Improving Technical Writing Skills through the Judicious Use of Infographics

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Motivation

This paper shares the experiences and outcomes of teaching data visualization techniques within graduate engineering classes taught in the US and Israel. We will describe how infographics were used to improve student's technical documentation and ways to get the students involved and enthusiastic in using graphics instead of text.

The motivation behind this effort was driven by the first author's experience in industry where he worked for over 25 years including 10 years as Vice President of technology for a global telecommunications software company that employed over 25,000 people in 50 countries. As in many hi-tech industries, I was inundated with reading material and had little time to read long documents. Consequently, common practice was to require that documents be concise and have all key findings be presented using a few well-designed infographics [2]. Typically, we would we would just read the introduction, examine the diagrams and review the conclusion. The main body of text was only read if clarifications or in-depth information was needed. Not only did this save time but also, as most of our employers were not native speakers of English, focusing on infographics and less on text reduced misunderstandings [1].

After moving to academia, I found that students were unaware of the writing style that is used in today's high-paced industries. While many schools offer writing intensive programs [3] and some guidance on the use of graphs and charts [4], students do not receive enough instruction on how to develop and integrate infographics [12] within their documentation. This is particularly true of the many international students in my classes that had not taken any technical writing classes in their respective countries before coming to the US for their graduate studies.

The data visualization techniques and principles I used in my classes are based on Edward Tufte's [13] classical work, The Visual Display of Quantitative Information, as well as methods proposed by Krum [1] and Lankow et al [2].

The Issue

The importance of communications education has long been recognized by the National Science Foundation and accreditation agencies. Indeed, in 2000 the Accreditation Board for Engineering and Technology mandated that graduates must show proficiency in being able to communicate effectively. While students may not love to write, they are also well aware that "Engineers who don't write well end up working for engineers who do [9]".

In 2014, we conducted an internal faculty survey to determine which writing skills students need to improve most. The top 4 concerns that were raised were the inability of the students to:

- Organize ideas in writing
- Write effective sentences
- Develop complex ideas in writing
- Think critically

In my classes, I found that students were unprepared and unaware of the writing style that is needed in today's high-paced industries. Their responses were mostly textual and used few infographics. They tend to provide unnecessary detail and repeat the same information using slightly different words. The graphs they did use were unclear and not well designed. A typical example is shown in Figure 1.

Figure 1: Initial Attempt at Using Infographics

Some of the issues in this diagram include

- Use of different colors for each data cell (coloring should be used sparingly and needs to make a clear point)
- Use of 28 point fonts (resulting in this one diagram taking up almost an entire page)
- The vertical axis is formatted the same way as the data cell
- The colors of each column extend 1 inch below the table
- Lack of measurement units - e.g. cost per month ($), delay (msec)
- The number of significant digits in each cell (e.g. cost/month could be depicted in thousands of dollars such as 131K, 142K, etc. or the attribute could be cost per month ($K)
- The use of a comma to represent the decimal point

The Learning Process

The main challenge was for the students to understand what I was trying to achieve. For this, we looked at their initial homework assignments (such as shown in Figure 1) and discussed some of the issues with their diagrams. I then shared with them examples from the software industry (high-level design documents, user manuals, requests for proposals, etc.) that illustrated the quantity and quality of diagrams that are incorporated into technical documentation.

In each subsequent lesson, I would spend a few minutes on various aspects of infographics including:

1. Presenting and discussing a number of examples to get students intrigued by the power of infographics
2. Providing quantifiable metrics to measure the efficiency and accuracy of an infographic
3. Listing a small number of guidelines and best practices they should follow
4. Describing the process they should follow to integrate infographics within their documents
5. Applying these principles to analyze diagrams in their written assignments and in the class textbook

The objective was not to make the students experts in graphical design. Rather, it was to get them interested in infographics and learn how they could be used to improve their assignments and increase their career readiness. The rest of this section provides more detail on the process and examples used in class.

The first step was to have the students appreciate the elegance and efficiency of a diagram as opposed to writing out the same information in text. Charles Minard's [7] classic space-time diagram from 1869 depicting the attack of Napoleon on Russia was my obvious first choice. However, the infographic that appealed to them most was a modern example shown in Figure 2.

