A Case Study on Undergraduate Students' Interpretation of Misleading Graphs in Public Media

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Contemporary news media frequently utilizes graphs to simplify the presentation of complex information. However, prevalence of misleading graphs on public platforms often makes readers susceptible to false information. This raises pertinent questions regarding the efficacy of our education system in adequately preparing students to interpret graphs. In this paper we present a case study that aims to explore undergraduate students' interaction with misleading graphs and unpack their mathematical reasoning as they do so to identify patterns that can explain their graph interpretation abilities. The study's findings suggest that students who focused on the data in a graph, rather than its shape, demonstrated better proficiency in graph comprehension and in identifying misleading elements.

Keywords: Graphs, Media, Misinformation, Critical mathematics

Today, most of the news media uses different forms of visualizations to simplify the presentation of complex information. Our brains better process data when they are presented in visual forms, such as graphs and tables, enabling us to discern significant patterns that might otherwise be overlooked (Tufte, 1985). While graphs can significantly improve information processing, the prevalence of misleading graphs in news and public media exposes readers to false information and poses a significant threat to democracy (Cairo, 2014). The risk is heightened during critical events such as pandemics and elections, as misleading graphs can directly influence public perceptions and decision-making regarding health and voting behavior. Under such circumstances, the question remains to what extent are students prepared to interpret graphs and identify misleading graphs published on public platforms?

While prior research has reported students' struggle with identification of misleading visualizations, particularly graphs (Ramly et. al., 2021), there exists a lack of understanding of the reasons behind such struggle. With the aim to fill the gap, in this paper we present a case study that investigates the question, how do undergraduate students interpret misleading graphs in public media, and what patterns in their mathematical reasoning can explain their ability or inability to identify inaccuracies in these visualizations? We hypothesize, once we identify these patterns, we can introduce them in our teaching and learning of graph comprehension and foster within students a habit of critically assessing the accuracies of graphs.

Theoretical Framework

This study is developed on the theories of critical mathematics literacy (Frankenstein, 1994) and graphicacy (Wainer, 1992). While critical mathematics literacy views mathematics as a socio-political tool for identifying and questioning societal injustices (Frankenstein, 2001), graphicacy focuses on understanding and interpreting graphical data (Wainer, 1992). By combining these frameworks, we argue that during this age of prominence in visual data, students' graph comprehension skills would enable them to uncover hidden patterns or biases embedded in visualizations and prompt them to ask relevant questions about data that would develop their fundamental critical analytical skills and enables them to comprehend the complexities of society.

Researchers have proposed various frameworks for evaluating an individual's graphical comprehension; this study utilizes Curcio's (1987) framework, which assesses graph comprehension through three aspects: reading the data, reading between the data, and reading beyond the data. While extracting data from graphs is emphasized in reading the data, identifying relationships between variables presented in graphs is the focus of reading between the data. The advanced level of graph comprehension, reading beyond data, involves making future predictions based on given trends in data. In this study, students interpreted graphs extracted from news media and we used the framework of reading the data, reading between the data, and reading beyond the data to measure their graph comprehension skills.

Method

Worksheet

To investigate students' interaction with misleading graphs, we asked them to complete a worksheet containing graphs with some mathematical inconsistencies. In the first bar graph on federal welfare (Figure 1- Left) presented by the Republican side of the Senate Budget Committee, the y-axis was truncated, and in the second "job loss by quarter" graph (Figure 1-Right) extracted from Fox News, the scales along the x-axis and the y-axis were inconsistent.

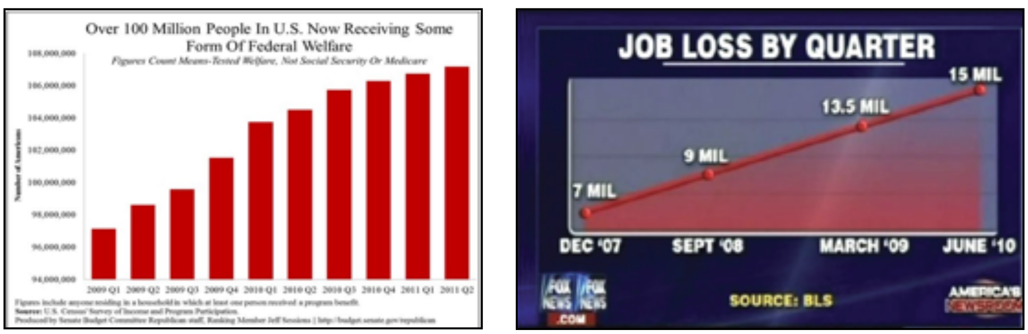

Figure 1. Left - Graph on US Federal Welfare; Right- Graph on Job Loss by Quarter

