Addressing Educational Standards, Grades 9-12

In grades 9-12, students are exposed to a greater variety of subjects and are more interested in applying what they are learning to their lives. They typically delve into topics and develop skills and knowledge that prepare them for college and careers. According to educational standards, in grades 9-12, students tackle more complex mathematics, and expand their scientific understanding of living systems (e.g., through the study of natural selection and mechanisms leading to adaptation, through study of how disturbance can alter ecosystems and their functions). They have a better sense of geography and spatial patterns, and are able to use sophisticated tools and technologies to explore their world. By high school, students are more aware of current issues such as global climate change, and can grapple with such issues in the context of their various courses.

Participation in Project BudBurst can provide an engaging, real-world context for learning about many of these topics, as well as a way to become involved in a community of practice. It also provides opportunities for students to develop skill with scientific practices such as collecting and analyzing data, developing arguments and conclusions from evidence, and communicating their ideas both written and orally. All of these are important content and skills for high school students to learn as defined by today's educational standards.

Because Project BudBurst is a national citizen science program, this document addresses national education standards. District and state requirements of course vary, however many base their standards on these common national standards.

National Science Education Standards

National Science Education Standards (NSES) specify scientific content knowledge and inquiry skills appropriate for multiple grade bands. According to NSES, in grades 9-12 students' understanding will include abstract knowledge and comprehensive theories. It will also encompass scales both small and large. Specific content and inquiry skills defined in NSES for grades 9-12 that may be addressed through use of Project BudBurst are listed on the next page.

Grades 9-12 Topic	Grades 9-12 Content Standards
LS: Biological Evolution	Biological *classifications* are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities that reflect their evolutionary relationships.
LS: Interdependence of Organisms	Living organisms have the capacity to produce *populations* of infinite size, but *environments* and resources are finite.
LS: Matter, Energy, and Organization in Living Systems	The *distribution and abundance of organisms and populations* in ecosystems are limited by the availability of matter and *energy* and the ability of the ecosystem to recycle materials.
LS: Behavior of Organisms	*Organisms have behavioral responses* to internal changes and to *external stimuli.* Responses to external stimuli can result from interactions with the organism's own species and others, as well as *environmental changes*.
NS: Science as a Human Endeavor	Individuals and teams have contributed and will continue to contribute to the scientific enterprise. Doing science can be as simple as an individual conducting field studies or as complex as hundreds of people working on a major scientific question.
NS: Nature of Scientific Knowledge	Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available.

Grades 9-12 Inquiry Standards

- *Identify questions and concepts that guide scientific investigations*. Students should demonstrate appropriate procedures, a knowledge base, and conceptual understanding of scientific investigations.
- *Use technology and mathematics to improve investigations and communications.* The use of computers for the collections, analysis, and display of data is also a part of this standard. Mathematics plans an essential role in all aspects of an inquiry. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results
- *Formulate and revise scientific explanations and models using logic and evidence.*
- *Recognize and analyze alternative explanations and models.* This emphasizes the critical abilities of analyzing an argument by reviewing current scientific understanding, weighing the evidence, and examining the logic so as to decide which explanations and models are best.

Geography Standards

Because Project BudBurst is a national project, with participants monitoring plants across the continent, students have easy access to data similar to that which they collect in their local area but submitted from locations across the United States. This provides a unique opportunity for students to experience and make meaning of large-scale spatial data. Incorporating this type of learning experience into classroom instruction can help teachers address geography instruction. While geography is not typically taught as a stand-alone course in most high schools, there is a growing awareness that geography can be integrated across the curriculum and is a particularly good fit with environmental and earth sciences.

National geography standards are comprised of 18 standards that define what a geographically informed person should know and understand. Below are the particular standards that may be addressed through use of Project BudBurst in the classroom.

The World in Spatial Terms

- **Standard 1:** *How to use maps* and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.
- **Standard 3:** How to analyze the spatial organization of people, places, *and environments on Earth's surface.*

Places and Regions

- **Standard 4:** The physical and human characteristics of places.

Physical Systems

- **Standard 8:** The characteristics and spatial distribution of ecosystems on Earth's surface.

Environment and Society

- **Standard 14:** How human actions modify the physical environment

Common Core Standards

A majority of states have adopted Common Core Standards for English Language Arts and Mathematics (http://www.corestandards.org/in-the-states). Incorporation of Project

BudBurst, a citizen science program, in classroom instruction can help address these standards.

Common Core Standards for Language Arts are based on an integrated model of literacy (reading, writing, speaking, listening and language). They are designed to integrate language skills with other topics (i.e., history/social studies, science and technical subjects), through the incorporation of a variety of texts including science-based informational texts. The 9-10 grade *reading* standards, for example, state that students should be able to "*Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text; assess the extent to which the reasoning and evidence in a text support the author's claims; and compare and contrast treatments of the same topic in several primary and secondary sources."* Using Project BudBurst informational texts and related resources, students can develop proficiency in reading while at the same time learn about phenology, ecosystems and climate change. By giving students direct experience with observation and data collection that produces data in a format similar to that reported in scientific texts, students participating in Project BudBurst are also better prepared to read and assess relevant scientific texts.

Under the Common Core *writing* standards for 9-10 grades, students should be able to draw evidence from informational texts to support analysis, reflection, and research. Specifically, students should be able to *"Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation*." Participation in Project BudBurst can provide a framework for students to explore, investigate and communicate their understanding of scientific information.

