Data Nuggets: Bringing Real Data into the Classroom to Unearth Students' Quantitative & Inquiry Skills

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INQUIRY & INVESTIGATION

Data Nuggets: Bringing Real Data into the Classroom to Unearth Students' Quantitative & Inquiry Skills

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Abstract

Current educational reform calls for increased integration between science and mathematics to overcome the shortcomings in students' quantitative skills. Data Nuggets (free online resource, http://datanuggets.org) are worksheets that bring data into the classroom, repeatedly guiding students through the scientific method and making claims based on quantitative evidence. Created around recent and ongoing research, Data Nuggets provide background to a scientist and their study system, along with a real data set from their research. We demonstrate the use of Data Nuggets in the classroom and share a lesson that challenges students to answer a scientific question, use a data set to support their claim, and guides them through the construction of graphs to facilitate data interpretation. Data Nuggets can be used across K–16 grades and multiple times throughout the school year as students build their quantitative skills.

Key Words: *Data Nuggets; inquiry; quantitative literacy; differentiated instruction; biology; ecology; evolution.*

○ Introduction

Students in the United States are inadequately prepared for the science and mathematics needs of today's society and lag behind other industrialized countries (Steen, 1999; National Center for Education Statistics, 2005). High school graduates are leaving with mathematical and quantitative literacy skills well below minimum expectations (Massey, 1989; Forman & Steen, 1999), and as students begin college with low quantitative abilities, postsecondary institutions have no choice but to offer extensive remedial courses (U.S. Department of Education, 1996; Merisotis & Phipps, 2000). Educational shortcomings in quantitative and information literacy are only becoming more problematic as science and society increasingly rely on quantitative information found in large and complicated data sets. To prevent this, it is recommended that the connections between science and mathematics be made as early as possible (Šorgo, 2010; AAAS, 2011) and that quantitative skills be integrated across disciplines (AAAS, 2011; Common Core State Standards Initiative, 2014).

Data Nuggets get students excited about a research topic while increasing their quantitative skills and competency with the scientific method.

The landscape of science education is currently undergoing a fundamental shift. Educational standards and reform, such as the *Next Generation Science Standards* (NGSS Lead States, 2013) and *Vision and Change* (AAAS, 2011), focus on students' ability to analyze and interpret data, use mathematical thinking, and communicate arguments based on evidence. In other words, students should learn what it means to be a scientist and how to use the scientific method to make arguments based on evidence. Educators agree that science should be taught as an active process: instead of students memorizing facts in textbooks, the focus should be placed on students' ability to generate new knowledge by testing hypotheses and interpreting data (e.g., Chen & Steenhoek, 2014; Royer & Schultheis, 2014; also see College Board, 2013). However, it is often difficult for teachers to integrate these reforms into their classrooms, because of either a lack of training to deal with educational reform or a lack of resources.

Data Nuggets (http://datanuggets.org) are free K–16 educational resources that bring data collected by scientists into the classroom, giving students the chance to work with data from cutting-edge research. They were designed in response to teacher requests for lessons that would help students meet quantitative learning goals. Data Nuggets are built from recent and ongoing research; each worksheet provides a brief background to a research topic, the researcher's process as they developed their ideas, and a data set from their work. Students are challenged to answer a scientific question using the data set to support their claim and are guided through the construction of graphs to facilitate data interpretation. Data Nuggets get students excited about a research topic while increasing their quantitative skills and competency with the scientific method.

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○ Learning Objectives

Through the repeated use of Data Nuggets in the classroom, students will

- Understand that science is an active process and how we learn about the natural world. Scientific research begins by generating questions, leading to testable hypotheses and experimentation to gather supporting evidence. Evidence is based on the careful analysis of data and logical reasoning. The scientific method is not a linear process, and often experiments result in more questions than answers (Figure 1).
- Identify and differentiate between scientific questions, hypotheses, and predictions. Deciphering the difference between a prediction and a hypothesis is a common struggle for students of all ages. Data Nuggets offer repeated active engagement in distinguishing between these closely related concepts.
- Build their quantitative skills by working with data, graphing, and interpreting quantitative information. In each Data Nugget, students must work with data to create a graph and make a claim based on this evidence. Data Nuggets reinforce basic statistics, such as calculating means, identifying dependent and independent variables, and making appropriate graphs to visualize data.
- See science as an approachable and attainable career. When students engage in inquiry in the classroom, they are doing science. Exposure to contemporary research, especially projects done by young, early-career scientists, will help students recognize that they too can become researchers in the near future. Classroom discussions of current issues in science, how lessons relate to everyday issues, and careers in science improve student retention in STEM fields (Woolnough, 1994).

