Engineering Capstone Expectations Overview

- All engineering majors are required to participate in a 2-year capstone project. These projects are chosen based on the specialty of engineering they are interested in since JMU only offers a general engineering degree.
  - Ex: I (Ayana) am interested in environmental and civil engineering so I chose to work on a capstone project focused on stream restoration which involves replacing stream crossings.
- There are 13 capstone groups in the May 2023 class. The topics for these groups are as follows:
  - AISC Steel Bridge
  - Bio-inspired System
  - Biophysics Machines
  - Connected Relationships with IOT (Internet of Things)
  - Collegiate Wind Competition
  - Fire Protection System
  - Mobile STEM Educational Venue
  - NASA Student Launch Initiative
  - Principles of Earthships
  - Shell EcoMarathon
  - Stream Restoration
  - Wearables (Data recording technology) - GymSense
  - Wearables - HydroIntelligence
- **All of the information below is from the ENGR432 Class Canvas Page which is created and provided by Dr. Jacquelyn Nagel**

Final Paper Requirements

Submit a professional report that, **at minimum**, includes the following sections:

- Executive Summary - A one page synopsis of the project that includes highlights from all the sections in the report
- Introduction - Describe the project, succinctly state the problem/need, explain the motivation for it, state the impact of it (cultural, social, economic, environmental), and provide some background knowledge that is needed to understand the project (lit review)
- Discussion of Process - Describe the process the team used to arrive at the final outcome to address the problem/need, explain why this approach was used and justify it, include appropriate design process language
- Engineering Requirements - Provide and explain the requirements that guided the project work and how they were created
- Exploration of Alternatives - Provide and explain the range of alternatives considered in the project work and how they were evaluated
- Engineering Analysis - Provide and explain the analysis performed that guided the project work, this section should include calculations, simulations, modeling, trade-offs, experiments or testing, and data collection and comparison
- Project Outcome - Discuss the final outcome of the project and how the analysis resulted in the final outcome
- Conclusion - Synthesize the prior sections of process, requirements, alternatives, analysis, and final solution into a cohesive conclusion for the project
- Project Management - Provide and explain the project management approach that guided the project work
- Teaming - Provide and explain who worked on the project and roles of each member
- References - Choose IEEE, APA, Chicago, or some other format for references and be consistent. Number sequentially as they appear in the document, and use brackets for in text citations (i.e. [1] or [4-7]).
- Optional Appendix - A place for sharing raw data, drawings, full set of sketches from concept generation, code, and anything else that another engineer might need to replicate your project.

Your team will need to determine the formatting. I am expecting that the conventions learned about technical writing and visuals will be used when creating the reports. It is expected that visuals (diagrams, graphs, tables, photos, etc.) will be included in the Discussion of Process, Engineering Requirements, Exploration of Alternatives, Engineering Analysis, and Project Outcome sections.

Technical Communication Assignment

Last semester your team sought feedback on the technical aspects of your project through the design panel review. This semester your team needs to seek feedback on the technical communication of your project - specifically the technical writing and visuals. The JMU Writing Center is a great resource for this, but others sources can also be used.

https://www.jmu.edu/uwc/appointments.shtml

NOTE: It's really easy to ask a professor or expert for feedback, but it has to be about the *technical communication* of the content, not the content itself. This is a key distinction! Your team, however, may ask for feedback on the content in addition to the technical communication of it.

You choose who to ask and when to ask. Must be completed by April 28th so there is at least a week to incorporate changes.

Deliverables:

1. File shared for collecting feedback
2. Who the report was shared with
3. Documentation of the feedback on the technical communication aspects of the report
4. Action plan based on the feedback

How Have ENGR Majors Reviewed Tech Comms:

02 Engineering Communication

Source: Chapter 1 in Part 3 of Designing Engineers by McCahan, Anderson, Kortschot, Weiss, Woodhouse, 2015, Wiley.

Learning outcomes

By the end of this module, you should demonstrate the ability to:

- Use language and conventions appropriate to professional engineering
- Avoid figurative language and other everyday communication habits that are not appropriate in professional engineering situations

1. Introduction

Engineering communication, like any professional language, is a subset of communication in general (see Figure 1). It uses many, but not all, of the words in everyday language. It uses many, but not all, familiar document forms. It also uses words differently than they are used in everyday language and adds words that are specific to engineering.

Engineering communication is characterized by brevity, clarity, and the use of objective scientific and mathematical data to support claims. Engineering communication is as unambiguous as possible and does not attempt to persuade the reader or listener by appealing to the emotions through dramatic or figurative language, such as the language found in the metaphors and similes of poetry. Such "flowery language" is highly discouraged in engineering.

The emphasis on clarity and the attempt to eliminate ambiguity reflect the enormous responsibility that engineers have and the trust that people put in them. Engineers' communication will affect human lives, property, economics, and the environment. Misunderstandings can be costly and even tragic.

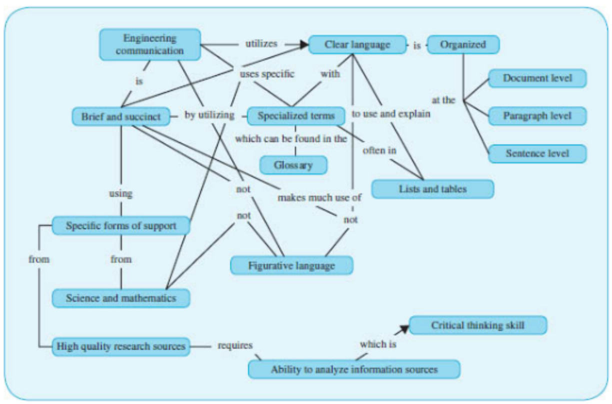


FIGURE 1 **Engineering communication is different than other forms of communication.** It draws on science and mathematics to support clear, concise, and objective expression of information.

2. Developing a Professional Voice and Creating Trust

Developing a ***professional voice*** means learning how to communicate appropriately in the working world—with business people, engineers, and other professionals. A "voice" is both the way you give presentations and also the tone and style of your writing. Taking part in a design project during your university education is a way of practicing this. It is a preparation, or a rehearsal, for your professional work as an engineer.

For engineering design projects, you will have to draw on your businesslike personas. You will have to dress and speak appropriately for different distinct situations: client interactions, supervisor or project manager meetings, instructional situations with instructors, and, finally, meetings with team members. In the future this will include people you manage. The number one rule in all these situations is respect. You show respect by consistently being polite, ensuring that your language and your tone are not insulting.

In order to develop your professional voice:

1. Make yourself aware of the principles and rules around each particular kind of communication task. Make sure you understand the rules and follow them. A business email, for example, is not the same as a personal email and if you do not appreciate the difference and you use language that is too informal, you may offend your client or the person you are writing to.

