GraphSmarts: New Tools for Improving Graphing Practices Among Biology Students



¹Department of Biological Sciences, Purdue University, ²SimBio, Inc. ³Department of Biological Science, California State University, Fullerton, and ⁴Teaching, Learning & Leadership, Graduate School of Education University of Pennsylvania

Graphing Practice in Biology

Graphing is an essential practice in biology used to explore patterns in data in order to make inferences⁹, communicate with others, and problem solve. As a practice, graphing is situated within a discipline and its community and the use of graphs not only allows one to understand data, but science concepts more broadly^{5,7}. As such, competence with graphing develops over time and is a desired outcome of undergraduate biology curricula.^{1,8}

In this project we aim to design assessments with real-world messy data⁵ in biological contexts relevant to introductory biology to reveal the feature of students' graphing practices to guide instruction and curriculum development.

GraphSmarts Assessment Design

We created the GraphSmarts digital assessment using an iterative Design-Based Research² approach guided by the Evidence-Centered Design (ECD) framework for digital assessment design⁶.

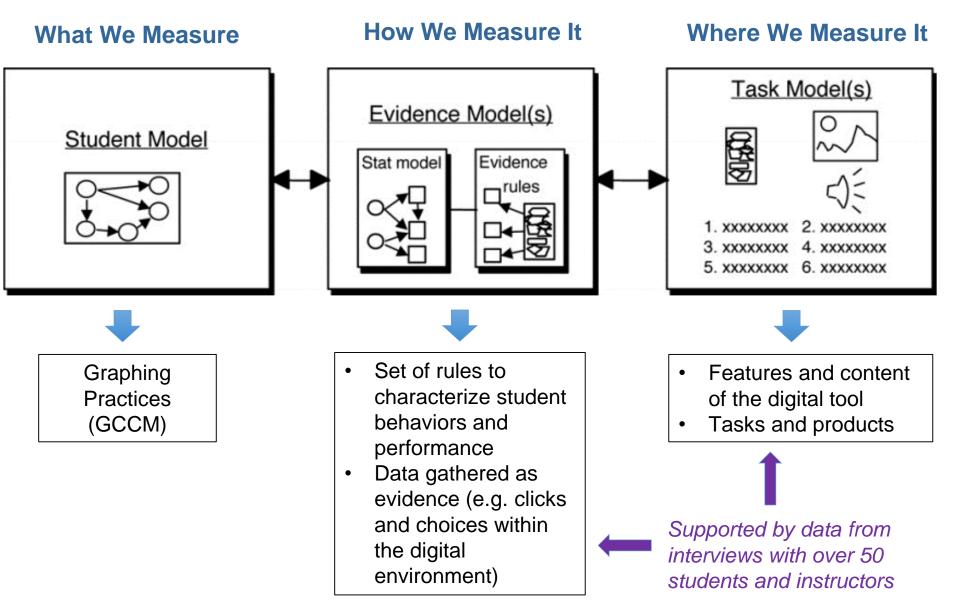


Figure 1. GraphSmarts assessment design process following Evidence-Centered Design⁶. Student model, evidence model, and task model(s) boxes from Mislevy, 2013.

Graph Construction Conceptual Model (Student Model)

Category	Description
Data Selection	Four concepts related to understanding the structure of the data being plotted and its relation to the prediction
Data Exploration	Four concepts related to manipulating and characterizing data on a graph (e.g. individual points vs. summary statistics, showing variance)
Graph Assembly	Five concepts related to drawing the graph (e.g. choosing type of graph, plotting points, following conventions)
Graph Reflection	Four concepts related to interpreting and evaluating the graph (e.g. identifying trends, drawing conclusions)

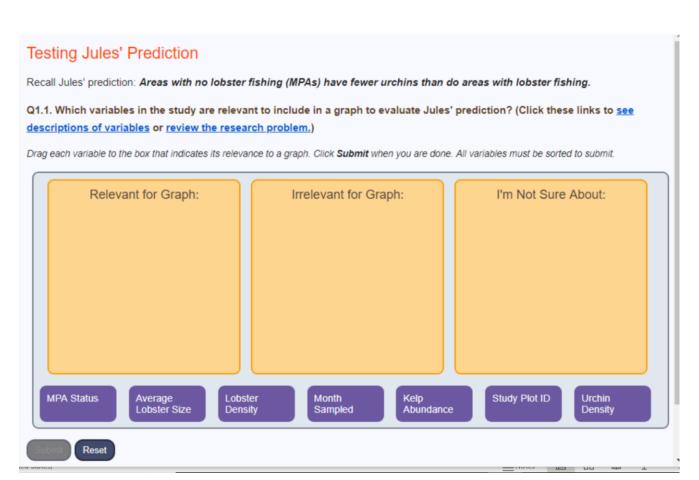
The Graph Construction Conceptual Model (GCCM) was articulated building on our own experiences teaching graphing, our past research on graphing in biology^{3,4}. We gathered face and content validity evidence through a scoping literature review and focus groups with biology (n = 5) and statistics education (n = 3)researchers and educators (Abraham et al., in preparation).