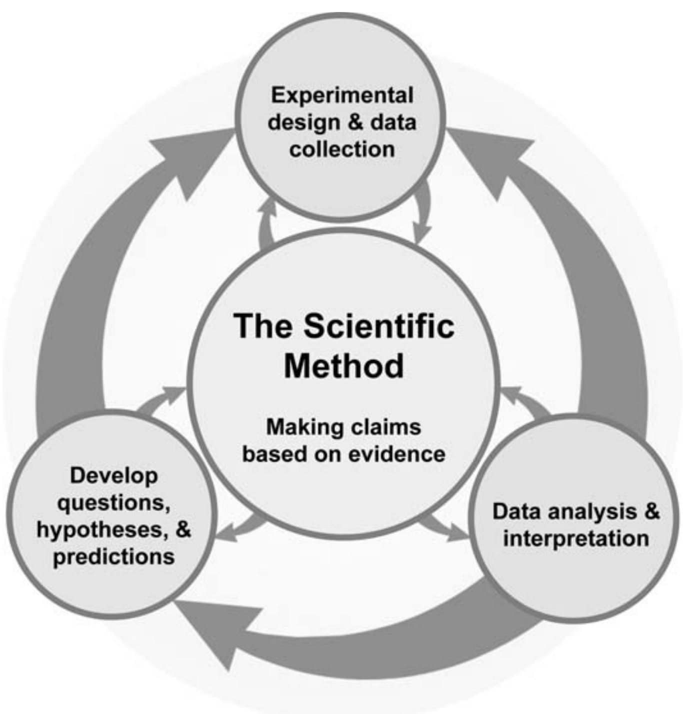

Figure 1. Scientific method schematic, modified from Understanding Science (2014).

○ Using Data Nuggets in Your Classroom

Data Nuggets can be used in the classroom once, as a series throughout the academic year, or as a take-home assignment. They can also be used as a pre- and post-assessment tool to evaluate effectiveness of lessons covering the scientific method and data analysis. With repeated use of Data Nuggets throughout the school year and across grades K–16, students receive extensive practice with the scientific method and working with quantitative data. Currently, there are 17 Data Nuggets available online, covering a variety of research areas such as climate change, animal behavior, invasive species, adaptation, and mutualisms (Table 1). Each Nugget has a reading level between 1 and 4 according to the vocabulary and content of the background information provided to students (Table 2). In addition, worksheets are coded according to the graphing skills required, building from a graph that is provided to a student-generated graph (Table 2). Teachers can assign increasing Reading and Graphing levels throughout the school year as students improve in their reading comprehension and comfort with data.

Each student in a classroom comes in with his or her own reading, quantitative, and critical-thinking skill set. Differentiated instruction allows teachers to address these disparities and help each student meet education standards (Levy, 2008). Data Nuggets allow for differentiated instruction, in that teachers can choose which worksheet to assign on the basis of a student's reading and quantitative skills. For example, within the same classroom, a student with poor reading comprehension but strong quantitative skills could use worksheet 1C, while a student with a contrasting skill set could use worksheet 3A.

○ An Example Data Nugget in the Classroom

Before using Data Nuggets in the classroom, students should be familiar with the scientific method and basic graphing skills. The first time a Data Nugget is used in the classroom, teachers may wish to guide students through the worksheet, having them read text aloud and create the graph together on the board. Each worksheet follows the scientific method and is based on the same template; once familiar with Data Nuggets, students should be able to complete the assignment on their own. Teachers can then use the provided grading rubric to see if students need further instruction on any area of the scientific method. Depending on the difficulty of a particular Nugget and students' comfort working with data, these worksheets can take 15 minutes or an entire class period.

Here, we demonstrate the use of a Data Nugget worksheet in the classroom. Follow along with the teachers' copy of the Data Nugget "Do invasive species escape their enemies?" provided at the end of this article. The student worksheets and other Nuggets can be found online.