2. Use ***style guides***. A style guide is a set of specific instructions for the formatting and language appropriate to a certain situation, whether it is a university course, professional journal, or business. It is not about "right or wrong" or grammar rules; some of its instructions will not apply to other situations. They pertain to the way the particular organization wants to represent itself and if you want to be part of that organization, your communication must follow its principles. If your course does not provide you with a style guide, purchase a writer's handbook and refer to it frequently. There are appropriate ways of doing everything, from writing a business email to formatting a slide for a presentation. Your client, supervisor, and grader will expect these as the basis of your communication. Knowing and following the particular engineering and business communication practices, as well as the particular forms required by your course or company, are minimum requirements.
3. Use tools such as agendas, notes, minutes, and your engineering notebook in order to keep yourself on track. In professional situations, time is limited and you must accomplish what you need to do efficiently (#teamdocuments).
4. Use plain, formal, business-like language, whether writing or speaking. Avoid slang expressions that are ***value-laden*** and may reflect your own ***bias***, rather than an objective scientific perspective (#makingstatementseffectively).
5. Always ensure that your writing is grammatically correct, your sentences are logically structured, and your spelling is correct. These details are almost never taught but almost always expected. Poor grammar, sentence structure, and spelling have a surprisingly negative effect on your credibility. Errors in grammar and spelling undermine the trust of your audience. They give the reader the impression that you are careless, you do not feel that the task at hand was worth the time to do properly or that you are unintelligent because you do not know the basics of the language. Since none of these things are likely to be true, you do not want to give the reader this impression.

2.1. Appropriate Conventions

Comprehensive lists of appropriate conventions can be found in technical writing handbooks, but even the most comprehensive will still be subject to the requirements of a particular organization, laboratory, journal, or course. Some key conventions that are likely to turn up include:

- Engineering writing is formal. Use whole words only, no contractions. That is, always write out "it is" fully; never contract it as "it's." The same goes for "cannot" or "will not."
- Representing numbers verbally or numerically. Numbers are best expressed numerically (i.e., 132 rather than one hundred and thirty two). However, when there are two numbers in a row, one is usually numeric and one is written as words. Which is numeric is going to depend on the situation. Some examples include:
  - Two 5-gram containers
  - The shipment included 1,438 five-meter bars

  Exceptions to the rule occur when both numbers are large. For example, "We ordered 390 550 cm long pipe sections last month." To avoid confusion this might be rewritten as "We ordered 390 pipe sections (550 cm length) last month" [1].
- When a number starts a sentence, it is always written as a word, such as "Five grams were used."

2.2. Figurative or “Advertising Language” and How to Avoid It

If plain language is language in which the ***explicit meaning*** has far more effect than the ***implied meaning***, then ***figurative language*** is the opposite. What it is *implying* is more important than what it is saying directly. Poetry is a good example of figurative language. When the poet Robert Burns writes, “My love is like a red, red rose,” he does not mean that he is in love with a flower. He intends readers to summon up all of their personal, positive associations with roses—their beauty, fragrance, elegance, delicate textures—and imagine a person who embodies these characteristics. In this example, Burns is using a ***simile***. It is a figure of speech that compares one thing with another and signals the comparison with a word such as “like.” In many cases the two things are completely unalike—a human and a flower (#makingstatementseffectively).

Another figure of speech is a ***metaphor.*** This compares two things more directly, by describing one *as* the other. A common example of a metaphor is “user friendly” or “environmentally friendly” (see Figure 2). In fact, since friendliness is a quality only found in living creatures—a friendly person, a friendly dog, a friendly dolphin—this figure of speech cannot possibly be literally true. “User friendly” implies that something is easy to use, perhaps intuitive or familiar in some way. “Environmentally friendly” implies that something will not harm the environment or perhaps will help it. Because these terms are vague and imprecise, they are of no use to the design engineer. Thus similes and metaphors are discouraged in engineering writing.

What is more, the purpose of similes, metaphors, or other figures of speech is to create a feeling. “My love is like a red, red rose” or “environmentally friendly” are ideas that make the audience *feel* good. That is why figurative language is so useful in advertising. It appeals to the emotions and facilitates emotional decision making. Making decisions based on emotion, rather than intellect and reason, is the opposite of good critical thinking and sound practice in engineering. So language that appeals to the emotion is characterized as “advertising language” and, like figurative language, is emphatically discouraged. Instead, the engineer *defines* the characteristics other people use metaphors and similes to refer to; for example, instead of “user-friendly” interface, the engineer will define ergonomic characteristics that make the technology more accessible or flexible in measureable ways—font sizes and types that have been tested for clarity on different platforms, or navigation tools such as menus and sidebars.

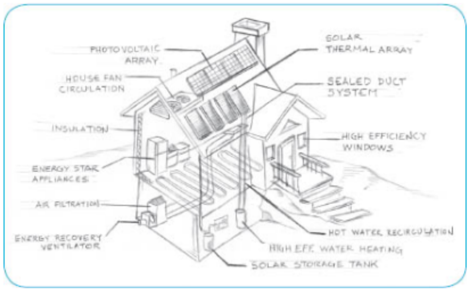


FIGURE 2 **“Green” or “environmentally friendly” are metaphors that imply specific specifications to an engineer.**

2.3. Bias-Free Language

Avoiding figurative language—metaphors and similes—and being aware of the implicit meanings of words will do a great deal toward making your language objective and bias free. You will also increase the acceptability of your language if you pay attention to, and use, the words that your client or supervisor uses in relation to social or political conditions with which you do not have a personal familiarity. Finally, become aware of your own values and how they affect the way you talk or write about topics such as religion, politics, and economic conditions. Ask yourself if the words you use are clear to others who have other beliefs or political positions or who do not agree with your beliefs.

3. Leaving This Skill Module

After working through this module you should be able to

- Write an brief engineering document using professionally appropriate language and appropriate conventions
- Identify and avoid figurative language and other everyday communication habits that are not appropriate in professional engineering situations

4. References

[1] Eisenberg, A. *A Beginner's Guide to Technical Communication*. Toronto: McGraw Hill, 1998.

[2] Howgego, J. (2013, July 15) Sound Waves Levitate and Move Objects. *Scientific American*. Retrieved from www.scientificamerican.com/article.cfm?id=sounds-waves-levitate-and-move-objects

02 Organizing Communication

Source: Chapter 2 in Part 3 of Designing Engineers by McCahan, Anderson, Kortschot, Weiss, Woodhouse, 2015, Wiley.

Learning outcomes

By the end of this module, you should demonstrate the ability to:

- Organize a document with numbered headings
- Organize a paragraph with a focused topic sentence that establishes relationships between the sentences in the paragraph
- Organize sentences so that ideas can easily be followed, even in longer more complex structures

1. Introduction

In addition to clear, objective language and well explained and supported statements, your writing has to be organized so that your readers can follow your ideas easily. Your documents must make sense as a whole; they must contain all the relevant and expected sections. Within the sections, the paragraphs must be written in a way that allows a reader to find information quickly and easily. Sentences must have a logical structure so that, no matter how long and complex, the reader is always clear on what is happening in the sentence and who, or what, is causing the action to occur.

