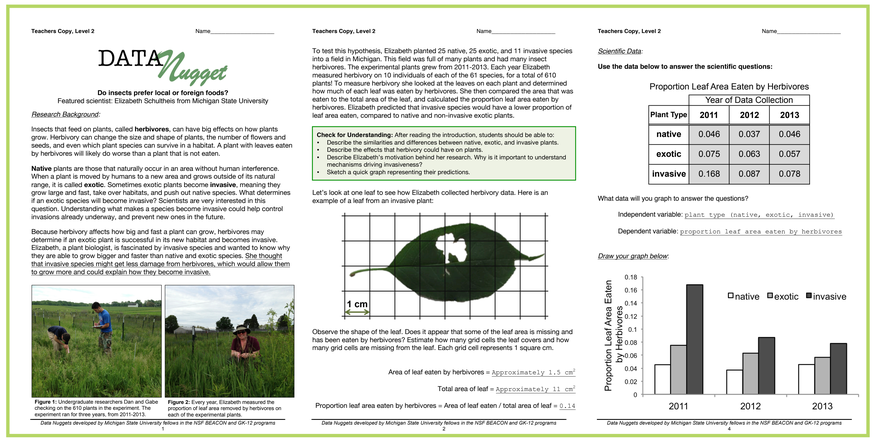
Scientific data in schools: Measuring the efficacy of an innovative approach to integrating quantitative reasoning in secondary science

MSU: Louise Mead (PI), Elizabeth Schultheis, Melissa Kjelvik, and Alexa Warwick
BSCS: Molly Stuhlsatz (PI), Chris Wilson (co-PI), and Audrey Mohan

Introduction

Data Nuggets (http://datanuggets.org) are free classroom activities, co-designed by scientists and teachers, which give students practice interpreting quantitative information and making claims based on evidence (Fig. 1). They are created from cutting-edge scientific research and include real, messy, scientific data. The goal of Data Nuggets is to engage students in the practices of science through an innovative approach that combines scientific content from authentic research with key concepts in quantitative reasoning. Data Nuggets help students understand how scientists create and modify scientific knowledge, while developing their quantitative skills and helping them function as critical thinkers in modern society.

Data Nuggets require a relatively small commitment from teachers and students yet can potentially have a large impact on student thinking, specifically around quantitative reasoning in the context of science. Establishing the efficacy of Data Nuggets will provide the field with new information about how supplementing existing curriculum with short interventions targeted at particular scientific practices can improve quantitative thinking. Data Nuggets also allow scientists to share their authentic research broadly, improving the understanding of science in society.



Teachers Copy, Level 2 — Name_____

DATA Nugget

Do insects prefer local or foreign foods?

Featured scientist: Elizabeth Schultheis from Michigan State University

Research Background:

Insects that feed on plants, called **herbivores**, can have big effects on how plants grow. Herbivory can change the size and shape of plants, the number of flowers and seeds, and even which plant species can survive in a habitat. A plant with leaves eaten by herbivores will likely do worse than a plant that is not eaten.

Native plants are those that naturally occur in an area without human interference. When a plant is moved by humans to a new area and grows outside of its natural range, it is called **exotic**. Sometimes exotic plants become **invasive**, meaning they grow large and fast, take over habitats, and push out native species. What determines if an exotic species will become invasive? Scientists are very interested in this question. Understanding what makes a species become invasive could help control invasions already underway, and prevent new ones in the future.

Because herbivory affects how big and fast a plant can grow, herbivores may determine if an exotic plant is successful in its new habitat and becomes invasive. Elizabeth, a plant biologist, is fascinated by invasive species and wanted to know why they are able to grow bigger and faster than native and exotic species. She thought that invasive species might get less damage from herbivores, which would allow them to grow more and could explain how they become invasive.

Figure 1: Undergraduate researchers Dan and Gabe checking on the 610 plants in the experiment. The experiment ran for three years, from 2011-2013.