To measure students' ability to comprehend graphs, each graph was accompanied by three questions assessing students' capacity to read the data, read between the data, and read beyond the data (Curcio, 1987). For instance, with the "job loss by quarter" graph, to investigate students' ability to read data we asked them to identify the number of people who lost jobs in September 2008. To measure students' capacity to read between the data, they were provided with a hypothetical situation where a local news agency claimed that joblessness increased at a constant rate between December 2007 and June 2010 and asked them if they agree with the claim. Finally, students were prompted to predict future job losses based on current trends to evaluate their ability to read beyond the data. Students were asked to write justifications for their answers to help the research team gain insights into their mathematical reasoning and identify patterns that can possibly explain why some students are better able to identify misleading graphs, while others are not.

Participants

This research was conducted in an urban private research university in the North-Eastern Region of the United States. Nineteen undergraduate Business Administration students enrolled in a Quantitative Reasoning Course participated in the study. The first author administered an anonymous graph worksheet to the students, which was independently answered by the students.

The research team performed open coding (Strauss & Corbin, 2004) to analyze the students' responses and the written justifications. In this paper, we will present our findings on students' interaction with the misleading graphs and will uncover patterns in their mathematical reasoning that could explain their comprehension of graphs published on public platforms.

Results

Students' responses to the three questions accompanying the two misleading graphs revealed that for both the graphs, students could correctly read the data. However, they experienced struggles while reading between and beyond the data from the graphs, especially for the graph on job loss numbers (Table 1).

Table 1. Table showing students' responses to the three levels of reading data for the two misleading graphs on Federal Welfare and Job loss numbers

Graphs		Graph 1 (Federal welfare)		Graph 2 (Job loss)	
Type of responses →		Right	Wrong	Right	Wrong
Type of Questions	Read the data	19	0	18	1
	Read between the data	17	1	9	10
	Read beyond the data	19	0	2	17

To unpack the reasons behind this challenge with reading between and beyond the data, we analyzed their written justifications. To measure their ability to read between the data for the "job loss by quarter" graph (Figure 1- Right), we asked them, "A local news agency claimed that joblessness increased at a constant rate between December 2007 and June 2010. Do you agree with the claim? Justify." Ten out of 19 students answered incorrectly, asserting that job loss increased at a constant rate in the given time period. Upon examining their rationales, we found that all the students attributed their conclusions to the shape of the graph. They made statements such as "The line is pretty straight which means it is steady and constant" and "I do agree with the claim due to the linear slope of the graph indicating the constant rate", indicating that students relied on the linearity of the graph to infer the constant increase in job loss numbers.

On the contrary, eight students correctly discerned that job loss numbers did not increase at a constant rate. On analyzing their written justifications, we found that the students consulted the numbers presented in the graph and performed mathematical computations. For instance, one student calculated "the slope between Sept 2008 and Mar 2009 is 0.75 (13.5 - 9 mil / 6 months) and the slope between Mar 2009 and Jun 2010 is about 0.1 (15 - 13.5 mil / 15 months)." They said, since "slopes do not equal, then the growth is not constant." Hence, for the "job loss by quarter" graph, students who concentrated on the shape of the graph, missed the discrepancy between the actual data and the graph's shape. In contrast, students who focused on the numerical data recognized that the job loss numbers given on the graph do not support the linear shape of the graph and thus identified the graph to be misleading.

