

Raising Expectations for the Quality of Graphical Elements in Reports and Presentations

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Engineering professionals and students are often unaware of, and therefore neglect, principles of design, rhetoric, and data display in preparing the illustrations, graphs, tables, equations, and schematics they include in reports and presentations. We have developed two learning modules to address this issue in the junior year. The first module is a two-hour workshop given in a mechanical engineering measurement systems course and the second module is a component of a technical and professional communications course. We present an overview of these activities. The goal of the modules is to expand the skill set and critical-thinking ability of our undergraduates. The goal of this paper is to share our approach, prompt awareness and discussion, and encourage adaptation in other programs.

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Introduction

Any engineering faculty member teaching a design course could attest to the generally poor quality of graphical elements—illustrations, graphs, tables, equations, and schematic drawings—submitted by students in their reports and presentations. And small wonder! Our professional community does the same. Technical journals, manuals, books, and conference presentations are rife with poorly-designed visuals.

The importance of “finding, telling, and showing the truth” is poignantly made by Edward Tufte¹ in his analysis of the evidence used by the engineers attempting to abort the January 1986 Space Shuttle Challenger launch and again, later that year, to explain to the presidential commission the relationship between O-ring damage and temperature.² As Tufte says, the engineers “had the correct theory and they were thinking causally, but they were not displaying causally.” We concur with his summary that the “design logic of the display should reflect the intellectual logic of the analysis.”

We have developed learning activities to introduce our students to the practice of giving graphical elements as much consideration and critical thought as other elements of a report or presentation such as effective information-gathering techniques, responsible use of quotations, paraphrases, and statistics, technical credibility, and coherence of communication. The graphics-related activities range from simple dos-and-don'ts for graphs and tables to discussing secondary literature concerning data graphics to revising extant visuals to crafting visuals based on rhetorical and analytical principles. Our goals are to change students' perspectives on what constitutes effective graphical

elements, and to make them adept at incorporating high-quality visuals into their oral and written deliverables. In this paper we present the details of these activities.

Limitations

We have no student learning data to specifically support our assertion that our approaches have greater efficacy than any other. We offer anecdotal information based on feedback from individual students and colleagues, but no evidence at this point in our work. However, in recent years we have seen a steady increase in our accreditation program-outcome measures supported by this material. Our methods do seem to contribute to meeting our learning objectives.

Principles/Theory

The principles and theory on which we draw to support our approach are interdisciplinary, drawing on engineering design, rhetoric, and data graphics.

The design principles we use are those familiar to all teachers of capstone design: identifying a need, defining the problem, generating multiple solution concepts, establishing constraints, determining evaluation criteria, analyzing alternatives, making decisions, and iterating until a final “best” solution emerges.³ Design of graphic elements such as tables and figures entails the same steps, applied not to a design of an engineering product but to the design of an artifact for communication.

The rhetorical principles that we teach and from which we proceed will seem familiar to teachers of both design and communication courses. Rhetoric seeks, in part, to persuade readers to adopt the perspective of an author or speaker. We strive to combine design

strategies and rhetorical techniques in activities centering on data graphics. We teach students classical Aristotelian rhetorical appeals—*ethos* (reputation of author or speaker), *pathos* (emotional appeals to a community’s values or needs), and *logos* (reasoned, logical discussion of evidence)—as well as the concepts of *exigence* (demonstrating that a problem exists and needs solving) and discourse communities.⁴ In short, we teach students to argue in visual *and* in written form.

For a theory of data graphics, we draw on Tufte.⁵ Our basic admonitions are to maximize data ink, to erase as much as possible without losing coherence, to design displays to show comparisons, and to eliminate non-data decoration or “chart-junk”.

Our Approach

We introduce students to our expectations for the quality of graphical elements in two modules, one in a measurements course and the other in a technical and professional communications course. By placing this material in the junior year we hope to see the benefits in senior-level work, including capstone design.

The measurements course is ME321 Measurement Systems, an introduction to engineering experimentation taught by Mechanical Engineering (ME) faculty. The communications course is RH330 Technical and Professional Communications, taught by English faculty. Both courses are required prerequisites for the ME senior-level design-build-test lab course.

The Two-Hour Workshop

The 2-hour workshop taught in the measurements course includes four activities, the first three of which take up roughly half the allotted time. The workshop activities use graphical elements from published work.

For activities 1–3, we use bad examples of graphical elements from a lab manual, a design report, and a conference paper. In activity 4 we use real data and a real report excerpt, but the graph is not the final version. We use the first draft of a graph, before it is edited for publication, as the bad example.

We distribute the excerpts one at a time, asking students to answer a set of questions that one would expect a reader to be able to answer, but cannot because of deficiencies of the graphical elements. We ask for suggested improvements to the graphical elements that would permit the questions to be answered.