Figure 2: Every year, Elizabeth measured the proportion of leaf area removed by herbivores on each of the experimental plants.

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

1

Teachers Copy, Level 2 — Name_____

To test this hypothesis, Elizabeth planted 25 native, 25 exotic, and 11 invasive species into a field in Michigan. This field was full of many plants and had many insect herbivores. The experimental plants grew from 2011-2013. Each year Elizabeth measured herbivory on 10 individuals of each of the 61 species, for a total of 610 plants! To measure herbivory she looked at the leaves on each plant and determined how much of each leaf was eaten by herbivores. She then compared the area that was eaten to the total area of the leaf, and calculated the proportion leaf area eaten by herbivores. Elizabeth predicted that invasive species would have a lower proportion of leaf area eaten, compared to native and non-invasive exotic plants.

Check for Understanding: After reading the introduction, students should be able to:
- Describe the similarities and differences between native, exotic, and invasive plants.
- Describe the effects that herbivory could have on plants.
- Describe Elizabeth's motivation behind her research. Why is it important to understand mechanisms driving invasiveness?
- Sketch a quick graph representing their predictions.

Let's look at one leaf to see how Elizabeth collected herbivory data. Here is an example of a leaf from an invasive plant:

Observe the shape of the leaf. Does it appear that some of the leaf area is missing and has been eaten by herbivores? Estimate how many grid cells the leaf covers and how many grid cells are missing from the leaf. Each grid cell represents 1 square cm.

Area of leaf eaten by herbivores = Approximately 1.5 cm^2

Total area of leaf = Approximately 11 cm^2

Proportion leaf area eaten by herbivores = Area of leaf eaten / total area of leaf = 0.14

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

2

Teachers Copy, Level 2 — Name_____

Scientific Data:

Use the data below to answer the scientific questions:

Proportion Leaf Area Eaten by Herbivores

	Year of Data Collection		
Plant Type	**2011**	**2012**	**2013**
native	0.046	0.037	0.046
exotic	0.075	0.063	0.057
invasive	0.168	0.087	0.078

What data will you graph to answer the questions?

Independent variable: plant type (native, exotic, invasive)

Dependent variable: proportion leaf area eaten by herbivores

Draw your graph below:

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

4

Figure 1. An example Data Nugget.

Goals

1. Increase connections between current Data Nuggets resources and Next Generation Science Standards (NGSS) practices.
2. Offer secondary teacher professional development to highlight strategies for increasing classroom use of quantitative activities.
3. Test the efficacy of Data Nuggets across high school biology classrooms using an experimental design framework (Fig. 2).

Research Study

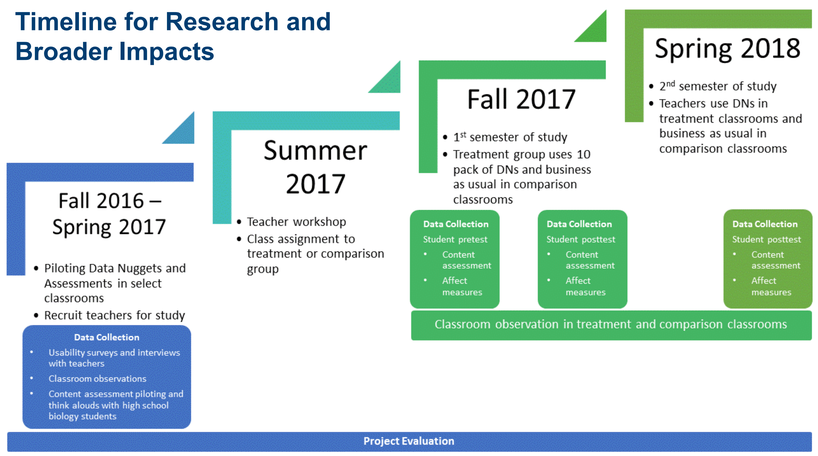


Figure 2. Timeline for Data Nuggets efficacy study and broader impacts.