Research Background

The first part of the Nugget provides students with relevant background knowledge on a topic and the process of the researcher who developed the experiment. The background section of each Nugget provides necessary scientific information as a story to capture the attention of students and engage them with more than just the conclusions of a study, including the process of the researcher behind the

Table 1. Data Nuggets currently available online, covering a variety of research areas such as climate change, animal behavior, invasive species, adaptation, and mutualisms.

Reading Level	Title	Keywords	Summary
1	Coral Bleaching and Climate Change	Climate change, coral bleaching, coral reef, marine, mutualism, temperature, animals, plants	Corals look brown and green because they have small plants, called "algae," which live inside them. The coral animal and the algae work together to produce food. When the water gets too warm, the algae leave and the corals turn white, called "coral bleaching."
1	Dangerously Bold	Animals, animal behavior, trade-off, fish, predation	The best habitat for young bluegill fish to get lots of food is in the open water, but open water has very few plants for hiding from predators. Safer habitats on the edge have less food. This sets up a trade-off whereby there are costs and benefits to using either habitat.
1	Do Sea Urchins Help Corals?	Coral reef, herbivory, marine, sea urchin, water, animals, competition	Corals only like to live in certain places. They hate living near algae because the algae and coral compete for the space they both need to grow. Perhaps if there are more animals eating algae on the reef, then corals have less competition and more space to grow.
2	Can We Grow Our Chocolate and Have the Rainforest Too?	Agriculture, animals, birds, ecology, plants, rainforest	There are times when animals can use crops for their habitat. One good example of this is cacao trees, which grow in the understory of the rainforest. Cacao plantations are kind of like mini-rainforests but are different in some important ways, including bird communities.
2	Do Insects Prefer Local or Exotic Foods?	Herbivory, invasive species, plants, insects, enemy release, ecology	Because herbivores are so important for how plants grow, they may determine how well an exotic plant does in its new habitat and whether it becomes invasive. If invasive species are those that get less damage from herbivores, it could help explain one of the causes of invasiveness.
2	Do Invasive Species Escape Their Enemies?	Herbivory, invasive species, plants, insects, enemy release, ecology	When a plant is moved across oceans, it may not bring its enemies along for the ride. Now that the plant is in a new area with nothing to eat or infect it, the plant may do very well and become invasive.
2	Fertilizing Biofuels May Cause Release of Greenhouse Gases	Biofuels, climate change, fertilization, greenhouse gases, nitrogen, plants	One way to reduce the amount of greenhouse gases we release into the atmosphere could be to grow our fuel instead of drilling for it. However, the plants we grow for biofuels don't absorb all greenhouse gas that is released during the process of growing them on farms and converting them into fuels.
2	Finding a Foothold	Animals, ecology, marine, mollusk, substrate, water	The ground at the beach is made of rocks of many different sizes, called "substrates." These can range from large boulders down to fine grains of sand, with many size variations in between. Different organisms live on each substrate type.
2	Fish Fights	Animal behavior, animals, fish, mating	In many animals, males fight for territories that they use to attract females for mating. Male stickleback fish fight each other to gain territories along the bottom of the shallow areas of a lake. Perhaps more aggressive males are better at defending their territory and nests.
2	Which Guy Should She Choose?	Animal behavior, animals, fish, mating	Mating behavior is intriguing to study because in many animal species, males use a lot of energy to attract a female. Yet some males are able to attract zero females while other males attract many females. What about the way a male looks, moves, or smells attracts the female?