2. Organizing a Document

In many situations you will be given a template, structure, form, or outline to organize your documents for you. However, there may be times when you have to work without a preset structure, the template provided may be partial or require modification or you may have to develop an outline yourself for your organization. Documents made up of several sections benefit from not only having clear, descriptive section ***headings***, but also having ***numbered headings***. Headings break up a document and signal readers about the kind of information they are about to read. This makes reading faster and information easier to understand. Numbering sections imposes a hierarchy on the information, identifying main ideas and the supporting ideas that belong to them (see Figure 1) (#writingreports).

Generally, no more than three levels of subsection are recommended. This avoids situations where you get subsections with little information and little connection to the other material. The relationships between paragraphs are the "thinking glue" that allows discreet pieces of data to come together to become coherent, effective ideas. Your ability to identify these relationships and show them clearly is an indication of another dimension of your intelligence, extending beyond your ability to solve a problem. They show that you are not only able to solve the problem, but that you have a good understanding of why the solution works and, by implication, how other, varied problems might be solved. They show that you can put together ideas in new and original ways.

To use numbered headings as an outline, begin by organizing the headings of your document. Make sure that the headings and subheadings contain full ideas so that your outline not only tells you what the sections of your document are, but also what the content of that section is going to be. So, do not simply write "1.0 Introduction." Write something that has real information in it, such as "1.0 Introduction: Increasing Security of Financial Data at Cyberbank Washington."

Many engineering students begin with an outline and find that it helps to keep them organized. Others prefer to start at the beginning and write to the end, in a more intuitive process. The problem with the second, intuitive process, especially in group work, is that it makes planning more difficult and if you do not build in significant amounts of time (and, at some point, an outline to organize what you have written) the coherence of your document and intelligibility of your ideas will be compromised.

1. Topic AA

1.1. AA – Support point 1

1.2. AA – Support point 2

1.2.1. AA – Support point 2-sub-point 1

1.2.2. AA – Support point 2-sub-point 2

FIGURE 1 **Example of *numbered headings***. Note that all ideas in section 1 must relate to topic AA. If there is a paragraph or sentence that deals with a different topic, it will belong in a different section.

3. Basics of Organized Paragraphs

Your goal, when writing, should be to produce documents that can be read once, quickly, and understood immediately. This means that, although the complex technical concepts may need some explanation, the paragraphs and sentences should be straightforward. When you are writing, imagine that your reader is in a hurry, is only looking for specific pieces of information and does not want to read the whole document from beginning to end.

Paragraph size and structure help. It is more difficult to find specific ideas in long paragraphs that have many ideas mixed up together. Shorter paragraphs that deal with one idea at a time and announce the idea at the start of the paragraph are much easier to search through for desired information.

You may have been taught two pieces of contradictory advice. One is that every paragraph must identify and explore a single idea and the other is that essays should have five paragraphs. The five paragraph essay is used to ensure that short high school essays have more than one idea—hopefully, three ideas: one per paragraph, plus an introduction and a conclusion. Applying the five-paragraph essay form to engineering report writing is like trying to pick up water with a fork. It is the wrong tool for the job. Writing a five-paragraph essay is a practice you should now abandon unless *specifically* instructed to use this form by your instructor.

An organized, logical paragraph for a reader in the 21st century should be short, have only one idea, and a full development of that single idea. An essay—or any other document—should not be limited by numbers of paragraphs. It should have as many paragraphs as are required to fully identify every claim that support your main ideas.

You probably know about ***topic sentences***, but here is another way of looking at this device (see Figure 2). If you adopt the three-step approach to writing (claim-explanation-evidence), you will always put your main statement in your first sentence. That will clearly identify to the reader what idea you are developing in the paragraph. The reader looking for that idea will be able to find it easily (#makingstatementseffectively).

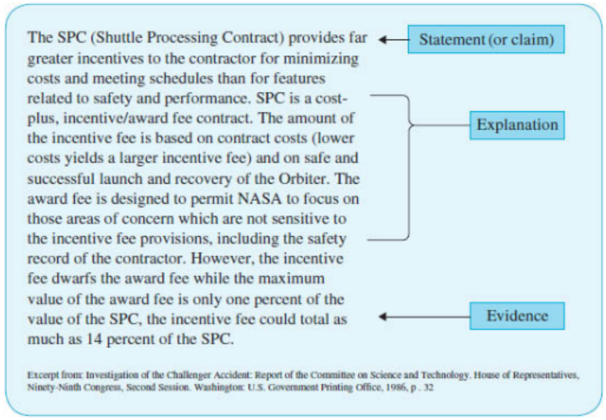


FIGURE 2 **A typical paragraph from an engineering report organized using the claim-explanation-evidence structure.**

After identifying your main idea, explain it. That will take at least a couple of sentences. Finally, include the support—the objective evidence that gives credibility to your idea and its explanation. That can take one or more sentences. This means that no paragraph can have only a single sentence because it will not have enough information in it to be complete. It also means that if you have a sentence that does not state the main idea, explain it, or support it, but instead talks about something else, then you will know that this sentence is not in the right paragraph. Remove it or move it elsewhere.

3.1. Using Lists

Some people may consider paragraphs to be "better writing" than lists, but in engineering writing, the goal is to provide information as concisely and clearly as possible. Sometimes lists are the best way to do this. The choice of whether to use paragraphs or lists will depend on the kind of information being given. If you are expressing an idea that requires explanation and support, then generally a paragraph is the best choice. The sentences, in that case, will build on one another to develop the particular topic identified in the first line of the paragraph.

But if you are giving a number of different, individual facts—functions, objectives, or constraints, for example—then a list is best. Again, always keep in mind the reader is looking for particular information and introduce your list with a clear sentence or two identifying what the list is about. Make the sentence as specific to the document as possible. "The design has the following functions" is only minimally informative and not at all unique, whereas "To enable users to drink or fill water bottles at the same fountains, the design must have the following three primary functions."

Lists should be revised. You may draft a list as items come to mind, but you should go back to it and give some thought to the best order for those items before you submit the document. Should they go from least to most important, or the reverse? Should they go from most to least expensive? It does not actually matter what kind of organizational idea you use; there is not one that is better than another, but making a decision creates better writing than not making a decision. Determine what would be best for your particular document and reader.

You might find that there is a sequence implied in the list, in which case you might use a numbered list. Numbered lists are familiar from instructions or lab reports. They are an efficient mode of organizing information. Even if the list is not numbered, however, you can indicate the number of items in it, as in the example given above, for the water fountain: "To enable users to drink or fill water bottles at the same fountains, the design must have the following three primary functions." Alerting your readers to what is coming up is a way of helping them to process information sooner, and to read faster.

