Application of the Decoding the Disciplines Paradigm to Enhance Graphical Interpretation Skills of Introductory Biology Students

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Decoding the Disciplines Paradigm

Through a stepwise process involving interviews and self-reflection (**Figure 1**), participants in Decoding workshops identify the steps necessary to guide students through specific bottlenecks in their learning.

During Summer 2022, I participated in a “Decoding the Transition from High School to College” workshop that included both high school and university biology instructors. We worked together to each identify common topics or skills with which our students struggled.

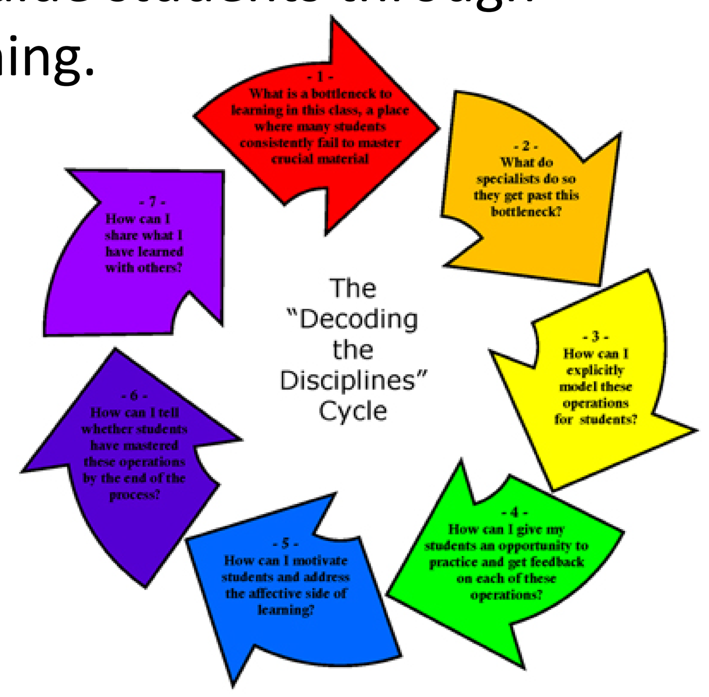


Figure 1: Steps taken by “decoders” when addressing a bottleneck in student learning.

The Graphing Bottleneck

Since 2018, I have taught an introductory biology course, “Biology L111: Foundations of Biology: Diversity, Evolution, and Ecology.” The course challenges students to approach these “soft” disciplines from a more quantitative and graphical perspective. Year after year, students struggled to understand the biological processes underlying the visual models of key concepts **(Figure 2).**

- gene x environment interactions
- natural selection
- genetic drift
- mutation-selection balance
- population growth
- resource competition

Figure 2: Introductory biology course concepts that often require graphical models for full comprehension.

During my decoding interview, I identified **11 steps** that my students would have to complete to correctly answer one of my more challenging graphical questions on a ***timed*** exam.

This profoundly revealing process helped me realize that I was not providing nearly enough guidance (or “scaffolding”) through a very high-level thought process for my **teenage** students.

My solution → the ***“graphing checklist.”***

The Graphing Checklist

The three primary sections of the checklist involve ***orientation***, ***pattern recognition***, and ***interpretation.*** Interpretation requires the highest level of thinking during which students must identify *why* the function is changing in this way, identify intercepts or equilibria, and connect it with underlying biological processes. Below is an example of a completed graphing checklist for the logistic population growth model (**Figure 3**).