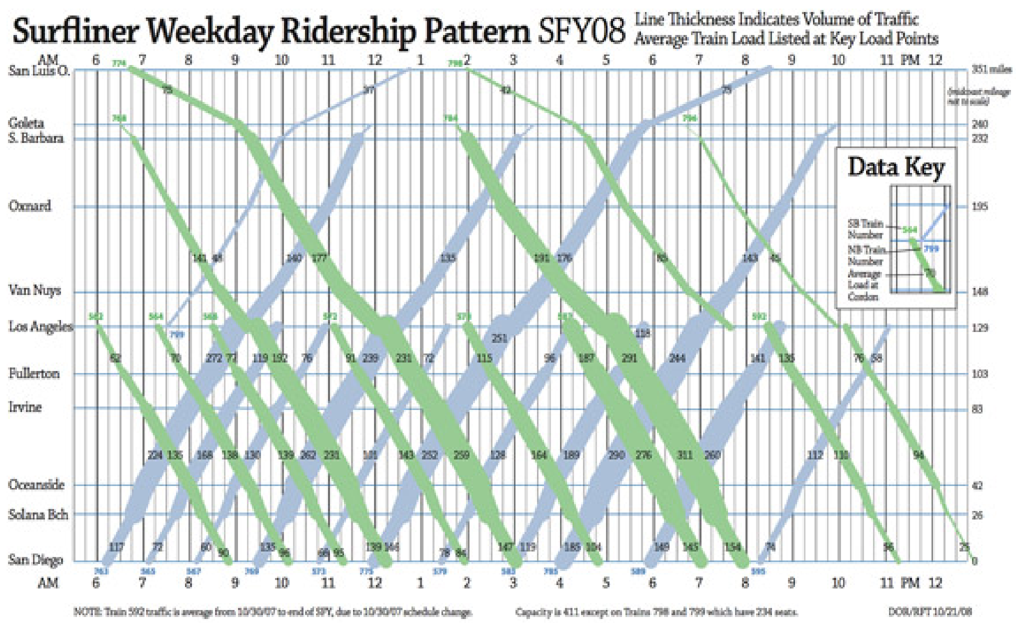


Figure 2: An Efficient Space-Time Diagram

This infographic depicts a train schedule using the X-axis to represent time and the Y-axis, the stations. The clever idea used here was that instead of having the stations equally spaced apart on the Y-axis, the stations were linearly spaced based on the distance between them in the real world. Consequently, the angle of the line represents the speed of the train - the greater the angle line, the faster the train. In addition, the width of the line depicts the average load for that time of day and section of the track.

The students loved the elegance and efficiency of this approach. They made many suggestions on ways to improve the diagram such as integrating cost, train type, etc. During subsequent lessons, the students enjoyed analyzing diagrams used in the textbook, which became an integral part of the learning process.

The second step was to provide some concrete metrics and formulas that the students could use to determine the accuracy and efficiency of a diagram. Being engineers, the use of formulas appealed to them and helped them compare diagrams in a quantifiable manner. The first formula was used was the data ink ratio defined by Tufte [13] as:

$$Data\_ink\ ratio = \frac{Data\_ink}{Total\_ink}$$

= Proportion of ink used to display non-redundant information
= 1.0 - proportion of graphic that can be erased without loss of information

Using this metric, we then analyzed and compared the two diagrams in Figure 3 [12]. The students concluded that although both diagrams show the same information, the diagram on the right uses less ink and is clearer.

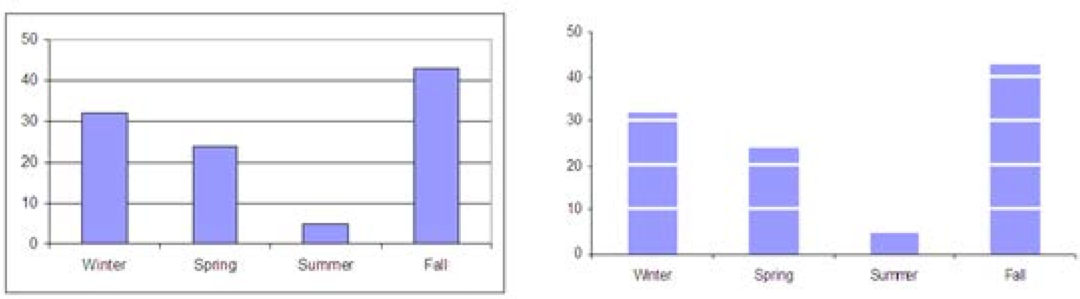


Figure 3: Inefficient Use of Space and Color

We also looked at the default graphs provided by Microsoft Excel. As shown in Figure 4, we displayed the same data using different built-in options and compared the clarity and efficiency of each layout.

