Graphing and Estimation as Tools to Improve Critical Thinking in High School Chemistry Students

MONTANA STATE UNIVERSITY MSSE

THE WILLISTON NORTHAMPTON SCHOOL 1841

Background:

Chemistry in the Community is a conceptual chemistry course with very little math. In place of the math, the class devotes time to real-world connections, class discussions, and projects. The students tend to struggle with math skills and "student skills" in general, such as organization, motivation, and critical thinking.

Furthermore, students struggle with creating and interpreting graphs. They have a difficult time converting data between tables, graphical representations, and narrative forms. In addition to being valuable in chemistry and other science classes, improved proficient graphing skills and critical thinking have real-world applications, ranging from economics to advertising to weather.

Conceptual Framework:

In an era when scientific data is often politicized or interpreted based on "beliefs" rather than facts, the accurate analysis and interpretation of graphs remains a crucial component of critical thinking, visual literacy, and responsible citizenship. In their article "Instructional Strategies to Develop Graphing Skills in the College Science Classroom," Harsh and Schmitt-Harsh (2016) quote the American Association for the Advancement of Science as saying, "Proficiency in graphing is considered a central element of scientific literacy, given the importance of succinctly communicating complex information."

The need for consistent graphing practice was confirmed by Roth and McGinn who discussed in a 1997 Science Education journal article whether graphing is a cognitive ability or an acquired skill. In this Action Research project, students were tasked with working on their quantitative reasoning and the connection between numbers and visual information. Brasell and Rowe (1993) were the inspiration for asking students to analyze graphs from a variety of sources and to work through explaining those graphs both in writing and in class discussion and presentations.

Research Question:

Are estimation and real-world graphing effective strategies for improving students' critical thinking and graph creation/interpretation skills?

Sub-questions:

- Will requiring students to use graphs to model scientific phenomena and communicate their reasoning increase their self-efficacy?
- Is graphing real-world scenarios or data effective at encouraging students to think more about the meaning of graphs and to appreciate the significance of graphing data?
- Do students show improved graphing ability and interest when using Excel over graphing by hand?
- Will daily visual exercises in number sense (i.e. Estimation180 and GraphingStories) improve students' comfort with data and graphing?

Methodology:

Through a series of early formative assessments, I established where my students were in their abilities to create simple scatter plot graphs showing the relationship between two variables. Likewise, I assessed their ability to correctly draw information from a variety of complex and unfamiliar graphs.

After that, I began each class period with a visual quantitative reasoning exercise. This included a combination of Estimation180 (drawn from www.Estimation180.com) and Graphing Stories (drawn and adapted from www.graphingstories.com). In the first, students estimated values and defended those estimates with mathematical argumentation. In the second, they watched quick videos and then attempted to graph the action.

Periodically, I ran a number of graphing-specific lessons and tasks. This included real-world graphing, lab-based graphing, and analyzing both scientific graphs and graphs from the media. To analyze results, I compiled and scored student work, and then used a combination of surveys and interviews to provide qualitative information.

Timeline:

- Trimester 1 – Baseline / Formative Assessments
- Trimesters 2 + 3 – Treatment
  - Mining + Atmospheric graphing (real-world data – RQ #2)
  - Visual Patterns and Graphing Stories (number sense activities – RQ #4))
  - Frequent labs and lab graphing (modeling phenomena – RQs #1 + #3)
- Trimester 3 – Applying Graphing Skills
  - Analyzing and critiquing real-world graphs (real-world data – RQ #2)

Acknowledgements:

- This project was supported by the Williston Northampton School, particularly Bill Berghoff (Science Department Head) and Peter Valine (Dean of Faculty), and by the MSSE program at Montana State University, particularly Dr. Marcie Reuer (advisor) and Dr. Greg Francis (reader).
- Special thanks to Carey Baldwin for statistical analysis advice.
- Special thanks to Lori Pelliccia for reading and proofing drafts.

Data + Analysis:

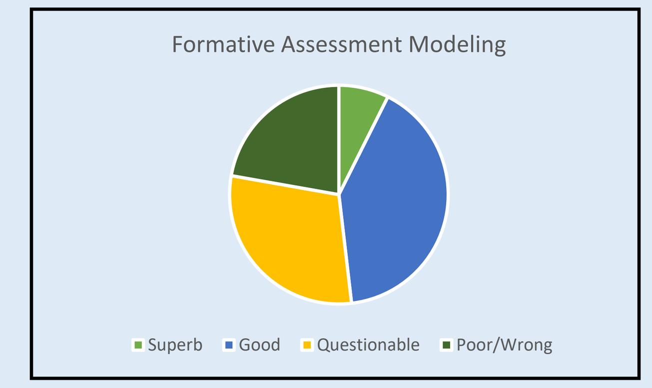

Figure 1. Quality of Student Graph Creation Prior to Treatment (Oct), *n* = 10.

