Connecting Ardusat to the Next Generation Science Standards

David D. Thornburg, PhD
Thornburg Center
dthornburg@aol.com

Abstract
In 2013 the Next Generation Science Standards (NGSS) were published as national guidelines for K-12 science education. The standards were developed by a consortium of 26 states and by the National Science Teachers Association, the American Association for the Advancement of Science, the National Research Council, and Achieve, a nonprofit organization that was also involved in developing math and English standards.

Rather than focus on specific curricular objectives, these standards outline a framework that addresses how science is taught, instead of the details of what is taught on a grade-by-grade basis. This approach was taken to address the perception that the US science curriculum was a mile wide and an inch deep. At the time of this writing (mid-2015) over 40 states are showing interest in adopting these standards. One goal of these standards is to increase the level of interest in the sciences for students nationwide.

One challenge resulting from these new standards is helping educators make the pedagogical shifts needed to transform the curriculum from one based on the nouns of science (*what* is taught) to one based more on the verbs of science (the *how* of science) resulting in students learning the thought processes of scientists as they pursue their work. Another challenge is that, for the first time, engineering is included in the standards from K-12.

This paper illustrates a project (Ardusat) that, by itself, addresses every aspect of the standards and is appropriate for students in the middle grades through high school.

The Ardusat Project
Arduino is a tool for making computers that can sense and control more of the physical world than a desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects, with the ability to control output devices (lamps, motors, etc.) and read digital and analog input devices (light, temperature, etc.) based on short programs (called sketches) written in the Processing language which is similar to Java and C++. The Arduino board is used by a wide community of students and hobbyists to

build devices (such as robots) with a combination of hardware and software and, in the past few years, it has become the standard for microcontroller systems. The circuit board itself (not including sensors or output devices) is available from many sources for a very low price.

The Ardusat project allows school children to create programs for the Arduino with a variety of sensors, and for these programs to be sent to specially equipped cubesats – small satellites whose base size is 10 cm on each side by 30 cm long – that are in orbit about 400 km above the Earth (about the height of the International Space Station.) While cubesats are not a new technology, historically these small devices were primarily the domain of college students. The Ardusat project opens space exploration to younger students for the first time.

Cubesats are typically launched by hitching a ride on rockets carrying other payloads, and are pushed out when they reach the desired altitude. The Ardusat devices stay in orbit for a couple of years before entering the atmosphere and burning up, thus insuring they do not add to the debris in space.

Ardusat with photocells deployed as seen from space

Because cubesats are much less expensive than traditional satellites, this technology has the potential to democratize space exploration. With 20 new cubesats (built and launched by their partner, Spire) planned for 2015, students around the world will be able to put their programs on a special website where they will be uploaded to a satellite to run an experiment, with the resulting data file placed back on the site for student download. Because the satellites have numerous sensors as well as an Earth-facing camera, students are free to design quite complex experiments.

Radio communication with the constellation of Ardusats is maintained worldwide by the team who builds the satellites.

Ardusat is unique in that their devices are intended for use by students from the middle grades through high school, with the goal of improving STEM (science, technology, engineering, mathematics) education through experiments designed and conducted in space by the students themselves.

Later we will show the connection between the Ardusat project and the Next Generation Science Standards (NGSS), but first an overview of these standards is called for.

NGSS Overview

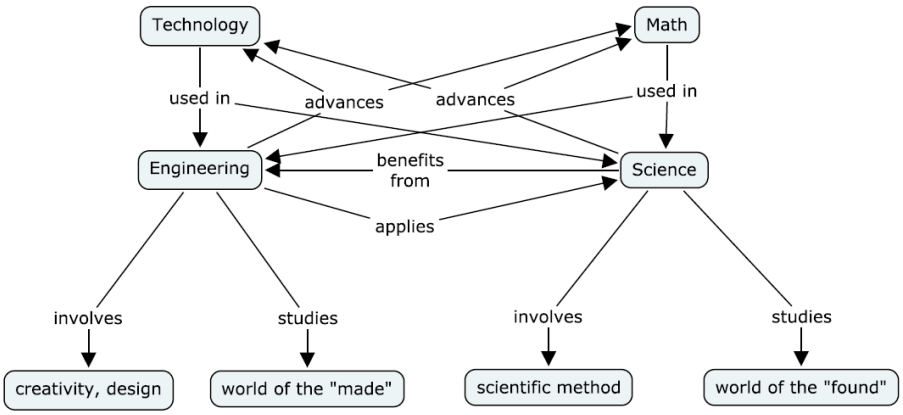
Unlike traditional standards for educational content, the NGSS is focused on how scientists do their work, rather than just on the memorization of decontextualized information. The goal is to build an interest in the sciences by students, as well as have them learn how to think scientifically.

While the NGSS document is large, there are only seven goals addressed by these standards:

NGSS Goals

1. K-12 science education should reflect the interconnected nature of science as it is practiced and experienced in the real world.
2. The Next Generation Science Standards are student performance expectations – NOT curriculum.
3. The science concepts in the NGSS build coherently from K–12.
4. The NGSS focus on deeper understanding of content as well as application of content.
5. Science and engineering are integrated in the NGSS, from K–12.
6. The NGSS are designed to prepare students for college, career, and citizenship.
7. The NGSS and Common Core State Standards (English Language Arts and Mathematics) are aligned.

