Graph Construction Conceptual Model (GCCM)

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Lead author: Joel K Abraham, CSU Fullerton
Authors: Stephanie Gardner, Purdue University
Elizabeth Suazo-Flores, Purdue University
Eli Meir, SimBiotic Software

Introduction

When teaching and assessing scientific skills, it is useful to have a formal model of the elements that comprise competency in that skill. A model provides concrete criteria for comparing students and experts, which helps determine where additional instruction is needed. A model can also be used to create learning outcomes for instruction. This document is a draft of the Graph Construction Conceptual Model (GCCM) for assessing student competence in graph construction in the biological sciences.

The model comprises 17 practices, listed below. We call them "practices" because making a good graph is as much a shared social construct within a field as it is a universally defined skill. For instance, in most biological fields the convention is to put the independent variable on the x-axis – being a competent grapher of biological data involves knowing and using this practice.

The GCCM has undergone extensive validation via a several different avenues and is currently in prep for publication. As this is pre-publication, we ask that this document not be shared, but please use it for your own purposes. Items may change as we refine the model for publication.

Categories of Graph Construction Practices

The GCCM divides graph construction into four broad categories.

1. **Data Selection** includes practices involved in choosing which data to include on a graph such as choosing variables and recognizing important characteristics of the data for each variable.
2. **Data Exploration** includes practices that help one characterize data such as summarizing with statistics and accounting for variability.
3. **Graph Assembly** includes practices needed for plotting data such as choosing a type of graph and following customs about how to plot and what to include.
4. **Graph Reflection** includes practices that are often categorized under "graph interpretation" such as identifying trends and interpreting results, as well as recognizing strengths and weaknesses of a particular graphical representation.

Using This Model in To Improve Graph Construction Education

The GCCM is designed to be a tool that can help improve both assessment and teaching of graph construction. Identifying specific practices that go into constructing good graphs helps to focus attention on elements of graphing that a particular student or student population could improve.

Looking at graphs your students build with these practices in mind can help you to see specific practices where your students may benefit from more practice or instruction, and others where they are already demonstrating competence. Students who demonstrate competence in all these practices are likely making accurate, easy to read and interpret graphs that facilitate their exploring and drawing conclusions about biological questions.

The Full GCCM – Winter 2022 Draft

Through our research, we've identified 17 important practices for constructing graphs in the biological sciences

Category	Activity Code	Activity Statement
Data Selection	Data Type	Differentiates between quantitative (i.e. ratio, interval) and qualitative (i.e. ordinal, nominal) data types
	Variable Relevance	Selects variables for the graph that are relevant to a scientific claim in the context of a given research question, hypothesis, prediction, or objective
	Variable Categorization	Identifies variables as related or causally linked in the context of a stated research question, hypothesis, prediction, or objective
	Data Filtering/Prioritizing	Plots appropriate data points, and appropriately excludes data points (e.g. missing data, corrupted samples), from each variable based on data characteristics
Data Exploration	Data Form	Differentiates between data as a set of individual values (i.e. sample data) versus data as a distribution that could be summarized (i.e. aggregate data)
	Data Summarization	Plots individual or summarized data to communicate information efficiently for a given data set and intended purpose
	Statistics Selection	If summarizing data, selects appropriate descriptive statistic for a given data set and intended purpose
	Data Variability	Displays variation in data in a form appropriate for a given graph type and intended purpose
Graph Assembly	Graph Type	Selects a graph appropriate for the data type and intended purpose
	Data Plotting	Plots data in the correct coordinates
	Graph Structure	Follows disciplinary conventions in scaling and assignment of axes of graph
	Graph Labeling	Includes succinct axis labels, graph captions, or a title that effectively communicate the data plotted, in what way they have been transformed, and what graph elements (e.g. error bars, symbols) represent
	Graph Communication	Designs graph to efficiently communicate data for a given purpose
Graph Reflection	Data Points	Extracts values of sample or aggregate data points from the graph
	Data Description	Describes the characteristics (i.e. central tendency, variability) and patterns of the graphed data for the plotted values and graph type
	Graph Selection	When one or more graphs are constructed, evaluates the affordances and limitations of each graph for exploring data characteristics or for supporting a scientific claim
	Scientific Claim	Interprets the constructed graph to support a scientific claim in the context of a given research question, hypothesis, prediction, or objective