Characterizing Undergraduate Biology Students' Graphing Practices

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Significance

Graphing is one practice[3] used by scientists to explore and analyze quantitative data. Learners struggle to combine different knowledge bases to analyze data and represent it in a graph.[3,5,11] Then, there is a need to provide learners with spaces to grapple with graphs. These spaces can be useful for researchers and instructors to explore students' graphing practices.

RQ: What are undergraduate biology students' graphing practices when working in a novel digital graphing tool?

Project Long-Term Goal

Develop evidence-based **digital teaching and assessment modules** that can be used **to reveal student knowledge and skill, providing real-time formative feedback.**

The Digital Graphing Tool

The design of digital tool is guided by the design-based research[6] and Evidence-Centered Design process[12] frameworks.

Scenario for the Graphing Task

How do MPAs Affect the Food Chain?

Scientists in Australia have been tracking lobster, urchin, and kelp abundance, as well as lobster fishing patterns, in the MPA and non-MPA areas of coastal 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.

One of the graduate students who helped collect data on this project came up with the following ***prediction***:

Areas with no lobster fishing (MPAs) have fewer urchin than do areas with lobster fishing.

Variables available for graphing

Study Plot ID	Month Sampled	MPA Status	Lobster Density (#/m²)	Average Lobster Size (g)	Urchin Density (#/m²)	Kelp Abundance Score
1	Aug.	YES	1.10	410	9.5	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
5	Aug.	NO	0.75	385	9.5	MED

Conceptual Framework

Below are some of the domains of knowledge for graphing that constitute our framework.

1) Data Selection

- ***Variable Relevance:*** Identifies degree of relevance of each variable to research question/hypothesis[1,2,5,8]

2) Data Exploration

- ***Data Aggregation:*** Appropriately uses sample and aggregate data to communicate information efficiently for a given purpose. [10]
- ***Statistics Selection***: If aggregating data, selects appropriate statistics for a given data set and purpose. [10]

3) Graph Assembly

- ***Graph Type:*** Select a graph appropriate for the type of data[5]
- ***Graph Communication:*** Design graph to efficiently communicate information [7]

4) Graph Interpretation [9]

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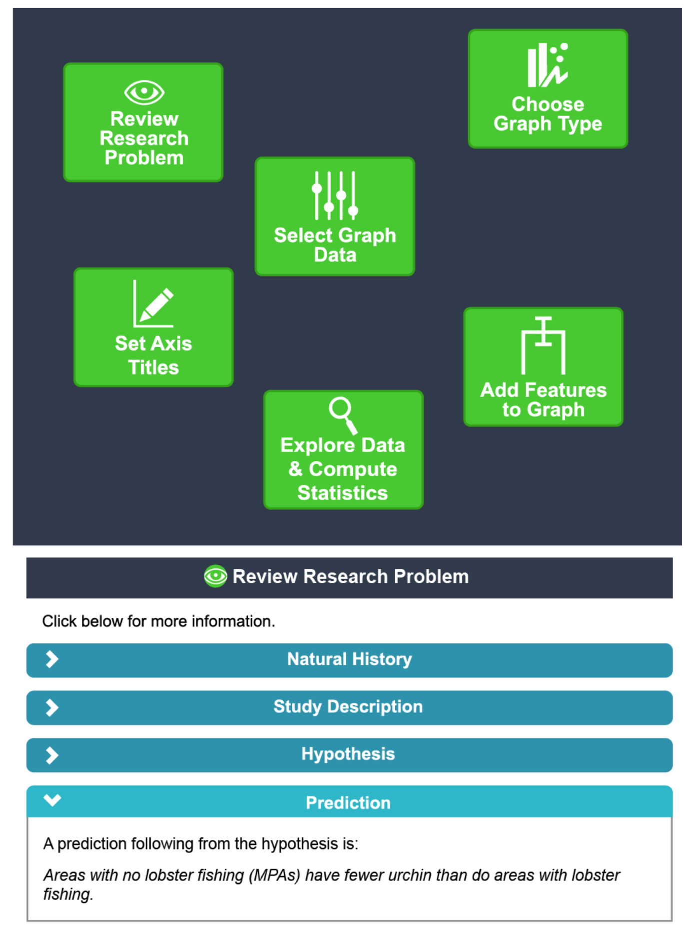
Research Setting and Elements of the Digital Tool

Variable Relevance Final Graph

Level of Relevance	Evidence Model	Out of 26
Directly Relevant	Includes **only** MPA **and** Urchin Density	3
Indirectly Relevant	Includes (MPA **or** Urchin Density) **and** (any other variable) **or** Includes Urchin Density **and** MPA **and** any other variable	17
Irrelevant	Does not include MPA **or** Urchin Density	6



Interview Protocol (subset)

- I see that you plotted (y) vs. (x). Why did you choose to plot those data over other choices from the data table?
- What type of graph did you make?
- Why did you decide to create the graph that you did?

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Methods and Data Analysis

Participants: 26 undergraduate biology students from two Midwestern Universities.

Research Setting:

1) Participants were asked to use a novel program to make a graph testing a prediction in the context of conservation biology.

Prompt: One approach to analyzing data to test ideas is to make a graph of the data. On the following page, you will use a graph "constructor" to help you analyze the field data and test the prediction.