A similar pattern emerged from the "US Federal Welfare" graph (Figure 1- Left). To assess students' ability to read between the data, we asked them, "A local news agency claimed that the number of Americans who received federal welfare doubled from the first Quarter of 2009 to the fourth Quarter of 2009. Do you agree with the claim? Justify." Only two students failed to identify the misleading nature of the graph and asserted that the number of Americans who received federal welfare during the fourth Quarter of 2009 doubled from the first Quarter. Upon analyzing their written justifications, we found that both students focused on the relative height of the bars to reach the conclusion. One student said, "The size of the bar for 2009 in the fourth quarter could be considered double what it looked like in the first quarter." Conversely, students who answered correctly mainly focused on the numbers given on the graph and engaged in some form of mathematical calculation. For instance, one student who answered correctly to the question, wrote, "Find the bar that says 2009 Q1 and the bar that says 2009 Q4 on the x-axis and identify the number of Americans by reading the y-axis. Find the difference between the two data. In 2009 Q1, the Number of Americans was about 97,000,000 and in 2009 Q4, it was about 101,000,000. There was only a 4 million difference."

To assess students' ability to read beyond the data presented in the "job loss by quarter" graph we asked them "With the current trend following, what would be the total number of job losses in the next quarter?" Given that the graph was misleading, we hypothesized that students' responses to the previous question would influence their approach to this one. If students acknowledged in the prior question that job loss did not increase at a constant rate, it might lead them to infer that it is not feasible to predict the future job loss numbers. To streamline the coding process, we decided, students who would not make any predictions would be considered as having answered the question correctly. All other responses were marked as incorrect.

In the previous question, ten students who failed to recognize the discrepancy between the job loss numbers and the shape of the graph, made some predictions about future job loss numbers. Upon examining students' prediction strategies, we found that most students calculated the job loss numbers in the three given quarters, found the average job loss numbers and used the value to predict the job loss number in the next quarter. During the process although they found that in each quarter job loss numbers did not increase constantly, they did not make any explicit comment on the nature of the graph. Among the nine students who correctly discerned that job loss figures did not exhibit a constant increase, two expressed their inability to forecast future job loss numbers. One of them said, "I can't say because the progression of the numbers is not going at a constant rate." The seven other students who recognized that the graph was misleading, projected some future job loss numbers. They made assumptions about the rate of job loss from the previous three quarters and conducted mathematical computations to reach their conclusion. For instance, one student predicted that the cumulative job loss number by the end of the next quarter would be 16.66 million because, between March 2009 and June 2010, job loss numbers increased by 11.11%, and "considering 11.11% increase rate, the number of job losses in the next quarter (Q3'10) would be approximately 16,666,500".

Upon reviewing students' responses to the "reading beyond the data" question, we realized that, although our intention was for students to recognize that the misleading graph was not a reliable tool for making predictions, the way we phrased the question might have unintentionally limited students' thinking about the inconsistencies present in the graph. Most students focused on a hypothetical situation and made assumptions about the current rate of job loss to make future predictions about the same. Further, upon analyzing each student's predicted job loss numbers, we found that many of them made errors in their mathematical calculations. However, the goal of the study was not to measure the mathematical correctness of the students' calculations; rather focus on their strategies that could explain their graph comprehension.

Discussions

Based on students' responses to the graph worksheet, this study draws the following conclusions. Students showed greater proficiency in reading data from the graphs compared to reading between and beyond the data. Students who failed to identify misleading elements of the graphs relied more on the shape of the graphs rather than the actual data. Conversely, students who closely examined the data provided on the graphs and conducted mathematical calculations, used their mathematical outcomes as evidence in support their answers. The findings of the study, mainly the gap between students' potential to reading the data and reading between and beyond the data is particularly worrisome. It suggests that as news consumers, while we may excel at extracting data from graphs, we often fail to thoroughly analyze the relationships between variables depicted in visualizations and think beyond what is presented to us. As a result, if confronted with a misleading graph, such as the one on job loss numbers, we would be prone to accepting the information at face value rather than questioning the accuracy of the data. Since the study had no scope to get deeper into students' responses through interviews, we are uncertain of the reasons behind the gap between students' ability to read the data and critically analyze the data.

Consequently, this study proposes the following recommendations to enhance students' graph comprehension. First, educators should encourage students to focus on the data presented in graphs rather than being distracted by their visual shapes or design elements. Second, graph literacy should be introduced through authentic, real-world graphs rather than hypothetical ones, as understanding graphs requires more than just knowing mathematical rules-they must be interpreted within relevant contexts. Lastly, fostering graph comprehension in real-life scenarios involves cultivating students' habit of critical questioning prompting them to ask who the graph represents and excludes, and what biases might be embedded in the graphs.

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