Table 1. continued

Reading Level	Title	Keywords	Summary
3	Does a Partner in Crime Make It Easier to Invade?	Evolution, legume, plants, mutualism, rhizobia, invasive species	Mutualisms can affect what happens when a plant species is moved somewhere it hasn't been before. For invasive legumes with rhizobial mutualists, rhizobia may not be transported with it and the plant will have to form new relationships with rhizobia in the new location.
3	Fair Traders or Freeloaders? – Cooperative and Uncooperative Bacteria	Evolution, legume, plants, mutualism, rhizobia, nitrogen, fertilization	Rhizobia are mutualists with legume plants and live in bumps on the plant roots. Rhizobia turn nitrogen from the air into a form that plants can use. Under some conditions this mutualism could break down – for example, if one of the traded resources is very abundant in the environment.
3	Float Down the River: Total Suspended Solids	River, water, suspended solids, dam, reservoir	As the river flows, it picks up bits of dead plants, algae, and other living and nonliving particles from riverbed. These suspended solids are important for the river food web but can be influenced by human activities, such as the construction of dams.
3	Marvelous Mud	Mud, phosphorus, water, wetland	Because mud is wet most of the time, it tends to have different properties than soil. Dead organic matter is an important part of mud and tends to build up in wetlands because it is decomposed more slowly under water, where microbes do not have all the oxygen they need to break it down quickly.
4	Cheaters in Nature – Are Mutualisms Always Beneficial?	Evolution, legume, plants, mutualism, parasitism, rhizobia, nitrogen, fertilization	Mutualisms are a special type of relationship in nature whereby two species work together and both benefit. Usually this cooperation leads to each partner species doing better when the other is around. But what happens when one partner cheats and takes more than it gives?
4	Dangerous Aquatic Prey: Can Predators Adapt to Toxic Algae?	Adaptation, algae, evolution, marine, predation	Microscopic algae form the base of all aquatic food chains. Some algae produce toxins, and when these algae reach high population levels they form a toxic "algal bloom." Can predators feeding on toxic prey for many generations evolve resistance, by natural selection, to the toxic prey?
4	The Ground Has Gas!	Climate change, temperature, greenhouse gases, nitrogen, plants	Nitrous oxide and carbon dioxide are responsible for much of global warming. Sometimes soils give off, or emit, these greenhouse gases into the Earth's atmosphere, adding to climate change. Currently, scientists are figuring out what causes differences in how much of each type of greenhouse gas soils emit.

ideas and data. Readers find stories more engaging, easier to comprehend, and more memorable than descriptive, expository writing (Britton et al., 1983; Graesser et al., 1994). Stories are "sticky" because they appeal to our desire for causality and goals (Bartlett, 1932; Gentner, 1976; Wilson, 2002), and the reasoning behind an idea increases reader interest (Frick, 1992; Kim, 1999). For these reasons, teachers have found that "students find Data Nuggets interesting to use" (Dennis VanWeeden, middle school biology teacher).

Paragraph 1 of the Research Background provides relevant scientific knowledge needed to understand the Nugget. If a teacher feels that students need additional background information to gain comfort with a topic, the Nugget can be tied into existing curriculum and complement a topic already discussed in class, or students can independently research the topic, using online resources and journal articles. Paragraph 2 brings in exploration and discovery. Scientists discuss how they first became interested in the topic and how they developed their questions. The final paragraph states the hypothesis and prediction and shares the experimental design and data collection methods used by the scientist. Following the background information, the scientist includes a picture of the experiment and the process of collecting data.

Scientific Question & Hypothesis

Next, the scientific question is stated and students must identify the hypothesis within the Research Background text. The hypothesis is the proposed explanation for an observation and leaves us with testable predictions that can either support or refute the hypothesis.

Table 2. Data Nuggets are assigned a reading level between 1 and 4, according to the vocabulary and content of the background information provided to students. Graphing levels allow students to develop their graphing skills over time, beginning with a graph provided and working up to creating a graph completely on their own.

Reading Level	
1	Elementary and above
2	Middle school and above
3	High school and above
4	Advanced high school students and college undergraduates
Graphing Level	
A	Graph provided; axes labeled and data displayed
B	Axis labels provided; student must graph data
C	Graph not provided; student must label axes and graph data

Scientific Data & Graphing

Data are presented as a table, and students are challenged to use the data to address the scientific question, including identifying the response and predictor variables. Students must use the data provided to create a graph that can be used to answer the scientific question. Basic statistics are either provided or must be calculated by the student. More challenging Nuggets require students to differentiate between data necessary to address a question and extra data columns that are not relevant.

Interpret the Data

Students answer the scientific question and support their claim with evidence. Teachers have noted that students need practice interpreting a data set once they have graphed it, but are rarely left with enough time to focus on this crucial part of the scientific method after a lengthy classroom inquiry project. "High school students know how to make bar and line graphs, but they rarely use the information in the graph when discussing the conclusions they've made. Even when I give instructions to 'explain if the data supported your hypothesis, using specific examples,' very few students do. Students need to understand why the graphs are made and the value of the analysis in the conclusions they form" (Liz Ratashak, high school biology teacher). Data Nuggets reinforce these important, but often overlooked skills, and guide students through graphing and data interpretation in less time than inquiry projects.