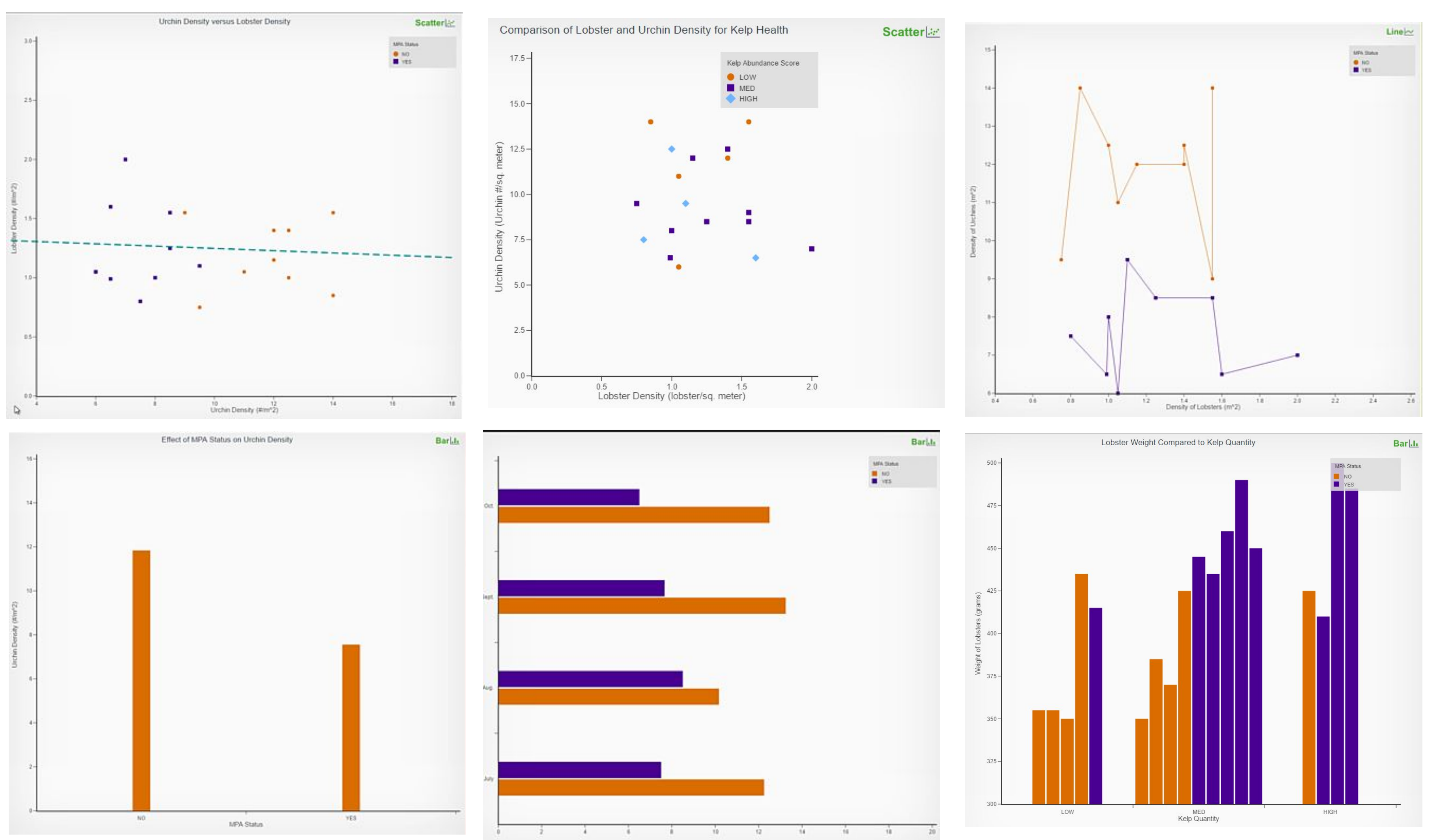
2) Semi-structured interviews were conducted to elicit students' justifications for their graphs. Interviews lasted between 20 and 60 minutes.

Data Source: Students' graphs constructions and transcripts of interviews.

Data Analysis

- Variables, characteristics of the data, and graph types plotted were identified.
- The first author conducted open coding to the transcripts of students' justifications for their variables and graph types selected. Other two researchers analyzed this data with the identified coding scheme. Later, the first author met with them to discuss the codes until agreement was achieved.

Findings: Students' Graphs



Findings: Students' Justifications

Justifications for variables selected	Hypothesis	Prediction	Context	Other
Out of 26	8	9	7	2

Justifications for graph types	Data Characteristics	Visualization	Data Characteristics and Visualization	Other
Out of 26	6	11	6	3

Graph type	Bar	Line	Scatter
Out of 26	11	3	12

Discussion

- Participants mostly:
  - focused on testing the hypothesis or prediction, which resulted in a variety of graphs
  - selected a bar or scatter graphs for visual and data characteristics reasons
  - plotted raw data, which suggests they did not see a need to plot aggregated data (Konold et al., 2015)
- As described in D'Ambrosio et al. (2004), this study reveals students' struggles to combine different knowledge bases. For instance, knowledge of data analysis and experimentation in biology.
- Teaching graphing to undergraduate students using interdisciplinary lenses explicitly could be a way to advance their graphing skills.

Next Steps

- Recruit a large, diverse pool of undergraduate students to work on the digital tool to:
  - refine our conceptual framework
  - develop and evaluate evidence models for all relevant student graphing practices
  - define areas of student competence and difficulty with graphing in our digital environment
- Compare students' practices and evidence models, supported by interview data, to identify areas for graphing tool refinement and revision

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