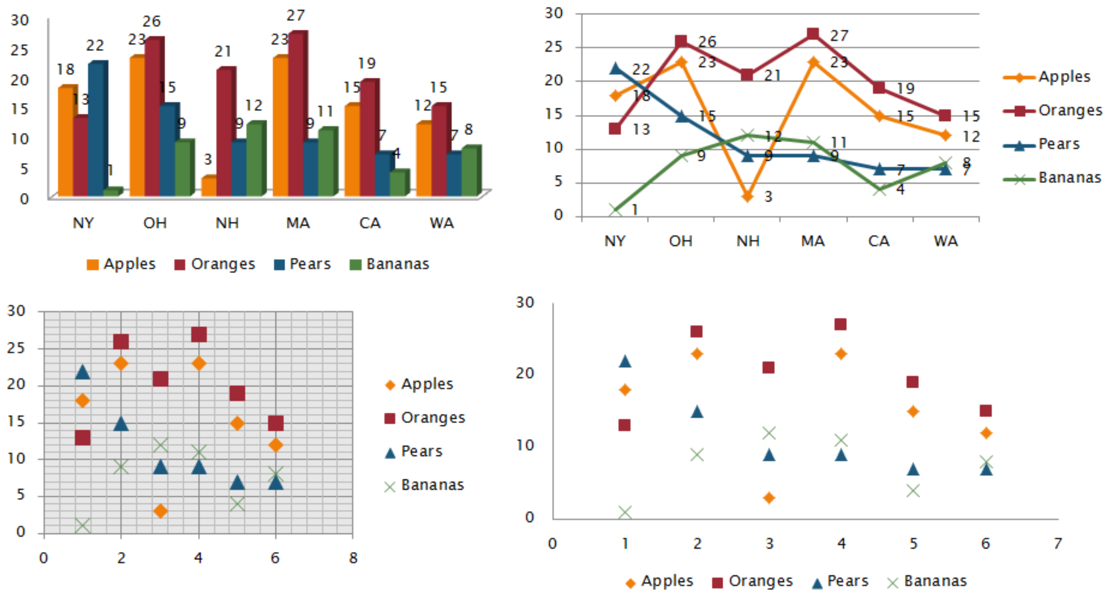


Figure 4: Comparing Excel's Predefined Tables

The pros and cons of each diagram are beyond the scope of this paper but the outcome of the analysis was that students understood the limitations of Excel and obtained a better understanding of what constitutes a good infographic.

Another metric that we looked at was graphical integrity which Tufte [13] calls the "lie-factor" and uses the following formula:

$$\text{The lie factor} = \frac{\text{Size of effect shown in the graphic}}{\text{Size of effect in the data}}$$

Using this formula, we analyzed the diagrams in Figure 5 and showed that the diagram on the right has a lie factor of over 5 while the one on the left has a lie factor of over 14. The students were at first stunned. Then they realized that the basis of the misconception is due to a single dimensional metric being framed in a two dimensional framework. These metrics aroused a lot of interest and, after which, there was always some student who commented on the accuracy or efficiency of any graphic shown in class.