4. Basics of Organized Sentences

An effective sentence has its own kind of logic. You must master that logic so that when you are expressing difficult concepts your sentence structure helps, rather than hinders, the reader's understanding. In addition, your sentences should be quick to read and unambiguous. So, beyond using plain value-free language, your sentences have to follow expected patterns of development specific to the language you are writing in. In English, the two key pieces of information the reader needs to have in order to understand a sentence are: 1) who or what is doing something and 2) the action that the person or system or entity is performing. The first is often called the "subject" and can be represented as a name, a noun, or a pronoun. The second is often called the "action" and is represented by a verb. Many sentences have a third component, an object or complement. This is the part of the sentence that receives or finishes the action.

In the English language, there are two basic sentence patterns: ***active*** and ***passive***. The ***active voice*** is the more logical and easy to follow; it puts the subject first and the action second. That is, it identifies who is doing the action and what the action is: this is the easiest order possible for a reader to take in meaning in the English language. A ***simple sentence*** is one that has only a single action or idea. The following sentence is a simple, active sentence: "A design project often starts with a statement from a client."

But not all sentences can be active and short. In scientific writing, in order to maintain the idea of objectivity, the subject of the action cannot always be easily identified. Consider the case of a lab report. In an experiment, it is the experimenter who is doing the action, but if you are the experimenter, you do not write up your experiment with a bunch of sentences starting with the word "I": "I put the liquid in the beaker," or "I mixed in some sodium chloride." So, you often end up using the passive voice: "The liquid was placed in the beaker," or "Sodium chloride was added to the beaker."

The passive voice creates writing challenges, especially when you are writing ***compound sentences*** or ***complex sentences***. Often the subject is hidden. In the sentence "The hypothesis was not verified by the results," the action is being performed by the researcher, but the researcher has no place in the idea. The idea should exist, according to scientific practice, separately from any individual involved. However, you can make objective active sentences if you work at it. For example, the sentence "The hypothesis was not verified by the results" can be rewritten as "The results did not verify the hypothesis" without losing any objectivity but gaining the value of an active sentence. That value becomes important when combining simple sentences to create compound or complex sentences.

So, the sentence "The results did not verify the hypothesis" is a simple, active sentence. It has one idea and has a subject, action and object in a conventional, easy to understand order. If you add another sentence to it—say the sentence "There was a high degree of error"—then you can have a ***compound sentence***: "There was a high degree of error and the results did not verify the hypothesis." A compound sentence is made up of two simple sentences joined with the word "and." It is perhaps the easiest long sentence form to use, but it has two conditions. The units joined with a simple conjunction such as "and" have to be of fairly equal importance and they have to no special relation to one another.

A special relationship between ideas creates dependencies in sentences. This kind of sentence is called a ***complex sentence***. One group of words, or clause, is "dependent" on another in order to be understood fully. You can turn the compound sentence above into a complex sentence by turning it around: "The results did not verify the hypothesis but there was a high degree of error." Now, the word that is combining the two ideas is "but," which indicates a contradiction or change in direction. The second way of writing the sentence brings out the idea that the error might have been the reason the results did not verify the hypothesis. This idea is implied in the compound sentence, but made more explicit in a complex sentence.

Because you will need to use compound, complex, and even compound/complex sentences, which combine the two forms, and these sentences can go on for quite a while, you have to have ways of ensuring that the reader does not get lost. The best way to ensure this is to consider the sentence like a road and identify signposts. Remember, the reader is looking for the subject and the action. So track those first. Let's take the compound/complex sentence that begins this paragraph. First we'll track it for the subject.

Because you will need to use compound, complex, and even compound/complex sentences, which combine the two forms, and these sentences can go on for quite a while, you haveto have ways of ensuring that the reader does not get lost.

Now, we will italicize the *actions*.

Because you *will need to use* compound, complex, and even compound/complex sentences, which combine the two forms, and these sentences *can go on* for quite a while, you *have to have ways of ensuring* that the reader does not get lost.

Notice you can break this long sentence into four short sentences:

- You *will need to use* compound, complex, and even compound/complex sentences.
- Compound/complex sentences *combine* the two forms.
- These sentences *can go on* for quite a while.
- You *have to have ways of ensuring* that the reader does not get lost.

These are simple sentences on their own and, if we have to, we can locate their subjects and actions. The phrase "compound, complex, and even compound/complex sentences" is the ***object*** of the first clause and "compound/complex sentences" the subject of the second, but the word "which" allows the writer to combine these two ideas and eliminate the repetition of the words "compound/complex sentences". After the words "two forms," the word "and" allows the writer to include another simple sentence: "These sentences can go on for a while."

However, the word "because" begins the long sentence. "Because" turns any clause that follows it into what is known as a ***dependent clause***. That is a clause that cannot be understood on its own, but requires another clause to complete the idea. The reason for this is that "because" means that there is a cause and effect. Strangely, people usually put the effect first and the cause second, but in this case, the writer didn't. She or he put the effect clause at the end of the sentence: "you have to have ways of ensuring that the reader does not get lost." Once again, this is basically a simple sentence and it could stand on its own. Moreover, you usually see the clause beginning with "because" after the one on which it depends, mostly because we are told in grade school "never begin a sentence with 'because'!" This is not a grammatical rule, but it is easier than trying to teach children the difference between a dependent and an ***independent clause***. The real rule is "Any sentence with 'because' in it must have two clauses, one that sets up the effect and the other that sets up the cause."

The central complex sentence here is: "Because you can have compound, complex, and even compound/complex sentences, you have to have ways of ensuring that the reader does not get lost." The matter in the middle is all just further explanation. But the writer ensures that the reader does not get lost by making the signposts of the sentence, the subject and action, clear and easy to find. Also, the action is right next to the subject, making it easier for the reader to connect them. When you are writing long, complex sentences, the way to ensure that they are clear is to locate their subjects and actions. See if you can get the actions as close to the subjects as possible. This will help ensure the logic of your sentences and really help your reader.

5. Leaving This Skill Module

After working through this module you should be able to

- Create a document with numbered headings that enable a coherent outline of information
- Write unified paragraphs with focused topic sentences and relationships between the sentences
- Write a variety of sentences in which ideas can easily be followed

02 Cutting the Fluff

Source: IEEE Professional Communications Society Article "Cutting the Fluff from your Writing" by Celia Mathews Elliott - https://procomm.ieee.org/cutting-the-fluff-from-your-writing/

Good professional technical writing involves a struggle between conciseness and completeness. Writers need to provide the evidence and reasoning to justify their claims in the shortest space possible. Cutting too much or the wrong things, however, can damage your ability to support your decisions. It's important, then, to be able to differentiate between "fluff," unnecessary language adding little to nothing of value to the document, and the essence of the document. Celia Elliott's lecture on "fluff" helps do that by classifying "fluff" into four distinct categories, which we can vigorously seek out and eliminate:

1. Unnecessary words, redundancies, and wordy expressions
2. Pointless modifiers
3. Tautologies
4. Meaningless generalities

In this short article, we'll look at the first category. Unnecessary words, redundancies, and wordy expressions can slip in very easily, but they're also easy to identify. Consider the following simple sentence:

Some fluorophores appear green in colour, while others appear red in colour.

