High-Altitude Ballooning in Middle School: Focusing on Science and Engineering Practices

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During fall 2012 we carried out a high-altitude balloon research project with 8th-grade students from Burley Elementary School in Chicago, IL, which included a launch on November 18. An important focus was to engage the students in both science and engineering aspects of ballooning. This was partially motivated by the National Research Council's *Framework for K-12 Science Education*, and the recent release of the *Next Generation Science Standards*. In addition to identifying disciplinary core ideas and crosscutting concepts appropriate for each grade level, these documents strongly emphasize science and engineering *practices*, such as asking questions and defining problems, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, and obtaining, evaluating, and communicating information. We found that high-altitude ballooning provided an ideal context for teaching middle school science in the context of these practices. Here we will provide and overview of the eight practices and discuss concrete examples from our ballooning project at Burley School.

I. Science and Engineering Practices in the Next Generation Science Standards

Students who participate in high altitude ballooning are engaged in a variety of activities: They ask questions and make predictions about how temperature, pressure, cosmic ray intensity and other variables change during the flight. They test and refine different payload designs to maximize the likelihood that their experiments survive the harsh conditions of near space. They use software based on models of Earth's atmosphere to predict flight paths, ascent rates, and burst altitudes. They define and follow pre-and post-launch procedures for their investigations. They tabulate, graph, interpret, visualize, and analyze their data to identify patterns, test predictions, and infer explanations. They use mathematics and computation to statistically analyze their data or predict experimental results. They engage in arguments with other students about the correct explanation or the best experimental design and communicate scientific information in discussions, written reports and oral presentations.

These are common activities in almost any high-altitude balloon mission. But what do they have to do with science education standards? We often think of standards as specifying the content knowledge students should have at different grade levels, but the *Next Generation Science Standards*[1] (*NGSS*) go beyond content knowledge. All of the activities above are science and engineering *practices* that have a central role in the *NGSS* and the *Framework for K-12 Science Education*[2] on which the *NGSS* are based. These documents also specify the grade-appropriate competencies for each practice and the progression throughout K-12, and discuss similarities and differences between science and engineering. Engaging in these practices helps students better understand, and become more critical consumers of, the scientific information they hear about on TV and in the news. They experience how scientific knowledge is generated, and why scientists are more certain about some theories than about others. It makes this information more meaningful to them, helps them understand the creative aspects of science and engineering, and makes them realize the there is not a single scientific method that can be applied to all questions. In

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may also capture their interest and motivate them to continue their studies. The importance of engaging students in these practices is also emphasized in *Taking Science to School*[3] which points out that students cannot understand science without being able to participate productively in scientific practices and discourse. *Ready, Set, SCIENCE!*[4] explains that even though students obviously cannot behave exactly like scientists, they can develop many of the skills and practices that scientists demonstrate if they understand science as a process of building theories from evidence. In addition, *How Students Learn*[5] stresses that in order to be able to help students develop scientific knowledge that can be used flexibly to make sense of and appreciate the world around them, science teachers must be knowledgeable about the practices of the scientific community. Bybee[6] points out that the practices are not just learning outcomes but also instructional strategies that provide a means for students to understand science content.

The *NGSS* emphasize that students need to understand both the similarities and the differences between science and engineering. Science and engineering are similar in many ways, such as their use of systematic processes, models, mathematics and computing. However, scientists ask questions about the natural worlds and propose explanations that are tested by comparing predictions with observations and data, whereas engineers identify problems related to human needs and propose processes and products to solve them. In high-altitude ballooning missions these similarities and differences become apparent to the students because they are naturally exposed to both types of inquiry. They ask scientific questions about the conditions in Earth's atmosphere and collect data to test their predictions, and they identify and solve engineering problems related to payload design and mission operations.

II. Science and Engineering Practices in the Burley School Balloon Mission

Figure 1 shows the eight NGSS science and engineering practices organized into the four categories exploring, explaining, testing, and communicating. The arrows connecting each category to the other three illustrate that these activities usually occur repeatedly in different sequences. In the following section we will provide examples from the ballooning project we carried out with 8th grade students from Burley School in Chicago in fall 2012. The science and engineering practices helped us to create an organizational framework with regular goals that guided students through the many inherent challenges and allowed them to take ownership of all aspects of the project.