After a class discussion of an excerpt, we distribute an improved version in which the text, the graphic element, or both have been improved, and then ask the same questions. In the revised excerpts, students see many of their suggestions for improvement incorporated and they readily answer the questions.

Workshop activity 1—Excerpt from a lab manual

The first motivational activity is based on an excerpt from a lab manual from a micro-fabrication laboratory.⁶

Begin lab manual excerpt: The purpose of this prebake step (a drying process) is to remove excess solvent. This step stabilizes the resist film at room temperature. There are four major effects of removing solvent from a photoresist film: (1) the film thickness is reduced, (2) post-exposure bake and development properties are changed, (3) adhesion is improved, and (4) the film becomes less tacky, thus less susceptible to particulate contaminant. The bake is performed on a hot plate located under the hood. The bake temperature is about 100 degrees C for forty five seconds. See Fig. 1.



Figure 1: Hot plate for baking photoresist (the lab manual bad example.) *End of lab manual excerpt.*

For this lab-manual excerpt, we ask four questions:

1. How many knobs are there on the hotplate and what is the purpose of each?
2. How would you know if the hotplate were at a hot temperature?
3. What is the purpose of the Petri dish in this procedure?
4. Why did the author include the photo, what information is meant to be conveyed, and what information is actually conveyed?

Of course, students cannot answer the first three questions because the photo conveys none of this information. The fourth question helps students realize that the author is probably unaware that s/he has communicated poorly.

Next, we distribute a revised version of the excerpt with the photo replaced by the schematic shown in Figure 2, but with the narrative text unchanged. We ask the same set of questions, and students answer easily.

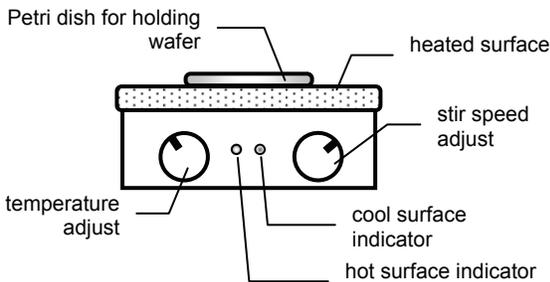


Figure 2: Hot plate for baking photoresist (the lab manual good example.)

Workshop activity 2—Excerpt from a design report

The second activity stresses the necessity of using equation editors and standard notation in creating equations for use with narratives, as well as the importance of appropriately incorporating equations with the flow of the narrative.

The design report excerpt briefly describes major and minor pressure losses in a heat exchanger, followed by about 12 lines of computer code *intended* to show the model relating pressure drop and friction factor.

For this excerpt, we ask four questions:

1. Doubling the velocity of the cold fluid has what effect on the pressure drop in the tube fluid?
2. What is the surface roughness of the tube material?
3. Does doubling the Reynolds number of the shell fluid increase or decrease its friction factor?
4. Do you think the author of the report would want you to be able to answer the preceding questions by reading his/her report? How well were you able to answer the questions from studying the excerpt?

With detailed study of the computer syntax and with some prior knowledge of the technical context, some students can begin to answer our questions. For most students, however, the “report” is incoherent.

Again we facilitate a class discussion eliciting their suggestions for improvement. We distribute a revised version, with the text rewritten and with equations correctly typeset and integrated thoroughly into the text, and students find the edited version superior to the original and answer the questions with increased ease.

Workshop activities 3 and 4

The third motivational activity is similar to the first two in structure, but focuses on elements of effective graphs of quantitative data. The “bad graph” example is taken from the proceedings of a technical conference.

The fourth activity is a practicum in applying our graphics standards. We give students a short report excerpted from conference proceedings, a spreadsheet with the original data, and a graph of the data made

using the default (and poor) settings in MSEXcel. We provide students our 2-page graphics guidelines and ask them to fix the graph, edit the report, and turn in their result. Once we have marked and returned this assignment, we hold students responsible for adhering to our standards in their subsequent work in the course.

Technical and Professional Comm. Module

Here we describe the ways in which RH330, Technical and Professional Communication (TPC), fuses rhetorical training and visual design principles. All engineering majors at Rose-Hulman must complete TPC, and its curriculum refines and expands upon skills students practice in ME321. Rhetoric suffuses the course, but rhetorical principles and graphical design principles coalesce in one particular assignment.

Eighty percent of RH330 consists of a Request for Proposals (RFP) project, a team-based, multi-deliverable, research- and writing-intensive undertaking modeled after engineering-based grant applications. Student teams (“companies”) are charged with choosing a localized environmental problem to rectify, researching relevant secondary sources, considering multiple solutions to the problem, arriving at a solution based on their research, and writing a two-part proposal arguing for their project.

One part of the RFP is the Project Rationale Presentation (PRP) assignment, whose main component is a PowerPoint slideshow that details the company’s decision-making process. We assign this deliverable after students have completed three writing assignments that employ appeals to emotion and reason, and that help establish their reputations as reliable communicators able to present an argument to specific audiences. Those skills are put to the test in new and different ways when we teach visual design.