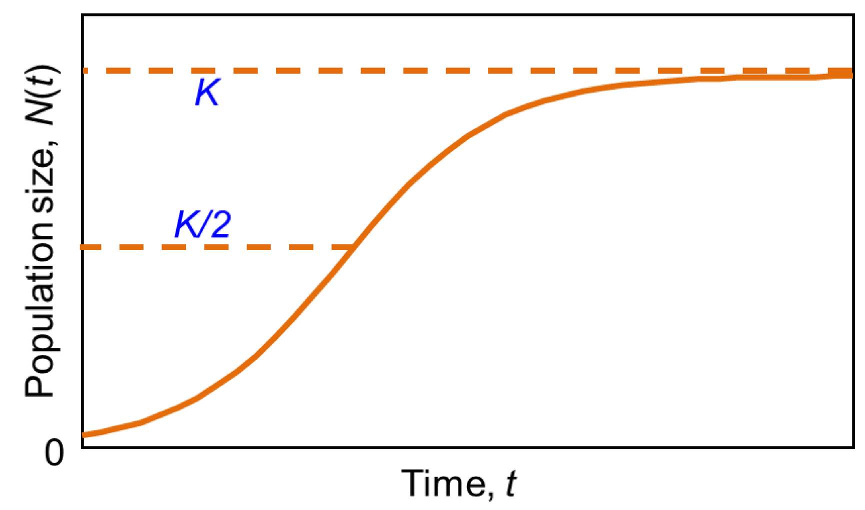


Figure 3: Changes in the size (number of individuals) in a generalized population of, for example, a wildlife species. $\boldsymbol{N_t}$ = population size at time (***t***). ***K*** = the carrying capacity of the population (number of individuals supported by the environment).

Part 1: Orientation

a) **What is the independent variable?** Look at x-axis label. Time

b) **What is the dependent variable?** Look at the y-axis label. Population size

c) **What scale and units are being used on these axes?** Not applicable

Part 2: Pattern Recognition

a) **What is the shape of the graph(s)?** **Non-linear curve**

b) **How is the graph of the dependent variable (y-axis) changing as you increase along the x-axis?** **Increases and then levels off and does not change**

c) **How would you describe the slope (rate of change) of the graph?** **Slope of curve begins steep and concave and then becomes convex and shallow, reaching an asymptote.**

d) **Write out this relationship.** **As time progresses, the population size increases rapidly and non-linearly, followed by slow growth, and finally reaches an asymptote.**

Part 3: Interpretation

a) **Why is the graph changing in this way?** If applicable, relate the graph to the relevant topic from class. **This is the logistic growth model, for which the per-capita growth rate (r) decreases as population size increases, because density-dependent factors such as resources and disease will eventually slow growth until K is reached, when growth stops**

b) **Are there any important points to note along this graph and how do they relate to the course concept?** **The y-intercept (initial population size, N_0), carrying capacity (K), and K/2 (the population size at which the population is growing most rapidly)**

c) **Have we discussed any graphs related to this one?** **Yes, we have shown how decreases in birth rate and increases in death rate as population size increases translate into decreasing per-capita growth rate (r) as population size increases. When r = 0, the population has reached K.**

Student Performance

In Biology L111 in Fall 2022 and 2023, a graphing checklist was filled out during class every time a new graph was introduced. When surveyed late in the semester, ***78% and 94% of students in 2022 and 2023***, respectively, found the checklists helpful for at least one aspect of the class (e.g., quizzes, homework).

In addition, the effectiveness of the graphing checklists was evaluated via identical pre- and post-class assessments of students’ abilities to successfully answer questions related to graphical orientation, pattern recognition, and interpretation (**Figure 4**).