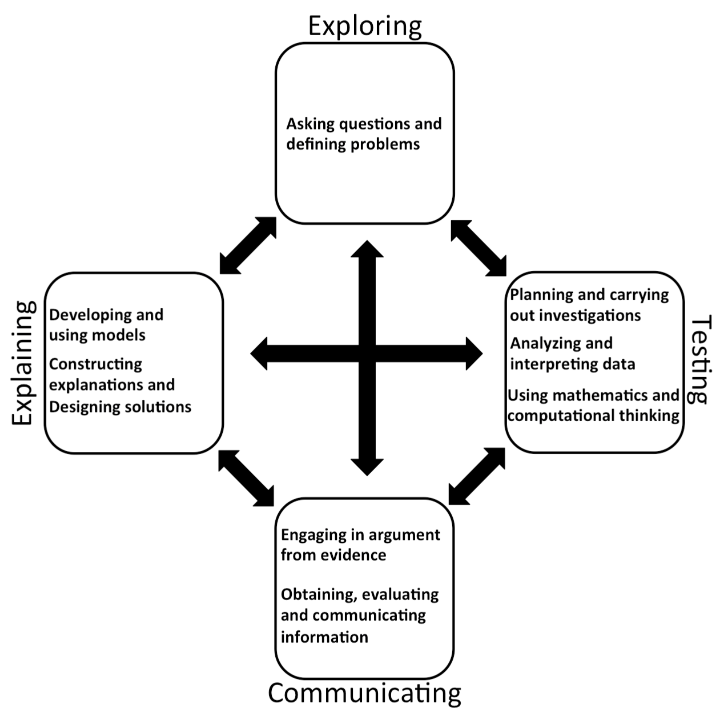

Figure 1. The eight science and engineering practices divided into four categories. The arrows illustrate that the practices usually occur repeatedly in different sequences.

A. Exploring

Practice:

- *Asking questions and defining problems*

There are many different ways scientific investigations get started. They often begin with an exploration phase during which scientists "poke around" in the literature, find inspiration in serendipitous observations, or engage in discussions with colleagues. This often leads to questions that then become the catalyst of formal investigations. The Burley students started their investigations by talking with their peers about what they already knew about changes in Earth's atmosphere, especially those changes that they had experienced themselves, for example when riding on elevators in high rise buildings or when hiking in the mountains. They researched background information in textbooks, periodicals, and the Internet. They also explored the equipment they had available for their projects. They generated and evaluated different ideas for research projects, narrowed down their choices based on interest and feasibility and formulated their final questions, such as "how does the loudness of sound generated by an MP3 player change during the ascent and descent?" and "how does cosmic radiation affect the behavior of pill bugs?"

Students also investigated possible designs for payload containers, for attaching their experiments, and for controlling variables such as pressure, temperature and radiation exposure. They defined engineering problems such as "how can I expose my experiment to the intense cosmic radiation of near space but protect it from the cold temperature and ultraviolet radiation?" After reviewing flight tracks from previous balloon flights, students realized that balloons could travel large distances in different directions, that the burst can occur at different altitudes, and that the ascent rate can vary significantly, possibly leading to undesirably short or long flights. They realized that they had to find a way to predict where the balloon would land based on time and place of launch so that they would be able to recover it after the flight and avoid a landing in a forest or lake. They also decided that they needed to be able to control the ascent rate so that the flight would last long enough to collect the required science data, but not so long that it could not be completed in the available time.

B. Explaining and Testing

Practices (Explaining):

- *Developing and using models*
- *Constructing explanations and designing solutions*

Inferring explanations of how the natural world works in the form of theories and hypothesis and testing them with data is at the heart of scientific investigations. There are often many competing explanations, and it is the job of scientists to figure out which one is supported by the most convincing evidence. After the Burley students determined which science questions they wanted to answer and what engineering problems they had to solve in order to do that, they needed to construct explanations for how and why the variables they were interested in would change during the flight based on their knowledge of science and their background research. To help them focus their ideas about what might happen during the flight and construct preliminary experimental hypotheses, students used research organizers to collect the background information, their own ideas and preliminary explanations and design ideas, and notes from group discussions. For example, based on their knowledge that sound waves need a medium to travel through, and that astronauts on the moon cannot talk to each other without radios because there is no air, they constructed an explanation for how less and less sound energy would be able to propagate from the MP3 player to the microphone inside their pod as the density of the atmosphere decreases during the ascent. This hypothesis allowed them to predict that the loudness of the sound recorded during the flight would decrease during the ascent and increase during the descent. They designed polystyrene payload containers that were light and allowed them to attach their experiments with cable ties and Velcro on both the inside and outside, and control pressure and temperature with soda bottle "pressure chambers" and chemical hand warmers. They used flight prediction software based on atmospheric models to predict the approximate ascent rate, burst altitude and landing area.