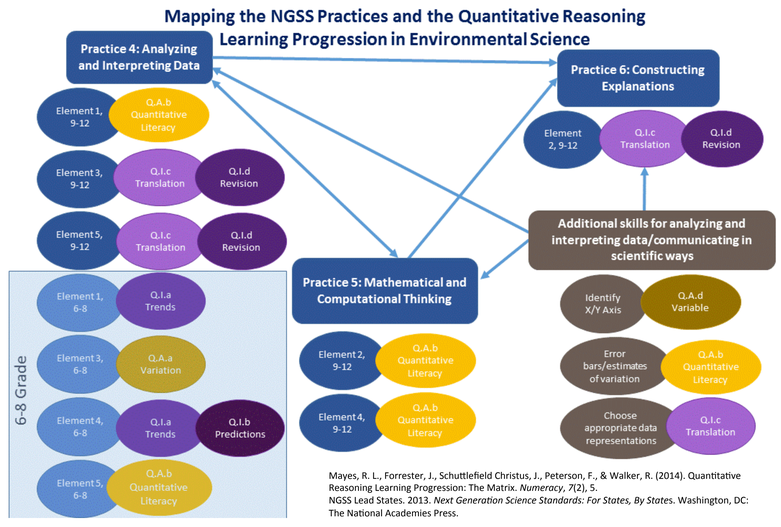
To test the efficacy of Data Nuggets (DNs) we are conducting a cluster-randomized trial that addresses the following research questions:

1) Do students in classrooms using DNs show a deeper understanding of quantitative reasoning in the context of science, improved understanding of and engagement in the practices and processes of science, and greater motivation and interest in science than students in Business as Usual (BaU) classrooms?
2) To what extent does teacher practice function as a mediator of treatment effects on student motivation, interest, engagement, or achievement?
3) To what extent do student motivation and interest function as mediators of student achievement on DNs?
4) To what extent do treatment effects differ on the basis of (i.e., are moderated by) gender, race/ethnicity, FRL status, ELL status, or baseline achievement?

The evidence from the efficacy study will demonstrate whether short, targeted interventions of classroom activities embedded within a typical curriculum can impact student outcomes. The study will take place in the classrooms of 30 teachers in Michigan, Colorado, and California. Treatment assignment will be at the classroom level.

Progress to Date

In Year 1 of the grant, we made progress toward our goals by
1) holding several working groups focused on postdoctoral researcher training and NGSS alignment;
2) beginning the development of teacher professional development, some of which will be piloted in August 2016;
3) aligning Data Nuggets with the NGSS and creating new Data Nuggets to fill gaps in content and practices;
4) identifying Data Nuggets for use in the efficacy trial;
5) performing a literature review on quantitative reasoning in the context of science to inform assessment development (Fig. 3); and
6) piloting revised activities in MI and CO high school classrooms.



Mayes, R. L., Forrester, J., Schuttlefield Christus, J., Peterson, F., & Walker, R. (2014). Quantitative Reasoning Learning Progression: The Matrix. *Numeracy*, *7*(2), 5.
NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

Figure 3. Connections among NGSS practices and the quantitative reasoning learning progression.

Year 2 Goals

Our goals for Year 2 of the grant are to
1) convene our advisory board;
2) recruit teacher population for our efficacy study;
3) finalize teacher professional development offerings;
4) obtain necessary school district IRB approvals; and
5) develop, pilot, and revise the student content assessment.

Funded by awards DRL-1503211 and DRL-1503005 from the National Science Foundation. Any opinions, findings, conclusions or recommendations are only those of the presenters and do not necessarily reflect the views of the NSF. For more information, visit our website or contact PIs Louise Mead (lsmead@msu.edu) and Molly Stuhlsatz (mstuhlsatz@bscs.org).