountability, it is essential that preservice teachers have high quality experiences if they are to become high quality teachers.

## ACKNOWLEDGEMENTS

The research presented in this paper was supported by a National Science Foundation grant (GEO-0331154). The views contained in this paper do not necessarily reflect the positions or policies at the National Science Foundation.

## REFERENCES

Bandura, A., 1997, Self-efficacy: The exercise of control, New York, W. H. Freeman.

Beerer, K., and Bodzin, A., 2003, Promoting inquiry-based science instruction: The validation of the Science Teacher Inquiry Rubric (STIR), Journal of Elementary Science Education, v. 15, p. 39-49.

Enochs, L., and Riggs, I., 1990, Further development of an elementary Science Teaching Efficacy Belief Instrument: A preservice elementary scale, School Science and Mathematics, v. 90, p. 694-706.

Fullan, M., 2000, The three stories of education reform, Phi Delta Kappan, v. 81, p. 581-584.

Grazer, B. (producer), and Howard, R. (director), 1995, Apollo 13 [Motion Picture], United States, Universal City Studios.

Leonard, J., 2002, Let's go fly a kite, Science and Children, v. 40, p. 20-24.

NASA Ames Research Center, 2001, The Lunar Prospector: Alka Rockets, Retrieved on November 23, 2005 from <http://lunar.arc.nasa.gov /education/activities/active4.htm>.

National Council of Teachers of Mathematics, 2000, Principles and standards for school mathematics, Reston, VA, NCTM.

National Council of Teachers of Mathematics and the National Aeronautics and Space Administration, 1997, Mission mathematics K-6, Reston, VA, NCTM.

National Research Council., 1996, National science education standards, Washington, D.C., National Academy Press.

Olive, D., 1996, Alka Rockets, Retrieved on November 23, 2005 from <http://www.spacegrant. hawaii.edu/class_acts/AlkaRocketTe.html>.

Schifter, D., and Fosnot, C. T., 1993, Reconstructing mathematics education: Stories of teachers meeting the challenge of reform, New York, Teachers College Press.

Wilson, J. D., 1996, An evaluation of the field experiences of the innovative model for the preparation of elementary teachers for science, mathematics, and technology, Journal of Teacher Education, v. 47, p. 53-59.