If we ask what information is redundant, we should see that "in colour" is unnecessary: green and red already imply colour. Eliminating four words might not seem like much, but they constitute 30% of the above sentence. Imagine cutting 30% from your entire document!

Wordy expressions are another blight on concise writing. Consider the following phrases: what single word might they be replaced with? * *Answers at the bottom of this page*

1. **Due to the fact that ...**
2. **In the very near future ...**
3. **On the order of ...**
4. **At the present time ...**
5. **A very limited number of cases that ...**

Importantly, fluff doesn't just get in the way of conciseness; it can get in the way of meaning. Take for example the following phrase:

...an electron whose spin is aligned with the two other electrons on either side of it...

Are we talking three electrons here, or five? Here, the suggested revision – "an electron whose spin is aligned with the electron on either side of it" – doesn't save as much space, but eliminates an ambiguity in the sentence itself.

Celia Elliott's lecture provides further examples of how to cut general wordiness, as well as the three other categories: pointless modifiers *(eg. essentially, basically)*, tautologies *(using different words to say the same thing without adding meaning)*, and meaningless generalities *(phrases so broad that they have been made contentless)*. Follow her advice to save much needed space in your writing.

**Answer key: because, soon, about, now, seldom*

04 Diagrammatic Elements

Source: Chapter 4 in Part 3 of Designing Engineers by McCahan, Anderson, Kortschot, Weiss, Woodhouse, 2015, Wiley.

Learning outcomes

By the end of this module, you should demonstrate the ability to:

- Explain the types of diagrams typically used in engineering communication and their purpose
- Explain the essential characteristics of a diagram, table, or graph
- Use basic diagrams, tables, and graphs to enhance understanding in documents and presentations
- Use diagrams to enhance your own problem solving processes

1. Introduction

Thinking like an engineer means thinking verbally, visually, and mathematically. Engineers take a problem from the real world or text form, such as a client statement, and transform it so that they can solve the problem with science and mathematics. To achieve that transformation, they use models whether it is simply to show inputs and outputs or more complicated phenomena. Models are often represented in ***diagrams***, which are essential to engineering thinking and communicating. They are used in design and problem solving and they are used in documenting the design or recommendation that is being made to a client. The results from problem solving are often depicted visually as graphs or charts before the solution is implemented back into the real world.

For many engineers, using diagrams is natural and intuitive. They draw quick, sometimes messy sketches, put boxes around important ideas, and draw arrows to show connections. Such sketches may seem ordinary, but they are essential to thinking, communicating, and documenting the problem solving process. Engineering reports may include both formal polished drawings and also sketches. Ultimately, engineering drawings are used to help others execute (i.e., make or build) the technology you have designed. Creating diagrams and sketching out problems may not be a natural habit for you now, but it is an important skill. Diagramming a problem may show you the way to transform your perception of the problem leading to an ingenious engineering solution.

Client statement (words) or problem
↓
scientific/mathematical construct (model) and diagram
↓
solution
↓
design or solution interpretation (charts and graphs)
↓
implementation back into the real world

Courtesy of the Authors

FIGURE 1 **Photograph of the existing streetlight that a client wants to change.**

For example, you are a part of a team that has been asked to design a new street light (see Figure 1). New light fixtures are more energy efficient and so the client wants to replace the old version. However, the old versions are mounted on concrete poles that still have a good usable life. You have to figure out the maximum weight of the new fixture so it can be safely installed on the existing poles. You might start by sketching a free-body diagram (see Figure 2) to help you clarify your understanding of the physical system.

2. Five Functions of Visual Forms

Using graphics to explain concepts in an engineering fashion expands on the familiar use of illustrations in documents. To do this effectively, it helps to understand the categories of visual expression. Visual forms fulfill five basic functions:

1. To execute
2. To identify
3. To enhance understanding
4. To instruct
5. To enhance visual appeal

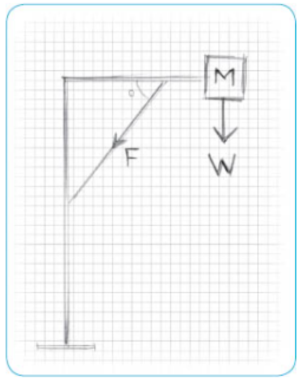


FIGURE 2 **A basic free-body diagram sketch used to solve the problem of estimating the safe maximum weight for the new light fixture.**

The first purpose, to execute, refers to formal engineering drawings that are used to execute a project. Formal engineering drawings will often start with a sketch of a part or system that is handed off to a technician or draftsman to render. Or you may learn in your upper year courses how to use ***computer-aided design (CAD)*** packages to create formal engineering drawings. How different types of systems are visualized in these drawings will depend on the discipline. Civil engineering drawings for a structure will use different diagrammatic standards to indicate types of walls and beams than electrical engineering drawings for printed circuit boards showing connections and components. The detailed standards for formal engineering drawings are beyond the scope of this text, but as you progress through your discipline your will learn to create and read formal engineering drawings in your field. Here we will discuss visual diagrams of the type that appear in reports, presentations, and in general instructions. These are also very necessary drawings in engineering communication and share common characteristics across disciplinary fields.

Diagrammatic communication refers to any kind of graphic representation of information: ***charts***, ***graphs***, ***diagrams***, ***flowcharts***, ***schematics***, ***tables***, ***pictures***, or ***photographs***. You are probably familiar with using these to illustrate your documents, but the ways that engineers use visual documentation to understand a problem is a skill you are currently developing. Graphics form a bridge between the problem in words, as it is presented to you by your client and discussed in your team, and the scientific and mathematical formulas and models that you, as an engineer, are going to use to solve the problem.

Information graphics, such as tables, diagrams, and graphs, are communication tools, but they are incomplete without text. The meaning of an information graphic is never self-evident. It is always necessary to explain to the reader what they should be seeing when they look at the graphic. The graphic should also serve a clear purpose within the text, not simply be there for show.

Every graphic you include should have

- A clear ***caption*** or ***title***
- A description in the text of the report or document in which they are imbedded
- A purpose in the context of the document

3. Diagrams and Schematics

The visualization of models and ideas in engineering go by many names: ***diagrams***, ***schematics***, ***flowcharts***, and many others. These drawings are typically a combination of visual elements (shapes and arrows) and textual elements (letters, numbers, symbols, and words) that are meant to assist both the reader and the writer (see example in Figure 3). Diagrams are used by engineers to help them solve a problem and help them communicate their solution to others. Diagrams are used to describe problems or systems.

Communicate a model. Diagrams communicate a model of the system. Diagrams typically only include elements essential for analyzing the system and leave out other aspects of the real system. For example, a cat sitting on a wall is modeled as a mass being operated on by the force of gravity. No information about the color of the cat would be included in the diagram.