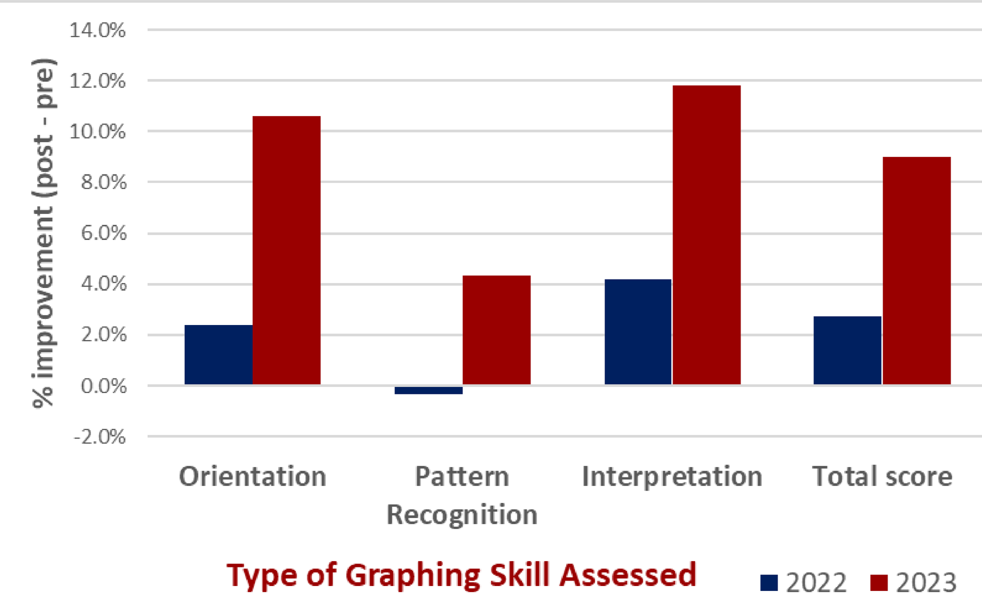


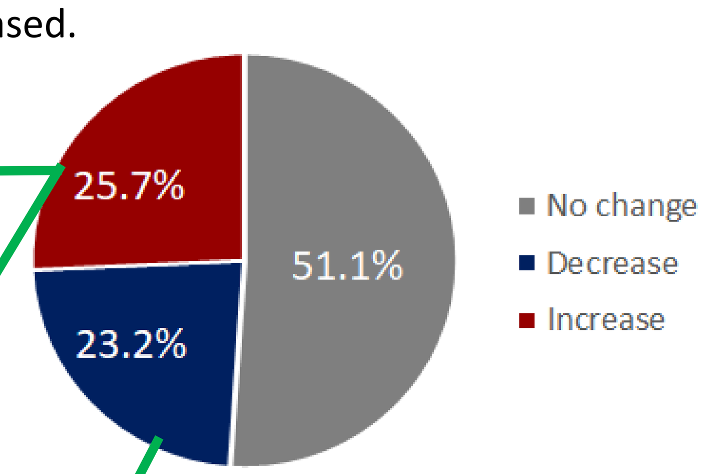
Figure 4: Percent improvement for scores on the same assessment at the start and end of the semester in 2022 and 2023. Scores for Orientation, Pattern Recognition, and Interpretation skills were averages of five, six, and five questions, respectively. Students exhibited significantly higher total scores in both years (paired t-test: 2022: t = -3.57, df = 276, P < 0.001; 2023: t = -8.47, df =126 276, P < 0.00001)

Students were also asked to rate their ability to read and interpret graphs at the beginning and end of the semester on a scale of 1 to 5 (ranging from very weak to very strong).

Students varied greatly in how they rated themselves before and after the course (**Figure 5**).

Figure 5: Percentages of students whose individual ratings of their ability to read and interpret graphs increased, decreased, or stayed the same after our 16-week class. Included below are comments made by students whose scores either increased or decreased.

From “moderate (3)” to “somewhat strong (4)”:
After this class, I definitely feel more confident in reading graphs and being able to explain them to someone else. I think the graphing checklists helped me a ton and I really appreciate them.



From “moderate (3)” to “very strong (5)”:
Especially after taking this class, my abilities to read graphs have definitely increased. The graphing checklists have immensely helped me and I’ve been getting graphing questions correct on quizzes which has shown my improvement.

From “moderate (3)” to “somewhat weak (2)”:
I thought I was decent at interpreting graphs until I took this class. There’s a lot that goes into interpreting graphs and histograms.

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