Your Next Step as a Scientist

Research does not end with the completion of an experiment, and findings will generate questions that require further experimentation. At the end of each Nugget, students discuss whether the data supported the hypothesis, whether the experiment fully answered the scientific question, what new questions the students feel should be investigated, and what future data could be collected to answer the new questions. In the teacher's copy, the scientists share what they did next to help the teacher lead discussion.

○ Data Nuggets & the Methods of Science

Data Nuggets give teachers the ability to bring their students through the entire scientific method without having to do repeated classroom inquiry projects, which consume both time and resources. The scientific method is rarely as linear as it appears to be in science textbooks. Every component of the scientific process does not necessarily lead to one predetermined next step, but it can cycle back to generate further questions and experiments (Figure 1). Students should not be frustrated by inquiry when experimental designs did not actually test what they thought, or when data do not support their hypothesis. This is the real process of science, what researchers go through every day, and what students can experience when using authentic experimental data.

Teachers have expressed that data collected during classroom inquiry projects can be intimidating. Results are usually "messy," with a lot of variation in the data, and often do not support the original hypotheses. This can be intimidating in a classroom setting with limited time or ability to conduct follow-up experiments. Because Data Nuggets are built around current and ongoing research, they often have data sets that do not support hypotheses or conform to predictions. Teachers have expressed that this will help students become more comfortable with results they get during classroom inquiry projects. Many times, confusing results are not just an outcome of "human error" when setting up an experiment or taking measurements, but instead could reveal interesting biological processes that were not originally considered.

Many educators are using Data Nuggets in ways that go beyond the basic template. A Nugget can be adjusted so that the worksheets are used to teach scientific writing or advanced statistics. When students are developing scientific writing skills, some professors have had their students create a Nugget based on their own classroom experiment, similar to a lab report. Many of our scientists have agreed to share original data sets if teachers would like to give their students the opportunity to work with raw data and perform more complicated statistics, such as analysis of variance or regression.

○ STEM Education Standards & Reform

"As we get our students ready for ACT testing, Data Nuggets are wonderful sets to use in our classroom because they are relevant and introduce real research to our students, who might not have this type of exposure otherwise" (Marcia Angle, Lawton Middle School).

Next Generation Science Standards

The recent call for reform of national K–12 science standards stemmed from the realization that students need to learn core scientific knowledge and actively practice scientific principles and skills simultaneously, rather than as distinct units (NGSS Lead States, 2013). Using this framework, the *Next Generation Science Standards* each have three dimensions – Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. Data Nuggets align with this call for synthesized teaching by providing an opportunity to learn about a specific scientific topic (Disciplinary Core Ideas), while observing patterns and assigning cause and effect (Crosscutting Concepts) by analyzing and interpreting data (Science and Engineering Practices). In Table 3, we highlight the NGSS Science and Engineering Practices and Crosscutting Concepts

Table 3. Next Generation Science Standards (NGSS) (AAAS, 2011) Science and Engineering Practices, Crosscutting Concepts, and ACT College Readiness Standards (for scores 28-32, ACT, Inc. 2014). Practices, concepts, and standards in bold and in dark gray boxes are covered when using Data Nugget resources. Boxes in light gray represent content-specific objectives and may be covered using specific Data Nugget worksheets.

NGSS Science & Engineering Practices	NGSS Crosscutting Concepts	ACT College Readiness Standards
Asking questions and defining problems	**Patterns:** Observed patterns of forms and events guide organization and classification, and prompt questions about relationships.	**Interpreting data:** Compare or combine data from a simple data presentation with data from a complex data presentation.
Developing and using models	**Cause and effect:** Mechanism and explanation. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated.	**Interpreting data:** Identify and/or use a complex mathematical relationship between data.
Planning and carrying out investigation	Scale, proportion, and quantity: It is critical to recognize what is relevant at different measures of size, time, and energy.	**Interpreting data:** Extrapolate from data points in a table or graph.
Analyzing and interpreting data	**Systems and system models:** Defining the system under study provides tools for understanding and testing ideas.	**Scientific Investigation:** Determine the hypothesis for an experiment.
Using mathematics and computational thinking	Energy and matter: Flows, cycles, and conservation.	**Scientific Investigation:** Identify an alternative method for testing a hypothesis.
Constructing explanations and designing solutions	Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	**Evaluation:** Select a complex hypothesis, prediction, or conclusion that is supported by a data presentation or model.
Engaging in argument from evidence	Stability and change: Conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	**Evaluation:** Determine whether new information supports or weakens a model and why.
Obtaining, evaluating, and communicating information		**Evaluation:** Use new information to make a prediction based on a model.

that Data Nuggets address. Note that Disciplinary Core Ideas are covered, but they vary depending on the specific selection of Nuggets by individual teachers.