Common Core Math Standards in grades 9-12 specify mathematics that all students should study in order to be college and career ready. In high school, in addition to algebra, geometry, and functions, students are also introduced to statistics and probability. The Common Core standards define statistics as a tool for describing variability in the data, and for discovering patterns and deviations from patterns. Specifically, students are expected to "*understand statistics as a process for making inferences about population parameters based on a random sample from that population.*" Participation in Project BudBurst, where students make observations of their plants, examine similar data on plants growing elsewhere, and use statistical concepts such as distributions, mean, variability, and random sampling to draw inferences about populations, can be an effective way to help students understand various math standards through direct experience and application.

A Framework for K-12 Science Education. Practices, Crosscutting Concepts, and Core Ideas

Building on the NSES, the new Framework for K-12 Science Education emphasizes the integration of scientific practices, crosscutting concepts and core ideas, and sets the expectation that educators incorporate all three dimensions throughout instruction. Guiding principles that underlie the structure of the framework include the natural investigative nature of students; the emphasis on a limited set of core ideas to allow for deeper exploration and understanding; and the recognition that science requires both knowledge and practice. The framework also describes learning where students "build progressively more sophisticated explanations of natural phenomena" rather than focusing only on description in early years and leaving explanation for later grades. In general, the new Framework and subsequent standards that will come from this framework stress the importance of giving students experience with authentic scientific practices in the context of important core ideas. Inviting students to become citizen scientists through Project BubBurst is a natural fit for this type of instruction. Project BudBurst students engage in studies of plants in their own environment, collecting their own data over time and making connections between observed events and natural phenomena.

A summary of the Framework's practices, concepts and core ideas is listed below, with samples of specific understandings at the grades 9-12 level included.

Scientific and Engineering Practices

1) Asking questions (for science) and defining problems (for engineering)

Students should be able to ask probing questions that seek to identify the premises of an argument, request further elaboration, refine a research question, or challenge the interpretation of a data set.

2) Developing and using models

3) Planning and carrying out investigations

Students should be able to formulate a question that can be investigated within the scope of the classroom, lab, or field with available resources and frame a hypothesis based on a model or theory; decide how much data are needed to produce reliable results and consider any limitations on the precisions of the data; consider possible confounding variables or effects and ensure that the investigation's design is sufficiently controlled.

4) Analyzing and interpreting data

Students should be able to use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and computer technology to collage, summarize and display data and to explore relationships between variables; recognize patterns in data that suggest relationships worth investigating further; distinguish between causal and correlational relationships; evaluate the strength of a conclusion that can be inferred from a dataset using appropriate math and statistical techniques.

5) **Using mathematics and computational thinking**
6) **Constructing explanations (for science) and designing solutions (for engineering)**

Students should be able to use primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon.

7) **Engaging in argument from evidence**

Construct a scientific argument showing how data support a claim. Explain how claims to knowledge are judged by the scientific community today and articulate the merits and limitations of peer review and the need for independent replication of critical investigations.

8) **Obtaining, evaluating, and communicating information**

Engage in a critical reading of primary scientific literature or of media reports of science and discuss the validity and reliability of the data, hypotheses, and conclusions.

Crosscutting Concepts

1) **Patterns**

It is important for students to develop ways to recognize, classify, and record patterns in the phenomena they observe. By high school, students should recognize that different patterns may be observed at each of the scales at which a system is studied.

2) **Cause and effect: Mechanism and explanation**

In high school, argumentation starts from students' own explanations of cause and effect, and this can help them appreciate standard scientific theories that explain the causal mechanisms in the systems under study.

3) **Scale, proportion, and quantity**
4) **Systems and system models**

Because of the size and complexity of the natural world, scientists define small portions for the convenience of investigation, and refer to these as 'systems.' By high school,

students should be able to identify the assumptions and approximations that have been built into a systems model and discuss how they limit the precisions and reliability of its predictions.

Disciplinary Core Ideas

Life Sciences

- LS1: From molecules to organisms: Structures and processes
- LS2: Ecosystems: interactions, energy and dynamics (in particular C. Ecosystem Dynamics, Functioning, and Resilience)

  What happens to ecosystems when the environment changes?"

  "A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status as opposed to becoming a very different ecosystem. … Anthropogenic changes in the environment – including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change – can disrupt and ecosystem and threaten the survival of some species."
- LS3: Heredity: Inheritance and variation of traits
- LS4: Biological Evolution: Unity and diversity

  How does the environment influence populations of organisms over multiple generations?

  "Natural selection leads to adaptation – that is to a population dominated by organisms that are well suited to survive and reproduce in a specific environment. … Changes in the physical environment, whether naturally occurring or human induced, have thus contributed the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline – and sometimes the extinction – of some species. If members cannot adjust to change that is too fast or too drastic, the opportunity for the species' evolution is lost."

Earth and Space Sciences

- ESS1: Earth's place in the universe
- ESS2: Earth's systems (in particular D. Weather and Climate)

  "Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate."
- ESS3: Earth and human activity (in particular D. Global Climate Change)

"Global climate models are often used to understand the process of climate change because these changes are complex and can occur slowly over Earth's history. Though the magnitudes of humans' impacts are greater than they have ever been, so too are humans' abilities to model, predict, and manage current and future impacts."