To teach the PRP, we introduce two chapters from Tufte’s book *Beautiful Evidence*: “The Fundamental Principles of Analytical Design” and “The Cognitive Style of PowerPoint: Pitching Out Corrupts Within.”⁷ The two works challenge students’ preconceived notions about data graphics and electronic slide shows, and offer compelling—and perhaps controversial—new criteria for visually conveying information. After assigning the chapters as homework and discussing them in class, we ask groups to create a graphic for their presentations that exhibit several of Tufte’s six principles, summed up in “the Grand Principle of analytical design: *The principles of analytical design are derived from the principles of analytical thinking.*”⁸ We also require a written analysis of how the graphic functions, which reinforces the need for students to think critically about the representation of data.

Generally, students find Tufte’s principles of analytical design relevant and applicable; furthermore,

students often effectively incorporate his argument about PowerPoint, even though it evokes a more divisive response. While we lack the space here to discuss Tufte's argument and the breadth of students' reactions to it, the title of an editorial Tufte wrote for *Wired* magazine in September 2003 should sufficiently suggest the tone of both: "PowerPoint is Evil."⁹

We supplement these activities with the scholarship of Michael Alley, who posits an alternative model of slide design called Assertion-Evidence.¹⁰ Rather than use PowerPoint's default heading-subheading setting, Alley argues for using sentence headlines (assertions) followed by graphical evidence enhanced by statistics and brief annotations (support for assertions).¹¹ Both Tufte and Alley, therefore, instill in their design recommendations a strong *rhetorical* element.

No matter students' opinions of Tufte and Alley, the PRP requires a Tufte- and Alley-influenced slideshow. Students prepare for this by revising slides from a PowerPoint presentation completed in a previous class. They must save the old and new slides in the same file, and then we select students to give short, informal presentations on what they changed, why they changed certain features, and what the changes add. The changes are almost always for the better, and result in a complete visual and cognitive overhaul of the slide.

For the PRP slideshow, which as per Tufte's suggestion includes a paper handout with tables and other types of quantitative data, students must use Alley's Assertion-Evidence paradigm. The results are, in the main, positive, persuasive, and aesthetically appealing. Even if students never again use Tufte's and Alley's principles once they complete TPC, they learn techniques that have been shown to increase the quality of data graphics and presentations.

Informal Appraisal and Conclusion

In both courses, ME321 Measurement Systems and RH330 Technical and Professional Communications, instructors report a common range of student reactions to this material including vocal resistance (a minority), indifference, pragmatic acceptance (a majority), and even enthusiasm (another minority).

With no evidence (quantitative or qualitative) to offer at this point in our work, we offer anecdotal information based on feedback from students and colleagues:

- A colleague has noticed an improvement in the graphical content of senior capstone presentations and reports positive remarks from the industrial clients.
- A rising senior has a summer internship in which he applies our graphical precepts to graphs of product certification data, earning the accolades of his supervisor and the company head.

- A rising senior returns from a summer internship and compliments us on the graphical elements modules, admitting that at the time he thought it was a waste of time but his internship convinced him otherwise.

In our opinion, the graphical elements modules we describe are important additions to the engineering curriculum, help us meet our learning objectives, and add value to the student learning experience. We intend for students to begin to learn that purposeful thought regarding the graphical elements of their reports and presentations is an essential element of effective communications and not simply a cumbersome set of requirements from overly fastidious instructors.

References

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- ⁴ Several theorists examine discourse communities in different settings and how they relate to the production of texts. See Porter, J. (1992) *Audience and Rhetoric: An Archaeological Composition of the Discourse Community*, Englewood Cliffs, NJ: Prentice Hall.
- ⁵ Tufte, E. (2001) *The Visual Display of Quantitative Information 2/e*, Graphics Press.
- ⁶ Introduction to MEMS: Fabrication and Applications, Lab Manual, Rose-Hulman Institute of Technology, 2003.
- ⁷ Tufte, E. *Beautiful Evidence*. Cheshire, CT: Graphics Press, 2006, pp. 125-139 and 157-185.
- ⁸ Tufte, E. *Beautiful Evidence*, p. 137, italics in original. See pp. 127-128, 130-131, 133, and 136 for each of the six specific principles.
- ⁹ Tufte, E., "PowerPoint is Evil." *Wired* 11.9, Sept. 2003 [<http://www.wired.com/wired/archive/11.09/ppt2.html>]
- ¹⁰ An overview of Alley's stance on PowerPoint can be found at *Rethinking the Design of Presentation Slides: The Assertion-Evidence Structure*, available at <http://www.writing.engr.psu.edu/slides.html>
- ¹¹ Alley, M., and Neeley, K. A., "Rethinking the Design of Presentation Slides: A Case for Sentence Headlines and Visual Evidence," *Technical Communication* 52.4 (2005), 417-426.