As mentioned in the abstract, of these goals, the one that causes concern in many teachers is the incorporation of engineering as a K-12 topic. If science explores the world of the found, engineering explores the world of the made. The exploration of these worlds is different enough to justify engineering as a separate discipline. The following figure shows the interconnections between science and engineering:



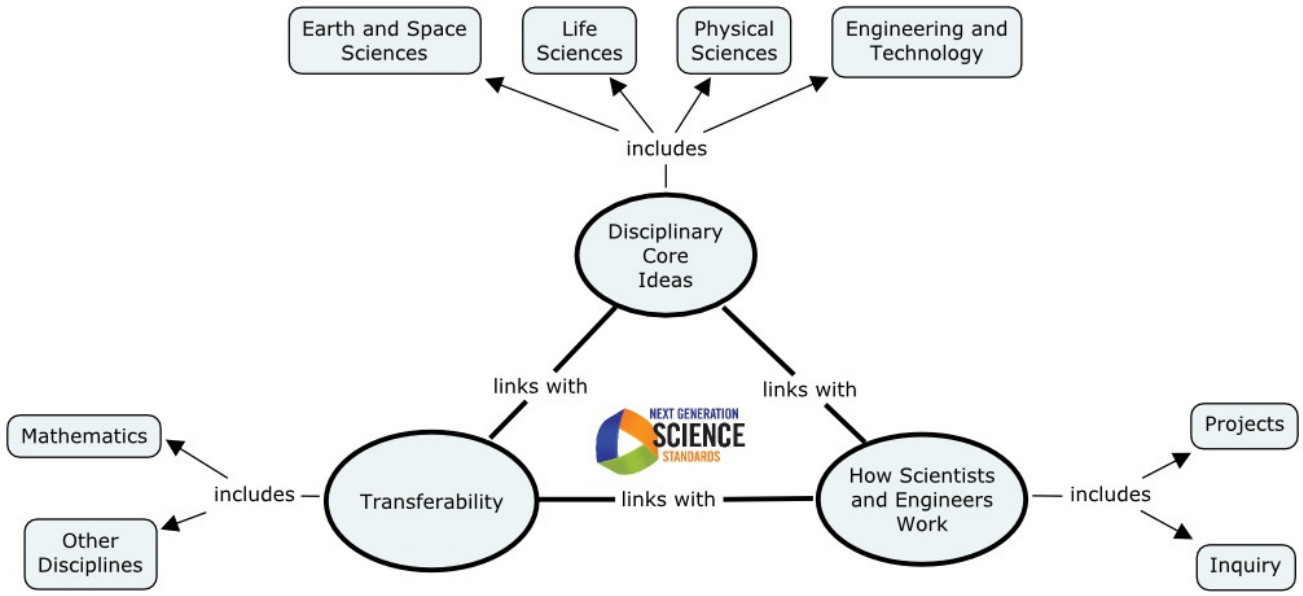
There are four disciplinary core ideas: Earth and Space Sciences, Life Sciences, Physical Sciences, and Engineering and Technology.

As for the structure of the NGSS, it can be thought of as a three-legged stool consisting of disciplinary core ideas, how scientists and engineers work, and transferability to other fields.

As for the leg relating to how scientists and engineers work, the key idea there is to move toward a pedagogical model based on inquiry-driven project-based learning. Not only is this pedagogical model known to help develop deeper understanding of concepts, it also stimulates interest in the material being explored.

The transferability leg connects to other subjects (especially mathematics and language arts), which are the topics of their own standards documents (the Common Core State Standards) that share some philosophical similarities to the NGSS.

With this overview of the structure of the NGSS, we are ready to show the connections between Ardusat and these standards.



Connections between Ardusat and the NGSS

If asked, many students are excited by the prospect of doing experiments of their own design in space. From the perspective of schools, interest by itself is not enough – the projects students do should have connection to existing standards mandated by the states. Even those states that haven't yet adopted the NGSS are interested in improving STEM education, and a strong connection to the NGSS addresses this goal even if those standards have yet to be formally accepted.

Looking at the NGSS, most connections are easy to find. First, all the disciplinary core ideas are addressed with Ardusat. The connections to Earth and Space Sciences, Physical Sciences, and Engineering and Technology are fairly obvious, and the addition of the Earth-facing camera provides an opportunity to explore Life Sciences as well. The engineering domain is addressed strongly with the design and implementation of programs for the Arduino, coupled with Earth-based experiments with this device. Physical science topics cover a wide spectrum. For example, how does the Ardusat maintain an orientation so the camera is always facing the Earth? Measurements made with on-board sensors as the Ardusat goes around the world at about 7.5 km/sec. provide more powerful exploration opportunities. Images from space, for example, will show areas with and without vegetation. This can be used as a springboard for more detailed life sciences projects.

The second realm of NGSS, How Scientists and Engineers Work, moves beyond the content of these subjects to the methodology. The cornerstone here is inquiry coupled with projects.

The ability of students to conduct experiments in space leads to a tremendous number of questions that are quite deep (these are called "driving questions"). For example, does temperature have meaning in space? How can we find out? In this case, because the Ardusat has a temperature sensor, data can be collected. But the temperature being measured is associated with the circuit board containing the sensor. Is this the same as measuring the temperature of space itself (assuming the concept has meaning)?

Contrast the project-based approach with the traditional lecture and textbook-driven model of education. Lectures limit learning, and projects expand it. As a result, this connection between Ardusat and NGSS is extremely powerful.

Finally, the third realm of NGSS – Transferability – also has strong connections to Ardusat, especially in the domain of mathematics. Everything from the derivation of algebraic representations of orbital speed to calculations of power consumption from the solar cells requires mathematics.

In short, Ardusat is strongly connected to every aspect of the NGSS, and is thus a perfect platform for those wanting to enhance their STEM education activities in their schools.

About the author

Dr. Thornburg is a child of the October sky. When Sputnik was launched his interests in science and engineering became quite strong. His doctorate spans all four of the STEM subjects, and he and his team conduct workshops and give presentations worldwide on STEM-related topics, including special workshops devoted to helping schools prepare for Ardusat-based projects. David has won numerous awards for his work in education and has written many books related to educational technologies.