Practices (Testing):

- *Planning and carrying out investigations*
- *Analyzing and interpreting data*
- *Using mathematics and computational thinking*

The students were given timelines to map out each step of their investigations with completion dates. They built the payload containers, attached their experiments, and planned, practiced and refined their pre-and post flight procedures. This included, for example, procedures to prepare and start the Vernier and HOBO data loggers and to place pill bugs into different flight "habitats." They conducted systematic drop experiments to test the durability of their payload designs. With their payload tested and ready for flight, the students generated mission procedures for predicting the flight path, preparing their payload for flight, filling and launching the balloon, tracking and chasing it during the flight, and recovering the payload after landing. Because each student had a role in the overall mission, the students coordinated the tasks that needed to be completed for the mission with the procedures of each experiment. After the flight they followed their post-flight procedures to recover their data and spent several weeks analyzing their data using statistics and computation, looking for patterns, and comparing it with their predictions to test their hypotheses.

C. Communicating

Practices:

- Engaging in argument from evidence
- Obtaining, evaluating and communicating information

The ability of scientists and engineers to communicate their results, present convincing arguments for their findings, and scrutinize them based on feedback from their peers is critically important for scientific progress. Such arguments can occur in peer reviewed journal articles, conference presentations and informal discussions. The Burley students communicated and engaged in arguments with each other, their teacher, and their university partner throughout the project, from constructing a research question and creating a research plan to executing the balloon flight and analyzing their data. At the end of three months of hard work on their ballooning projects, the students gave presentations about their findings to their peers, parents and community members.

III. Conclusion

Science education research shows that in order to understand how science works students have to participate productively in scientific practices through appropriately challenging activities that allow them to take authority over their learning and provide opportunities to scrutinize each others work using criteria that are accepted by the scientific community[3,4,5]. Furthermore, the practices are not just learning outcome, but they are also instructional strategies teachers can use to teach science content. This has been recognized in the *Framework for K-12 Science Education*[2] and the *Next Generation of Science Standards*[1], which highlights eight science and engineering practices with learning progressions across K-12. Working with 8th grade students from Burley School in Chicago, we found that high-altitude ballooning provides an ideal context for engaging middle school students in all eight of these practices.

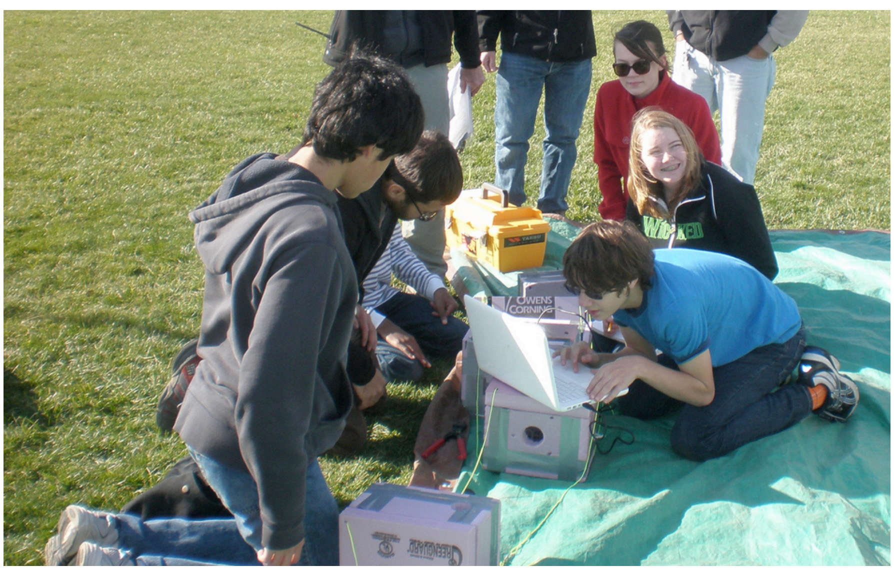

Figure 2. A group of Burley students and their teacher completing the pre-launch procedures for their experiment.

References

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