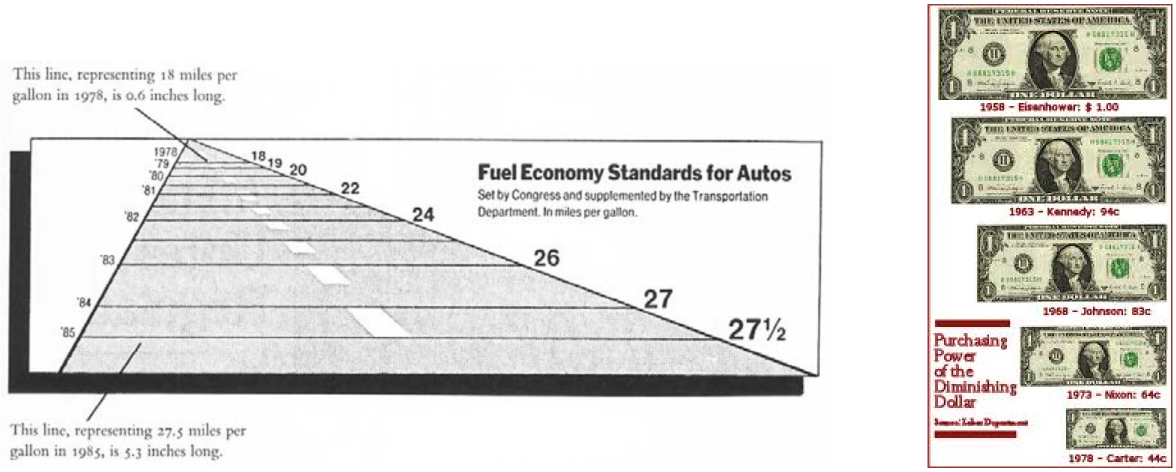


Figure 5: Misleading Data Representations

The third step was to describe some simple rules and best practices in the use of infographics. These included

- When and how to use colors
- Scaling and metrics
- Displaying significant values
- Font selection and sizes
- Column and row sizing

Throughout this process, we spent time in each lesson analyzing and critiquing examples from industry and academia. For example, the class text book included the diagram in Figure 6 to demonstrate how to map applications to locations.

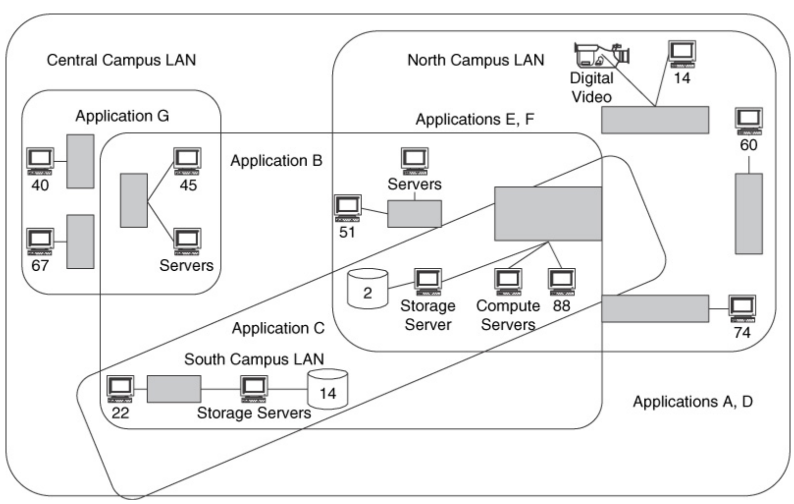


Figure 6: Text Book Diagram – Geospatial Layout

However, the student's initial feedback was that the diagram was not clear as the applications and locations used the same color and font. Consequently, in most of their homework assignments they used a coloring scheme such as shown in Figure 7.

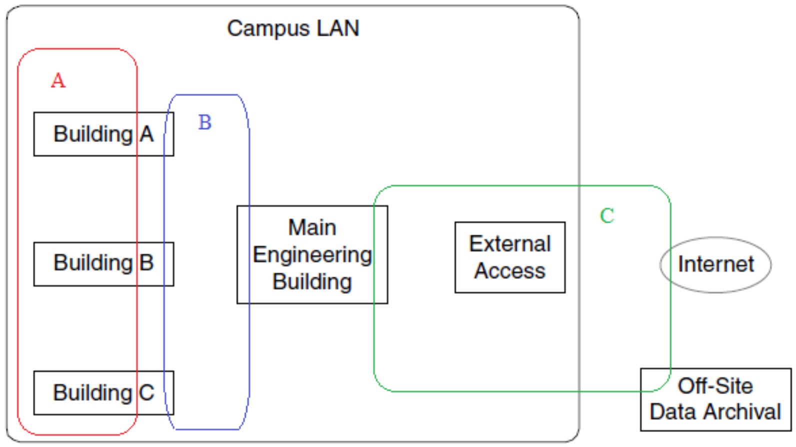


Figure 7: Student's Diagram – Geospatial Layout

Moreover, other students realized that this sort of diagram is not scalable and will become very unclear and messy if there are many applications and locations with complex mapping requirements. They suggested the use of a matrix as shown in Figure 8 below.

Building	App. A	App. B	App. C
A	✓	✓	
B	✓	✓	
C	✓	✓	
Main Engineering		✓	✓
External Access			✓
Internet			✓
Data Archival			✓

✓ - Connections between buildings

Figure 8: Student's Diagram – Matrix Layout

This approach was later on adopted by all the students, as it was clearly superior for the complex problems that they needed to solve in later assignments.