AP Biology Reform

Similar to the NGSS, the recent AP Biology reform shifted the emphasis from factual recall toward investigation and active participation in the process of science (College Board, 2013). The development of reasoning skills to make claims from evidence has become a priority. At least 25% of classroom time must be spent on hands-on activities, such as inquiry projects, which emphasize the process of science rather than specific concepts. This focus on depth rather than breadth leaves time for teachers to further develop reasoning skills that are necessary for analyzing and interpreting scientific content and data. Data Nuggets support these endeavors by providing a mechanism to increase quantitative skills through repeated exposure to the process of science and data interpretation, while also covering a wide range of topics to keep students and teachers engaged in contemporary science.

Common Core State Standards Initiative

Data Nuggets not only help students with understanding the scientific process, but also facilitate learning mathematical skills. The Common Core State Standards Initiative (2014) emphasizes the importance of clearly delineating how students should learn new mathematical concepts in a sequential manner, building on previous skills. Data Nuggets align with this thinking by incorporating graphing levels that build skills throughout the school year or throughout K–12 education (see Table 2). Additionally, these standards call for students to use math skills in an applied fashion to reinforce the connection between those skills and everyday life. Data Nuggets could be used as a way for teachers to bring in “real-world” applications of skills they are currently teaching.

ACT College Readiness Standards

The ACT College Readiness Standards are a long-running assessment of what students have learned and what they are ready to learn next (ACT, 2014). Decades of research have shown that the scores typically coincide with a student’s first-year performance in college.

Table 4. Advanced Placement (AP) Biology Science Practices (The College Board, 2014), Vision and Change Core Competencies (AAAS, 2011), Vision and Change Action Items (AAAS, 2011). Practices, competencies, and action items in bold and in dark gray boxes are achieved when using Data Nuggets resources. Boxes in light gray represent content-specific objectives and may be covered using specific Data Nugget worksheets.

	Vision and Change	
AP Biology Science Practices	Core Competencies	Action Items
Use representations and models to communicate scientific phenomena and solve scientific problems	**Ability to apply the process of science.** Biology is evidence based and grounded in the formal practices of observation, experimentation, and hypothesis testing.	**Introduce the scientific process to students early,** and integrate it into all undergraduate biology courses.
Use mathematics appropriately	**Ability to use quantitative reasoning.** Biology relies on applications of quantitative analysis and mathematical modeling.	Define learning goals so that they focus on teaching students the core concepts and align assessments so that they assess student understanding.
Engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course	Ability to use modeling and simulation. Biology focuses on the study of complex systems.	**Relate abstract concepts in biology to real-world examples on a regular basis,** and make biology content relevant by presenting problems in a real-life context.
Plan and implement data collection strategies in relation to a particular scientific question	**Ability to tap into the interdisciplinary nature of science.** Biology is an interdisciplinary science.	**Develop lifelong science learning competencies.**
Perform data analysis and evaluation of evidence	Ability to communicate and collaborate with other disciplines. Biology is a collaborative scientific discipline.	Introduce fewer concepts, but present them in greater depth.
Work with scientific explanations and theories	Ability to understand the relationship between science and society. Biology is conducted in a societal context.	**Stimulate the curiosity students have for learning about the natural world.**
Connect and relate knowledge across various scales, concepts, and representations in and across domains		**Demonstrate both the passion scientists have for their discipline and their delight in sharing their understanding of the world with students.**

By preparing students for success on the ACT test, teachers are also increasing readiness for college courses. As with NGSS, the rubric for the ACT science readiness scores clearly emphasizes the importance of understanding the practice and process of science rather than memorization of facts. The three main categories are interpreting data, scientific investigation, and evaluation – all of which depend on reasoning skills (see Table 3 for breakdown of each category). As Data Nuggets walk students through the entire process of science (interpreting, investigating, evaluating), each worksheet serves as practice for questions that students will see on the ACT test. More importantly, this means that Data Nuggets have the potential to develop skills that will better prepare students for college and beyond.