Communicate characteristics. Diagrams communicate the characteristics of the system. To do this diagrams often use a set of standard ***visual vocabulary*** to convey ideas. For example, in mechanical engineering a zigzag line is a spring, in electrical engineering a zigzag line is a resistor. The type of diagram and shape indicate the properties or characteristics of the component.

Communicate states. Diagrams communicate the ***state*** of mass, energy and information at particular points in time or space. For example, a flowchart will indicate points when decisions are made, or a phase diagram will indicate the state of matter (liquid, solid, gas).

Communicate relationships. Diagrams communicate the relationship between parts of a system. This may be a physical relationship between parts, or a conceptual relationship. For example, a diagram of a jet engine will show that the compressor stage comes before the combustor, a molecular diagram shows the arrangement of atoms in a compound, or a Venn diagram will show the conceptual relationship between sets.

Labeled to enhance understanding. Good diagrams are clearly labeled. ***Labels*** allow the writer to easily draw the reader's attention to a particular point in the diagram. Labeling components, states, steps, and other key points in the diagram also makes it easier to connect the diagram to both the text and equations. So the initial position of a mass can be labeled "1" in the diagram, and called x_1 in the related equation. This helps you track key aspects of the problem you are solving from reality, to the diagram, to the equation, and finally back to reality when you have solved the problem.

Communicate direction and motion. Diagrams often communicate the direction mass, energy, or information are moving in time, or space, or conceptually. Vectors and arrows are common elements in diagrams and are used to indicate direction and motion (see example in Figure 4).

Used in problem solving. Diagrams help you debug your work. If you are checking a solution, trying to debug a program, or figuring out an error in a process, then you can use the diagram to visualize and track the key quantities in the system, helping you to find errors or inconsistencies.

In a written report diagrams and schematics are treated as ***figures***. This means that the ***caption*** for the diagram goes below the diagram.

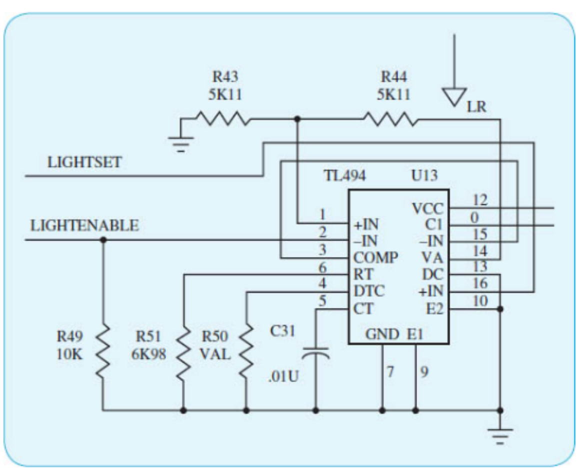


FIGURE 3 **An electrical schematic showing part of a circuit. The components labeled "R" are resistors, C31 is a capacitor, and U13 is a chip. This illustrates the use of standardized visual vocabulary (shapes) and labels to communicate the characteristics of the components.**

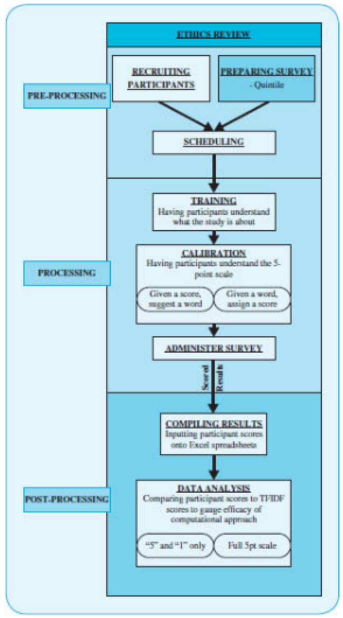


FIGURE 4 **Diagram of the methodology for a research study.** This figure illustrates the use of a diagram to show a process much like a flowchart. Arrows are used to indicate the order of processes in the plan.

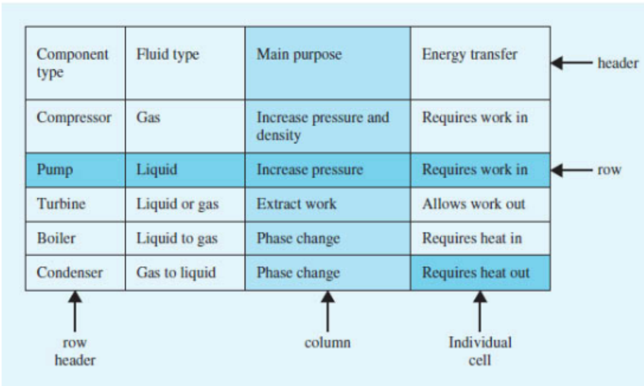
4. Tables and Matrices

Tables are typically used in engineering communication to organize information. They serve the purpose of allowing concepts to be compared and contrasted. The term table and the term ***matrix*** are often used interchangeably, and there is no formal distinction between them. Matrix, of course, is also a term used in mathematics, but in engineering design is used often when there are numbers as well as words in the cells. Examples include pairwise comparison method, and weighted decision matrix method.

Parts of a table (see Table 1):

- **Cell**: A ***cell*** is an individual box in the table. It typically contains a piece of information relating the header to the row header information.
- **Header**: The ***header*** (or column header) is the first row in the table. The cells in this row announce the title for each column.
- **Row header**: The ***row header*** is the first column in the table. The cells in this column announce the title for each row or give an essential piece of information that connects all of the information in the row.
- **Row**: A ***row*** is a set of cells along a horizontal path in the table.
- **Columns**: A ***column*** is a set of cells along a vertical path in the table.

TABLE 1: Comparison of components found in heat engine systems. This table illustrates the parts of a table. The table title goes here, at the top of the table, and can be more than one sentence.



Component type	Fluid type	Main purpose	Energy transfer
Compressor	Gas	Increase pressure and density	Requires work in
Pump	Liquid	Increase pressure	Requires work in
Turbine	Liquid or gas	Extract work	Allows work out
Boiler	Liquid to gas	Phase change	Requires heat in
Condenser	Gas to liquid	Phase change	Requires heat out

Very often tables are used to characterize items such as components of a system, solution approaches to a problem, stakeholders, or other sets of key considerations. The items are identified in the first column, and their characteristics are described across a row. The header is used to identify the categories of characteristics that are being examined. This gives you and the reader an easy way to visually take in a large amount of information and see how the information is connected and related (see example in Table 2).

TABLE 2: Temperature, pressure, and specific volume at points along the liquid and vapor saturation boundaries for water. This example illustrates a table used to communicate numerical data. Each row gives the data for a point on the saturation line.

