ABSTRACT: A science curriculum centered on snow and avalanches was implemented in a 5th grade classroom at Ophir School in Big Sky, MT. The curriculum content was developed by a PhD student as a part of the Graduate Teaching Fellows in K–12 Education Program (GK–12) of the National Science Foundation. The purpose of the curriculum was foremost to provide inquiry-based scientific content that both stimulated and motivated the students. Throughout the academic year, lessons, exercises, and field trips were conducted with particular focus on the decision-making triangle of snow, weather, and terrain. Various resources were utilized including assistance from the Gallatin National Forest Avalanche Center and the Big Sky Ski Patrol. One of the most important aspects of the curriculum is that the 5th grade students were able to participate in the education processes themselves which culminated in their development of a professional-quality poster. The poster was constructed for use as an educational tool for other grade school students and was presented, by the students, at the 2008 International Snow Science Workshop. Overall, the curriculum succeeded in exciting the students about science, with particular emphasis on snow science, and it is slated for further refinement during 2008/2009 academic year.

KEYWORDS: Avalanche Education, Snow Science, Science Education, Inquiry-based Education

1. INTRODUCTION

“If you can’t explain it simply, you don’t understand it well enough.”—Albert Einstein

Recognizing, as did Einstein, the importance of communication in science, the National Science Foundation established in 1999 the Graduate Teaching Fellows in K–12 Education Program (GK–12). This program has two specific goals (AAAS, 2008):

1. To improve the ability of graduate students in science, technology, engineering, and mathematics (STEM) to communicate their research to a broad audience and

2. To inspire and stimulate interest in science and engineering among students and teachers.

Within the GK–12 partnership between Montana State University (MSU) and Ophir School in Big Sky, MT, a snow science curriculum was implemented in a fifth grade class. This curriculum was composed of 15 lessons, a field trip, and final project. The material was developed by the primary author, a PhD student in Applied Mechanics researching the energy balance at the snow surface and how it affects snow metamorphism.

The snow science lessons focused on the widely used decision-making triangle of snowpack, weather, and terrain as described by Tremper (2001), and contained a variety of instruction methods that included interactive games, video clips, and hands-on activities. The field trip allowed the students to apply their knowledge of the snowpack as well as discover the intricacies associated with assessing snowpack stability. Finally, the students cumulated a winter season’s worth of snow and avalanche lessons by helping build a professional poster for display at Ophir School and presentation at the 2008 International Snow Science Workshop (ISSW).

The GK–12 Program at MSU is facilitated by the Big Sky Institute, which was established at MSU for interdisciplinary science integration, education, and outreach. As such, the expectation of the GK–12 Program expands beyond the aforementioned objectives by including a provision that the content
presented to the students is of local importance and revolves around the Greater Yellowstone Ecosystem. Considering the location of Ophir School in Big Sky, MT, snow and avalanches are certainly relevant to those living in the area. Additionally, the GK–12 Program desires lasting projects that both live-on after the fellow is finished and help teachers meet or exceed national and state science curriculum guidelines.

2. BACKGROUND

The history of snow and avalanche research at MSU is well established. The roots of the ISSW and the motto “A Merging of Theory and Practice” can be traced to the 1982 meeting at MSU in Bozeman, MT. Avalanche education is also well established in southwest Montana: during the 2007/2008 season the Gallatin National Forest Avalanche Center (GNFAC) conducted 96 lectures that reached nearly 4,000 people (Cabot, 2008).

The GK–12 Program at Montana started in 2005 and has since involved 28 teacher-fellow pairs and reached approximately 600 4th–8th grade students at 13 different schools. Snow science education was first introduced by Eric Lutz (Lutz et al., 2007) during the 2006/2007 academic year. His project included a similar curriculum as presented here that involved hands-on activities and field trips, including the use of tilt-board avalanche simulations, as shown in Figure 1.