Vision & Change

Vision and Change calls for undergraduate science education reform and stresses the importance of developing key scientific competencies during introductory biology courses (AAAS, 2011). These skills better prepare both students who continue on to pursue scientific careers and those who only take introductory courses. It is important, in the latter case especially, that these students leave with an understanding of how science works and how they can use the scientific process to validate data they may see and use in their everyday lives. The Data Nuggets program shares this vision of increased scientific competency (see Table 4). Data Nuggets are, in essence, a mini-lesson on the scientific process. Students learn about a study system and question, identify the hypothesis, analyze and interpret data, and brainstorm future experiments. While learning about current scientific research, students are also developing quantitative skills they can use in their own discipline. Additionally, the *Vision and Change* document proposes "action items" to help educators with the proposed reforms (Table 4). The use of Data Nuggets in classrooms incorporates many of these ideas, such as introducing the scientific process to students early and often, relating scientific concepts to real-world applications, and demonstrating the passion scientists have for their discipline.

○ The Future

Data Nuggets are continually under development, and new Nuggets are added monthly. When using Nuggets in classrooms and presenting at national education conferences, we continue to get great feedback from teachers on ways to improve the Nuggets and better integrate them into classroom settings. In the coming year, we will bring together leaders in science and math education research to identify the skills that students need to progress toward quantitative literacy, expand resources for use in undergraduate classrooms and AP courses, and develop an assessment to be administered in K–12 classrooms. An assessment will allow us to examine whether the use of Data Nuggets achieves the learning objectives described above, including increasing students' competency in quantitative standards and improving students' attitudes toward science.

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DATA Nugget

Do invasive species escape their enemies?

Featured scientist: Elizabeth Schultheis from Michigan State University

Research Background:

Invasive species, like zebra mussels and garlic mustard, are species that have been introduced by humans to a new area and negatively impact places they invade. Invasive species cost the United States over $100 billion per year by damaging habitats, displacing native species, and interfering with human interests.

Scientist Elizabeth has always been fascinated with invasive species' ability to take over and transform habitats. When reading scientific papers, she realized many things change for an invasive species when it is moved from one area to another. For example, a plant that is moved across oceans may not bring its enemies (like disease, predators, and herbivores) along for the ride. Now that the plant is in a new area with nothing to eat or infect it, the plant could potentially do very well and become invasive.

Elizabeth and other scientists set out to test whether invasive species are successful because they have escaped their enemies and get less damage from enemies compared to other native species. If a native plant has tons of insects that can eat it, while an invasive plant has few or none, this could explain how the invasive plant is able to take space away from the native plant. However, if researchers find that both types of plants have similar numbers of enemies and levels of damage, this might mean that enemy escape is not a good explanation for why invaders are successful.

To test this idea, a lab at Michigan State University collected data on invasive and native plant species in Kalamazoo County. They measured how many insects were found on each species of plant, as well as the percent of leaves that had been damaged by insect herbivores. The data they collected is found below and can be used to test whether invasive plants are successful because they get less damage from insects compared to native plants.

Scientists at Michigan State University collecting data on invasive and native plant species, such as the number of insects found on each plant and the percent of leaves damaged by insect herbivores.

Data Nuggets developed by Michigan State University fellows in the NSF BEACON and GK-12 programs

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Scientific Question: Are invasive species more successful than native species because they have escaped insect herbivores?

What is the hypothesis? Find the hypothesis in the background and underline it. A hypothesis is proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Scientific Data: Hint: students will have to calculate the average for each response variable and graph that number.

Use the data below to answer the scientific question:

Scientific Name	Species Status	Average number of insects per plant	Percent leaves with damage from insect herbivores
Trifolium repens	invasive	0.09	67.5
Silene latifolia	invasive	0.08	33.9
Daucus carota	invasive	0	13.3
Robinia pseudoacacia	invasive	0.57	86.3
Dianthus armeria	invasive	0.03	34.7
Hieracium caespitosum	invasive	0.06	27.2
Stellaria graminea	invasive	0	8.3
Rumex acetosella	invasive	0	47.5
Chenopodium album	invasive	0	0
Phleum pratense	invasive	0.06	29.1
Danthonia spicata	native	0	10.4
Apocynum cannabinum	native	0	21.6
Hieracium gronovii	native	0	20
Lespedeza capitata	native	0.08	66.7
Ambrosia artemisiifolia	native	0	40.5
Vitis riparia	native	0	100
Monarda fistulosa	native	0	30.5
Antennaria parlinii	native	0	17.7
Euphorbia corollata	native	0	8.3
Asclepias tuberosa	native	0.8	11.6

Average for Invasive	**0.089**	**34.78**
Average for Native	**0.088**	**32.73**

What data will you graph to answer the question?