T (C)	P (KPA)	V_F (M^3/KG)	V_G (M^3/KG)
0.01	0.61	1.000E-03	2.060E+02
10	1.23	1.000E-03	1.064E+02
20	2.34	1.002E-03	5.779E+01
30	4.25	1.004E-03	3.289E+01
40	7.38	1.008E-03	1.952E+01
50	12.35	1.012E-03	1.203E+01
60	19.94	1.017E-03	7.671E+00
70	31.19	1.023E-03	5.042E+00
80	47.39	1.029E-03	3.407E+00
90	70.14	1.036E-03	2.361E+00
100	101.35	1.044E-03	1.673E+00

5. Charts and Graphs

Charts and graphs are visual representations of data (see Figures 5 and 6). Charts and graphs usually represent quantitative (numerical) data, but can also sometimes be used to represent qualitative information. You are probably already familiar with bar charts, scatter plots, pie charts, and other examples of these types of figures as they are used in science laboratory reports. In engineering these types of visual graphics are used extensively to give the reader a visual understanding of data. They help the reader see trends in the data and they often are used to relate data to a model.

Charts and graphs:

- Are treated as figures in engineering reports; that is the caption for a graph goes below the figure.
- Should fairly represent the data, and not be used to warp the information to fit a predetermined conclusion. Related to this, the type of representation should fit the data. For example, a *histogram* is used to represent a distribution, a pie chart to represent percentage data.
- Should be clearly labeled. In particular the ***axes*** (if there are axes) must be labeled. For example, it is standard in a pie chart to include both a label for each slice and the numerical data associated with the slice.
- Are often used to relate observed behavior to a model. When using a graph or chart this way it is typical to plot the results predicted by the model on the same graph or chart with the experimental or observed data. This allows the reader to visually compare the observations and the results predicted by the model.
- Are always accompanied by a reference to the figure in the body text of the report. The text in the report must reference the figure (e.g., see Figure 5) and must explain to the reader what can be observed in the figure: "Figure 5 shows a plot of the liquid saturation boundary for water on the temperature-entropy plane." Note that the information in the text may repeat some information from the figure caption, but this is not considered redundant.

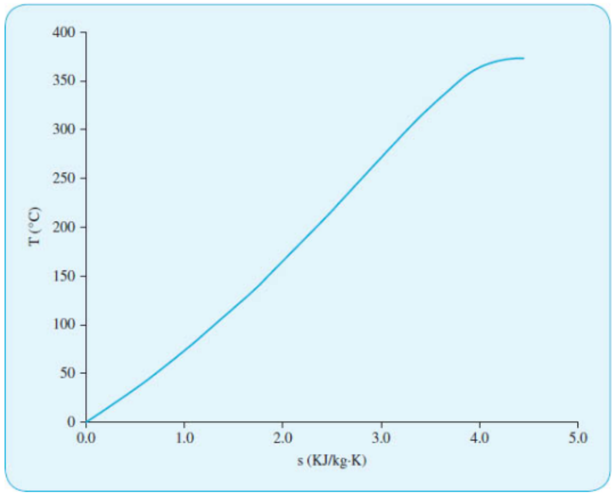


FIGURE 5 **Shows temperature versus entropy along the liquid saturation line for water.** This is an example of a graph demonstrating the use of labels and a descriptive caption.

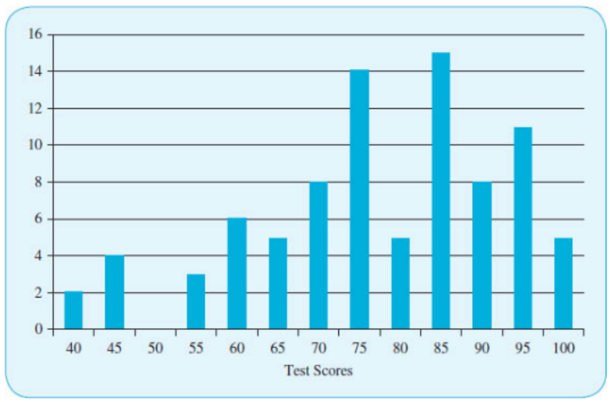


FIGURE 6 **Histogram showing test score distribution.** This is an example of a chart that allows the reader to visualize numeric data.

6. Conclusion

Concepts in engineering are often best communicated using a combination of text (verbal representation) and diagrammatic elements (visual representation). Diagrams, tables, graphs, and other visual elements give the reader another route to understanding data and verbal descriptions. To make diagrams effective they need to be clear, well labeled, and connected to the body text. While diagrams allow the reader to follow your writing more effectively; equally as important, developing diagrams and other visual representations allows you, as a problem solver, to clarify your understanding of a problem and work through problems more effectively.

04 Using Pictures and Photographs

Source: Chapter 5 in Part 3 of Designing Engineers by McCahan, Anderson, Kortschot, Weiss, Woodhouse, 2015, Wiley.

Learning outcomes

By the end of this module, you should demonstrate the ability to:

- Utilize graphics in both the process and documentation of design

1. Introduction

Diagrams such as flowcharts and graphs are used to transmit information and formal engineering drawings are used to execute a project. However, there are instances when a ***photograph*** or ***drawing*** (picture) best serves the purpose of communicating an idea. In engineering reports and presentations photographs and drawings can serve the purpose of enhancing the visual appeal of a document, but they are also used to identify phenomena. Photographs can present information to a reader (or audience) that a simple diagram or graph does not capture, and pictures are often used to instruct people on proper usage of technology.

2. Enhancing Visual Appeal

While formal engineering drawings are meant to be purely informational, there are times in reports and presentations when it is appropriate to use a visual to enhance the aesthetics of the communication. Photographs and drawings are visually interesting and can add to the appeal of a document, presentation, or poster. They tend to contain a lot of information—that is, many shapes, colors, objects, and activities can be included and these have different meanings for different people. The photographs also cause viewers to have feelings and associations and these too are different from one person to the next. This can be a strength or a weakness.

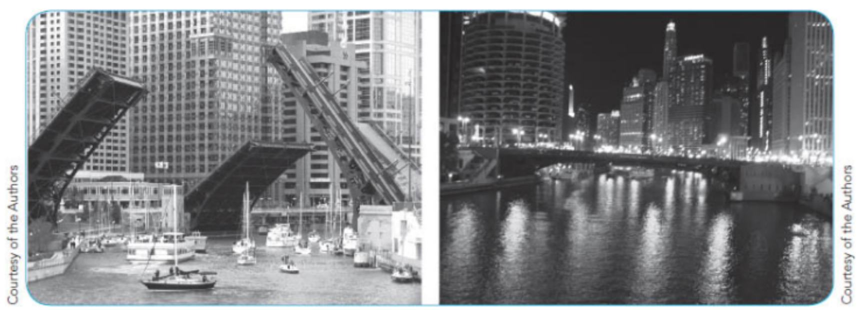


FIGURE 1 **Bascule bridges in raised position, Chicago 2009.** Photographs are packed with information, but it is all subject to the interpretation of the viewer, unlike diagrams, which often contain only essential information.