3. A LASTING PROJECT

The GK–12 Program desires each fellow to develop a project that will last beyond their tenure. In part, this article is satisfying this objective, but the true lasting component is the curriculum itself. The lessons summarized here have been compiled into a single interactive file that includes a brief summary of each lesson, a list of required materials, a detailed description, interactive web-links, handouts, quizzes, and video clips. The goal was to build a self-contained curriculum that would be easily distributed to educators interested in teaching snow science in their classroom.

Finally, in a collaborative effort, the desired long-term objective is to compile the snow science curriculums developed at MSU and Ophir School into a distributable package, including the two complete curriculums and an avalanche education awareness video filmed at Ophir. These multimedia educational tools would then be distributed with the assistance of the Forest Service (E. Lutz, 2008, personal communication).

4. THE CURRICULUM

4.1. Science Education Standards

The lessons discussed herein were developed based on inquiry and process learning, as laid out in National Science Education Standards (NRC, 1996). This standard states that science education should include “…the ‘processes of science’ and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science.” Specifically, this lesson may be used to meet the following content standards:

- Physical Science Standards: Motions and Forces and
- Science in Personal and Social Perspectives: Natural Hazards.

Additionally, the lessons also help meet the Montana Grade Level Expectations (McCulloch, 2007) stating that a fifth grade student:

1. Identifies a testable question, safely plans and conducts experimental investigations, and communicates results and
2. Identifies, describes, and models characteristics of properties and basic physical, chemical, and mechanical changes (e.g. forces in motion, work, and power).
Lesson Summary

The lesson plans focus on the decision-making triangle of snow, weather, and terrain. The following is a list of the individual lessons that were developed during the 2007/2008 academic calendar.

1. Avalanche Basics
2. Applying the Basics
4. The Human Factor: A Dozen More Turns
5. Snowpack: Introduction to Snow Crystals
6. Terrain: The Warning Signs
8. Weather: Tracking the Conditions
9. Review: The Decision-Making Triangle
10. Snow Stability: Testing Snow Exercise
11. Snow Stability: The Compression Test
12. Snow Metamorphism: Temperature Gradient
13. Digging a Snow Pit
14. Review: Who Wants to Be a Dollaraire?
15. Rescue

Each lesson is designed to be implemented in one or two class periods of 50 minutes with minimal resources and is designed as a supplement to other science content. Hence, only one lesson was given per week.

The first three lessons are focused on introducing the students to avalanche terminology, especially the concept of the weak-layer, slab, bed-surface, and slope. Also, the relationship between the force caused by the slab and strength of the weak-layer were demonstrated to the students through the use of Equation 1. This inequality explains that an avalanche occurs when the force of the slab exceeds the strength of the underlining weak-layer.

\[
\text{Force of Slab} > \text{Strength of Slab} \quad (1)
\]

After the students are comfortable with the terminology, a series of video clips is presented giving the students an opportunity to identify the components in actual avalanches. Finally, the students participate in a trivia game based on the former television show, *The Hollywood Squares*.

At this point the “human factor” is introduced and explained as the most important component. This is demonstrated to the students through the powerful movie, *A Dozen More Turns: An Avalanche on Mt. Nemesis* (2007). This film tells the story of an avalanche fatality and the choices that surrounded the tragedy. Despite its serious and sometimes graphic content the students received this film well and a discussion ensued following the film.

The snowpack lessons focused on six basic types of crystals: new, rounds, facets, surface hoar, crust, and wet. With each crystal, the formation process and the role with respect to avalanches is outlined through the use of a group exercise. After explaining verbally how each crystal looks, forms, and behaves, the students received a handout with an image and three questions for each snow type (Figure 2). This lesson was one of the more rewarding of the year; the students were involved, inquisitive, and excited by the exercise and throughout the remaining year they enjoyed discussing crystals.

The weather and terrain sections were also broken into simplified categories. Weather included wind, sky, and snowfall. Terrain included slope, clues, consequences, and wind. Additionally, the concept of red, yellow, and green light conditions was introduced. For each category the students focused on identifying features of terrain or weather patterns and how each affects the avalanche hazard.