Acknowledgements



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Contact Stephanie M. Gardner for further information: <u>sgardne@purdue.edu</u>



Stephanie M. Gardner¹, Eli Meir², Joel K. Abraham³, and Ryan Baker⁴

The GraphSmarts Assessment

Scenario for the Graphing Task

How do MPAs Affect the Food Chain?

been tracking lobster, urchin, and kelp abundance, as well as lobster fishing patterns, in the MPA and non-MPA Tasmania. As part of this larger project, scientists reasoned that stopping lobster fishing would increase lobster predation on urchins and therefore reduce the number of urchins in the kelp forest. Their reasoning is illustrated here



In other words, their hypothesis is:

Eliminating lobster fishing will result in decreased urchin abundance in the kelp forest, due to food chain dynamics.

Study Plot ID	Month Sampled	MPA Status	Lobster Density (#/m ²)	Average Lobster Size (g)	Urchin Density (#/m ²)	Kelp Abunda Score
1	Aug.	YES	1.1 <mark>0</mark>	410	9 <mark>.</mark> 5	HIGH
2	Sept.	YES	1.55	445	8.5	MED
3	Aug.	NO	1.15	350	12.0	MED
4	Oct	YES	2.00	435	7.0	MED

Select Y Data

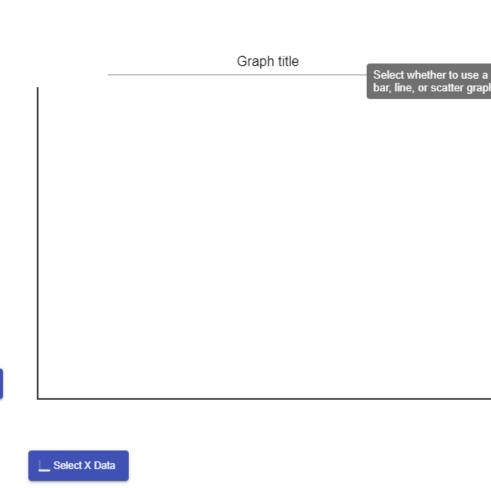
The Graphing Tasks

Three of the graduate students who helped collect data on this project developed predictions related to the research team's hypothesis

Jules: Areas with no lobster fishing (MPAs) have fewer urchins than do areas with lobster fishing.

Tayesha: Larger lobsters have a stronger negative impact on urchin population size.

Taylor: The level of kelp cover is higher where there are more lobsters.



Examples of GCCM-aligned Questions

Please answer the following questions about the graph on the right, which you made to address Jules' prediction: Areas with no lobster fishing (MPAs) have fewer urchins than do areas with lobster fishing. Review research problem Q1.2. Describe the pattern you see in your graph. Use the dropdowns to write the best description of the pattern My graph shows that Reset Q1.3. Do the data in your graph support or refute the prediction? Explain. MPA Status

Describing Student Graphing Practices

• Thematic coding of free-response items • Autoscoring of graphs and responses to constrained questions