Predictor variable: species type (invasive or native)
Response variables: Average number of insects per plant & percent leaves damaged by insect herbivores

Data Nuggets developed by Michigan State University fellows in the NSF BEACON and GK-12 programs
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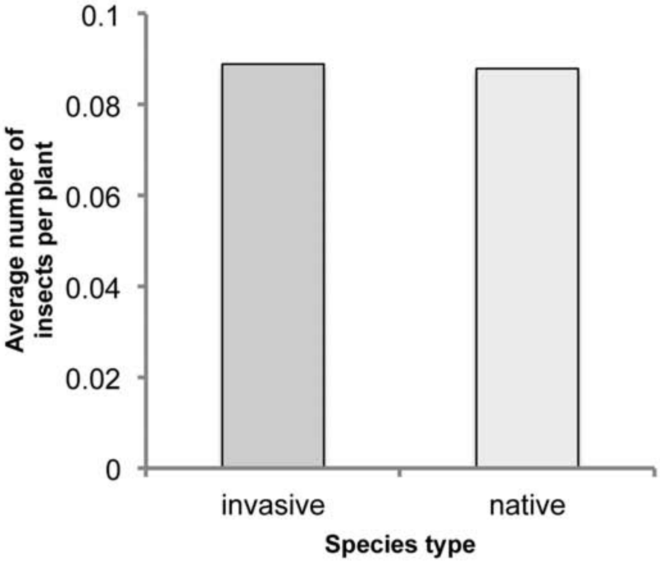
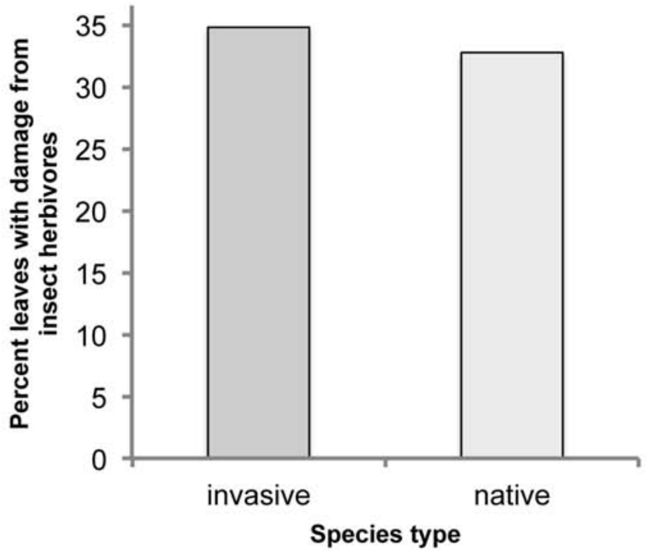
Draw your graphs below:





Interpret the data: Based on this evidence, write a statement that helps answer the scientific question. Connect the pattern in the data to a pattern in the natural world. Justify your reasoning using data.

Invasive and native plants have similar numbers of insect per plant (0.089 and 0.088 respectively) and similar percent leaves damaged (34.78% and 32.73% respectively). Therefore, there is no evidence that invasive plants are successful because they have escaped their enemies. In order to find support for the enemy escape hypothesis, invasive plants would have had to either have lower numbers of insects per plant, or lower damage from insect herbivores. The data do not support either of these predictions.

Your next step as a scientist: Science is an ongoing process. Did this study fully answer your original question? What new questions do you think should be investigated? What future data should be collected to answer them?

Because we did not find evidence for escape from insect herbivores in this experiment, our future experiments are looking at other types of enemies (such as disease and mammal herbivores).

If we continue to find no evidence for enemy escape, we will look into other mechanisms that might explain invasive species success – for example, invasive species could be more tolerant to enemy damage. In this case, a similar amount of damage on a native and invasive plant may lead to very different outcomes for the two species. The invasive species would be tolerant of the damage and able to perform well, while the native species would not be as tolerant and would experience reduced performance (growth, flower #, survival) compared to invasives.