Lessons 10–13 focused on teaching the students how to examine the snow using a snow pit, compression test, and the measurement and calculation of temperature gradient. At Ophir, the

![Figure 2: Example handout used for identifying the basic snow types.](image-url)
students were able to go outside and dig miniature snow pits. They completed the worksheet provided in Figure 3, which required both measurements and analysis. Additionally, these lessons served as a precursor to the field trip discussed in Section 4.3.

The final lesson, “Who Wants to Be a Dollaraire?,” mimicked the similarly name television game show and used questions from the entire snow science curriculum. This was a fun activity, and the possibility of winning money excited the students. This lesson could easily be built into a review before a final examination—with the game serving as a motivator to study.

4.3. Field Trip

The field trip was an excellent opportunity for the students to step inside an actual snow pit. The goal of the trip was to have the students perform a snow pit analysis using the methodologies learned in class, including the compression and the extended column test. The field trip was facilitated by the Big Sky Ski Patrol, which allowed the students to learn from professionals who examine snow on a daily basis.

Unfortunately, the weather did not cooperate with respect to digging detailed snow pits—it was cold, snowing, and blowing. However, the students did experience the difficulties associated with working in mountainous terrain in the winter. Despite the weather, many of the students were able to participate in performing compression test, which was also difficult because of the extremely strong and well-bonded snowpack at our location (Figure 4).

4.4. Final Project

Perhaps the most rewarding and unique portion of the curriculum was the final project: to develop a professional-quality poster for use in educating students at Ophir School and for presentation at the 2008 ISSW.

The poster development process was meant to give the students a glimpse into the work required to present scientific research at the international level. After spending time explaining the purpose of a scientific poster, the students spent a class period developing their own ideas for a snow science poster and presented them to their classmates.

In groups the students then began writing the text, which was divided into seven parts: introduction, human-factor, snowpack, weather, terrain, stability testing, and rescue. The students completed four revisions of the text. The final revision, along with their layout ideas, were compiled into a poster. This poster was presented at the 2008 ISSW by two students: Isabella Sarmiento and Micah Robin (Ophir School 2007/2008 Fifth Grade et al., 2008). These two students were chosen to represent their class at ISSW after winning an essay contest, Why should I go to ISSW?

5. CLOSING REMARKS

As discussed, the GK–12 Program has two specific goals: to improve the communication skills of the fellow and to increase interest in science among the students. Quantifying increased communication skills is difficult, but speaking as fellow in the GK–12 Program, I feel participation has improved my ability to relay complicated scientific concepts to the
both students and teachers. Of course, this was a struggle at times. For example, the temperature gradient concept and calculation was extremely difficult for the students to grasp, mostly due to the limited mathematical experience. Thus, this section spanned multiple weeks and lessons, and required various teaching methods. Eventually the students began to understand the concept, but a far simpler teaching approach was required than anticipated.

In order to gage the effectiveness of the program, student surveys were used that focused on measuring student interest at the beginning and end of the academic year. Within a 10% confidence level, the Ophir students were more inclined than the average student to state the following (J. LaFrance, 2008, personal communication):

1. “I believe that what is known about science changes as scientists come up with new ideas and solutions.” ($p = .056$)
2. “I believe you can learn science in lots of places, not only in laboratories or classrooms.” ($p = .057$)
3. “I believe working as a scientist would be an interesting way to earn a living.” ($p = .058$)

The average in this case consisted of five different schools involved with the GK–12 Program at MSU. The $p$-value listed at the end of each item is the calculated confidence level, each of which approach the 5% level.

Additionally, the excitement level of students, teachers, and parents surrounding the essay contest and ISSW conference was astonishing and served as a catalyst to sustain the interest of the students as the academic year came to an end.

Overall, the GK–12 Program allowed for exciting opportunities in education and has allowed snow and avalanche science to take center stage among more traditional science lessons—a trend that will continue into the 2008/2009 year and hopefully beyond.

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7. REFERENCES