- Bayesian Knowledge Tracing to describe student aggregate graphing
- practice

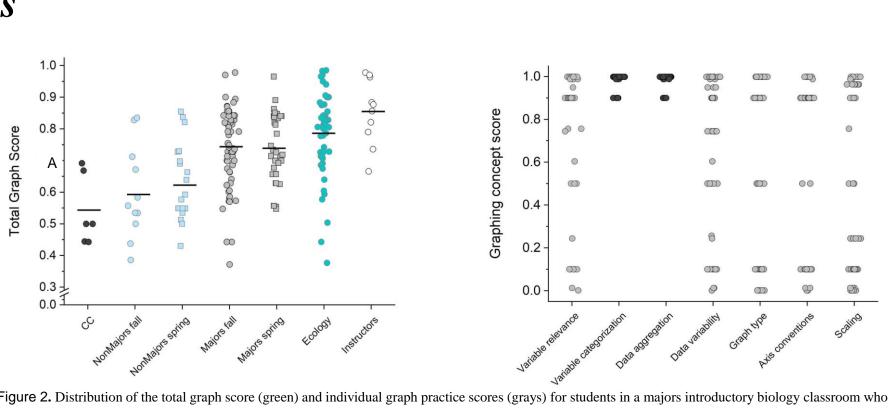
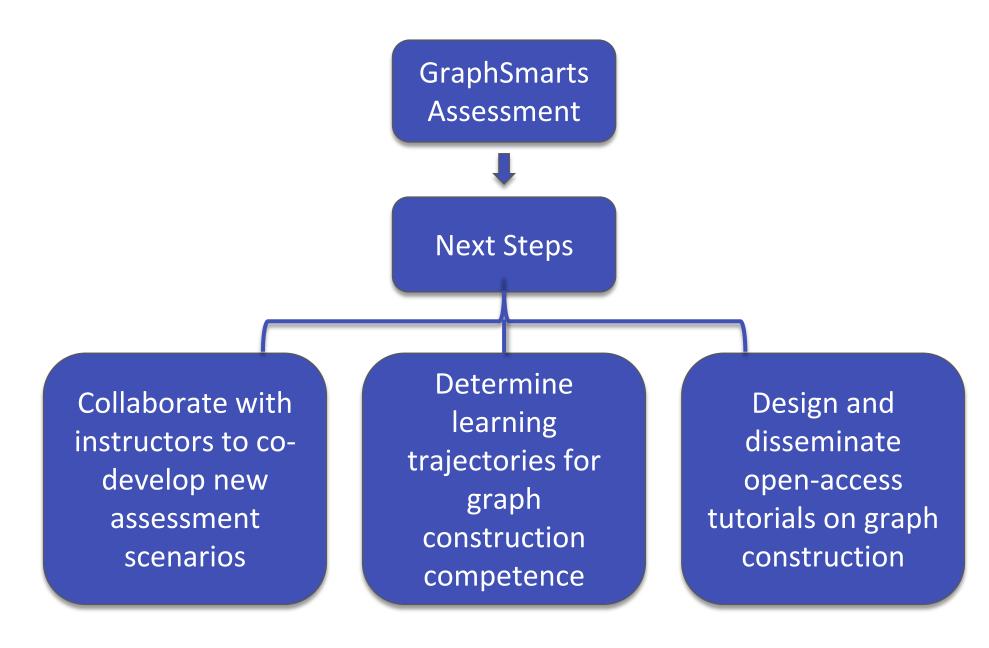


Figure 2. Distribution of the total graph score (green) and individual graph practice scores (grays) for students in a majors introductory biology classroom who completed the GraphSmarts assessment (N=60 students). Graph practice scores in light gray show variation across students within the class, illustrating practices that could be targeted for instruction for introductory biology students.



What's Next?

This work contributes to our long term goal of increasing undergraduate biology student competence in graph construction. We are excited to move on to the next phase of our work: expanding our tool kit for assessing student graph construction and developing new methods to understand how students learn about graphing. We will use this information to co-develop new instructional modules that can be used in introductory biology courses to better support students.



Get Involved!

We are actively looking for faculty partners at 2 and 4-year institutions who are interested in codeveloping new assessment scenarios (2021-2022) and open-access tutorials (2023-2024).

If you think you might be interested in joining us in this effort, please scan the QR code below to complete a brief form or email the project PI, Stephanie Gardner (<u>sgardne@purdue.edu</u>), with questions.



References

- 1. American Association for the Advancement of Science (AAAS) (2009). Conference Homepage. Vision and *Change in Undergraduate Biology Education: A View for the 21st Century.* www.visionandchange.org (accessed July 7, 2019).
- 2. Anderson T, Shattuck J. (2012). Design-based Research: A decade of progress in educational research? *Educational Researcher, 41*(Jan/Feb.), 16-25. Retrieved from http://edr.sagepub.com/content/41/1/7.full.pdf+html
- 3. Angra, A., & Gardner, S. M. (2016). Development of a framework for graph choice and construction. Advances in Physiology Education, 40(1), 123-128.
- 4. Angra, A., & Gardner, S. M. (2017). Reflecting on graphs: Attributes of graph choice and construction practices in biology. *CBE-Life Sciences Education*, 16(3), ar53.
- 5. Kjelvik, M. K., & Schultheis, E. H. (2019). Getting messy with authentic data: Exploring the potential of using data from scientific research to support student data literacy. CBE-Life Sciences Education, 18(2), es2. 6. Mislevy, R. J. (2013). Evidence-centered design for simulation-based assessment. *Military Medicine*, 178(10),
- 107-114. 7. Roth, W. M., & McGinn, M. K. (1997). Graphing: Cognitive ability or practice? Science Education, 81(1), 91-
- 106.
- 8. Shanahan, C., Shanahan, T., & Misischia, C. (2011). Analysis of expert readers in three disciplines: History, mathematics, and chemistry. Journal of Literacy Research, 43(4), 393-429.
- 9. Tukey, J. W. (1977). *Exploratory data analysis*. Reading, Mass.: Addison-Wesley Pub. Co.







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