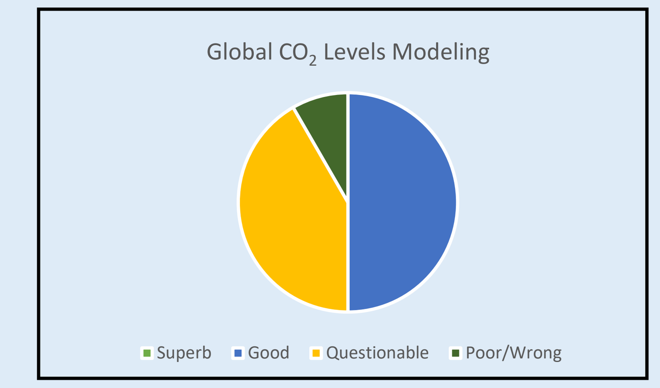

Figure 2. Quality of Student Graph Creation During Treatment (Feb), *n* = 9.

Graph Creation: Student performance in graph creation did not improve over the course of the treatment (Figures 1 + 2). Students continued to struggle to generate accurate graphs and to correctly analyze trends in graphs.

Graph Analysis: By the end of the course, between 25% and 67% students accurately and mathematically described trends in found real-world graphs (Figures 3 + 4).

Student Confidence: As self-reported, student confidence in graph creation, data analysis, and graph interpretation improved by nine, seven, and ten percent, respectively.

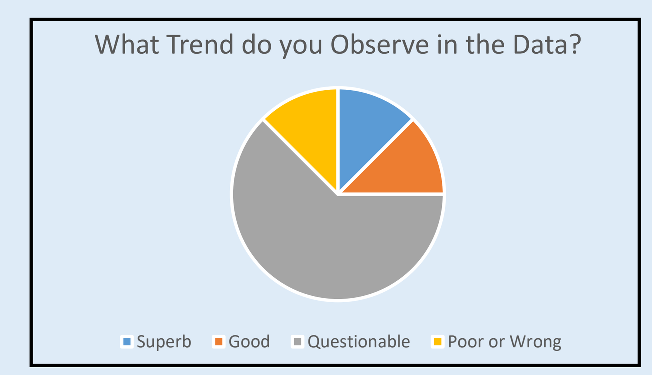

Figure 3. Accuracy of Real-world Graph Interpretation in April, *n* = 8.

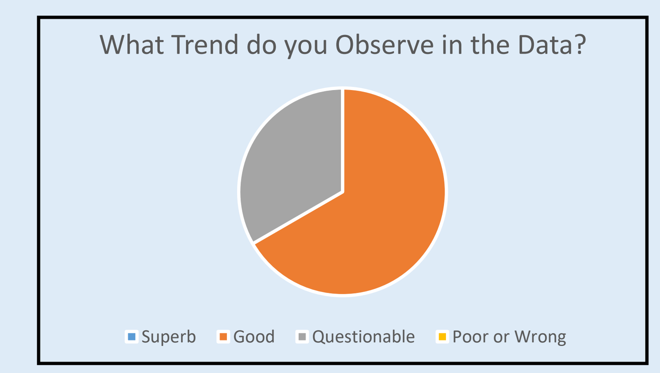

Figure 4. Accuracy of Real-world Graph Interpretation in May, *n* = 9.

Conclusion:

Students showed growth in drawing information from scientific graphs and making claims about that information. However, there was no statistically significant growth in their ability to create graphs or to reason mathematically. Conversation in class and interview feedback indicated that students improved their understanding of the significance of the mathematical elements in graphs. Likewise, their appreciation for the utility of graphs, and information conveyed by them, increased.

Despite overall mixed results, the real-world graphing assignments in April and May provide a succinct measure of some success in this study. Further, students demonstrated a growing proficiency with reading solubility graphs and with having accurate and mathematical discourse when answering questions about graphs. While the results of the individual sub-questions yielded mixed results, the ultimate goal of increasing critical thinking about graphical information in everyday life was met.