It is worth noticing that the student used a tick mark to indicate "yes" and a blank entry to represent "no". Upon asking the student why, the answer was that it was to be in line with the principle to improve the data ink ratio.

The final step was to explain to the students how to incorporate infographics into their assignments. As proposed by Pritchard and Honeycutt [10] the following process driven approach was adopted:

1. Write the introduction section following standard best practices
2. Design and draw a set of infographics that present the data in a clear and insightful manner. The considerations should include
    - o Design - scatterplot, histogram, control chart, sparklines, etc.
    - o What should be on each of the axes
    - o Font size and style
    - o Coloring scheme – how colors can be used to illustrate a point or focus the reader's attention
2. Sequence the infographics into a coherent story – similar to the approach proposed by Lankow et al [2].
3. Add text to
    - o Explain how the infographic represents the data, or
    - o Describe insights or conclusions that can inferred from infographic, or
    - o Link the infographics together
4. Write the conclusion following standard best practices

The process came together in the final assignment for the course where the students had to complete a comprehensive engineering project where they needed to run various simulations and analyze the results.

Findings

During the semester, we covered:

- Data visualization techniques such as scatterplots, histograms and sparklines
- The strengths and weaknesses of each graph type
- Metrics to measure the effectiveness of an infographic
- How to use colors and fonts effectively
- How to combine text with the infographics and how they complement each other

These techniques and best practices taught opened the student's eyes to a completely new perspective that was hitherto unknown to them. Surprisingly, the more they learned, the more they enjoyed and the more they invested. They would analyze diagrams in the class book, share good and bad examples from other lecturer's notes and even critique articles published in technical journals. The use of infographics became a key component in their assignments and the quality of their technical writing significantly improved. The documents were well structured and their answers were clear and concise. The average length of their homework decreased by a factor of two – saving me a lot of time as well.

The projects showed a marked improvement in two of the top four writing areas found by our faculty survey [11] - organizing and developing complex ideas. The students made extensive use of infographics and linked them together in a logical manner. For example, one of the teams submitted the well-designed infographic shown in Figure 9 that clearly and efficiently combined information from multiple simulations. Color was used to illustrate key findings and many issues we saw in earlier diagrams had been addressed. Not only did this diagram demonstrate significant investment in time and thought, but it also helped the students analyze and compare the results from multiple simulations.

TCET 760: Network Planning and Design

COMPARISON OF DELAY

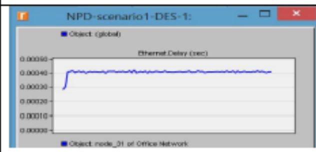
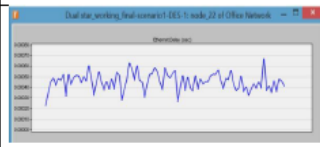
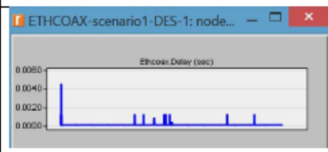
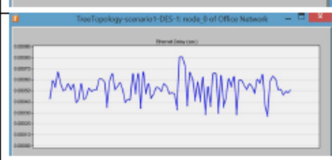
NETWORK	SIMULATION	NO.OF NODES	PEAK DELAY	WEIGHTED DELAY
STAR TOPOLOGY		30 NODES	0.40 MILLI SECONDS	0.013 MILLI SECONDS
DUAL STAR TOPOLOGY		20 NODES	0.67 MILLI SECONDS	0.0335 MILLI SECONDS
BUS TOPOLOGY		5 NODES	4.5 MILLI SECONDS	0.9 MILLI SECONDS
TREE TOPOLOGY		4 NODES	0.80 MILLI SECONDS	0.2 MILLI SECONDS
HYBRID TOPOLOGY		15 NODES	1.6 MILLI SECONDS	0.106 MILLI SECONDS

Figure 9: A Well Designed Infographic

The students still need to improve in being able to argue about the data and there were still some issues with the flow of the document. However, given that this was done within an engineering class I believe that this was an achievement and I know, from them, that it was a positive learning experience.

Feedback from student's course evaluation forms and face to face discussion was that the use of real technical documents from industry was very important in them realizing the importance infographics. They also commented on the value of having some simple formula they could use to evaluate an infographic and having a short list of best practices that they could follow.

In conclusion, the students realized that text, together with graphics, are much more than the sum of their parts. While the text provides context and explains how the diagram is constructed it is the graphics that present the information so we can detect patterns and trends, draw conclusions or make predictions.

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