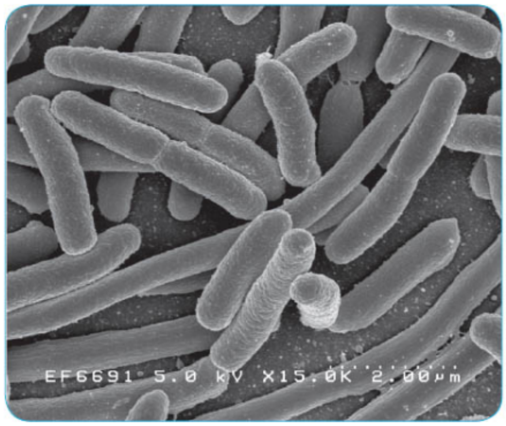
(Photos courtesy of P.E. Weiss.)

Take the two views of the Chicago River (Figure 1). They each give a very different sense of the same body of water. The daytime photograph on the left might be useful to show how a bascule bridge operates. But look at all the other activity in the scene: sailboats, tour-boats, pedestrians, not to mention the architecture all around, with unique architectural elements that catch the viewer's attention. There is a lot happening. One hardly knows where to look or what to focus on.

The nighttime photograph, on the right, has a completely different feeling. Looking at it, one gets a different sense of the location. Unless you know otherwise, you would likely not recognize the bascule bridge in the night photograph.

These photographs also have emotional information—the amount of activity, the kinds of objects, the colors and shapes may create all sorts of different feelings in the viewer. In fact, one of the values of photographs is their ability to evoke feelings. When used appropriately, photographs and pictures can make a reader or audience member respond more positively to your ideas. When used inappropriately, they distract the reader and might make your document or presentation seem less valuable, perhaps even silly.

Drawings or paintings have similar issues to photographs. They contain a lot of information and give the viewer feelings, but it is difficult to define and/or control exactly what the viewer is supposed to get from the image. Symmetry, shapes, colors, content and detail all contribute to the feelings that a photograph or drawing can result in. Further, these feelings change from person to person. Drawings, paintings, and photographs are effective ways to create emotional response but must be used thoughtfully. You must consider the emotion you are trying to create and choose a photograph or drawing carefully. In engineering reports pictures are infrequently used for visual appeal only, except perhaps on a report cover. They are more frequently used in presentations, specifically to illustrate the message of the slide or text.



National Institute of Allergy and Infectious Diseases

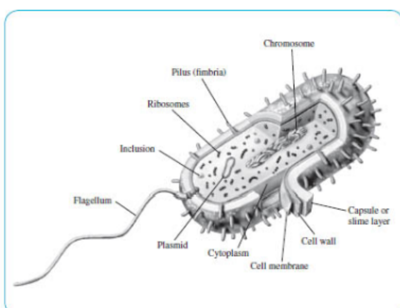
FIGURE 2 **Micrograph of Escherichia Coli.** Credit: Rocky Mountain Laboratories, NIAID, NIH. Public domain. www.niaid.nih.gov/SiteCollectionImages/topics/biodefenserelated/e_coli.jpg

3. Identifying Phenomena

In terms of identification, a photograph or picture can show only what something looks like because it only identifies something in a general sense; it is not very precise. Take, for example, a photograph of a hotel in a place you have never been to before. While it will help you recognize the hotel when you are finally right in front of it, it will be no good at helping you get to the hotel from the airport or train station. For that, you need a map, preferably one with the route highlighted.

So, if you wanted to answer the question, "What does E. Coli look like?" you might use a scanning electron micrograph. It gives a very good impression of the tubular shape of the bacteria (see Figure 2).

Photographs and drawings are useful in identifying the way something looks in a general sense, but to enhance understanding diagrams must be used. A diagram is a depiction of an object or process and it includes the most important details in a way that makes them stand out. It should also be well labeled so that all of its important components are brought to the attention of the viewer. In addition, dimensions must be shown when appropriate. These enable the viewer to appreciate the scale of the diagram (see Figure 3).



Jacquelyn and Laura Black, *Microbiology: Principles and Explorations*, 9th edition, John Wiley and Sons, Inc.

FIGURE 3 **A diagram of E.** Coli. Labels draw attention to details that are clarified in the diagram, versus the micrograph.

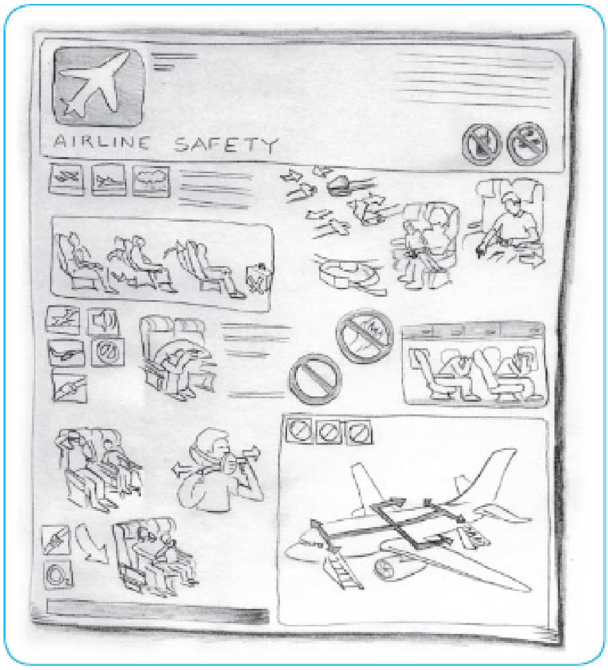


FIGURE 4 **An airplane safety card illustrates the use of pictorial instructions.** This card reduces details and provides step by step instructions in pictures only.

4. Instruction

Pictures (drawings) can be used to instruct; one situation that might be familiar is the instruction card you are asked to read on an airplane (see Figure 4). These instruction cards are intended to be understood by people no matter their language or education level. Therefore, the pictures are cartoonlike and simplified. Certain conventions, such as a diagonal red line through a picture, may be used to express abstract ideas. For these to be effective, people have to know what they mean, but many of these, such as the red circle with a diagonal line, meaning "No" as in "No smoking," are commonly seen all over the world.

5. Conclusion

Pictures and photographs are used to illustrate ideas in engineering reports and other documents. They complement the diagrams, graphs, and drawings that are used to convey ideas. Together with text, visual elements such as these help the reader get a more complete and multi-faceted understanding of concepts. Visuals, such as pictures, can also cut across language barriers. This can be advantageous when developing instructions, interfaces, and signage.

6. References

Irish, R., and Weiss, P.E. *Engineering Communication: From Principles to Practice*. 2nd ed. Toronto: Oxford University Press, 2013.

Manning, A., and Amare, N. "Using Visual Rhetoric to Avoid *PowerPoint* Pitfalls." *2005 IEEE International Professional Communication Conference Proceedings*.

04 Visual Rhetoric

Source: IEEE Professional Communications Society Article "Visual Rhetoric: Making Arguments Visually Using Elements of Visual Grammar." LINK: https://procomm.ieee.org/visual-rhetoric-making-arguments-visually-using-elements-of-visual-grammar/

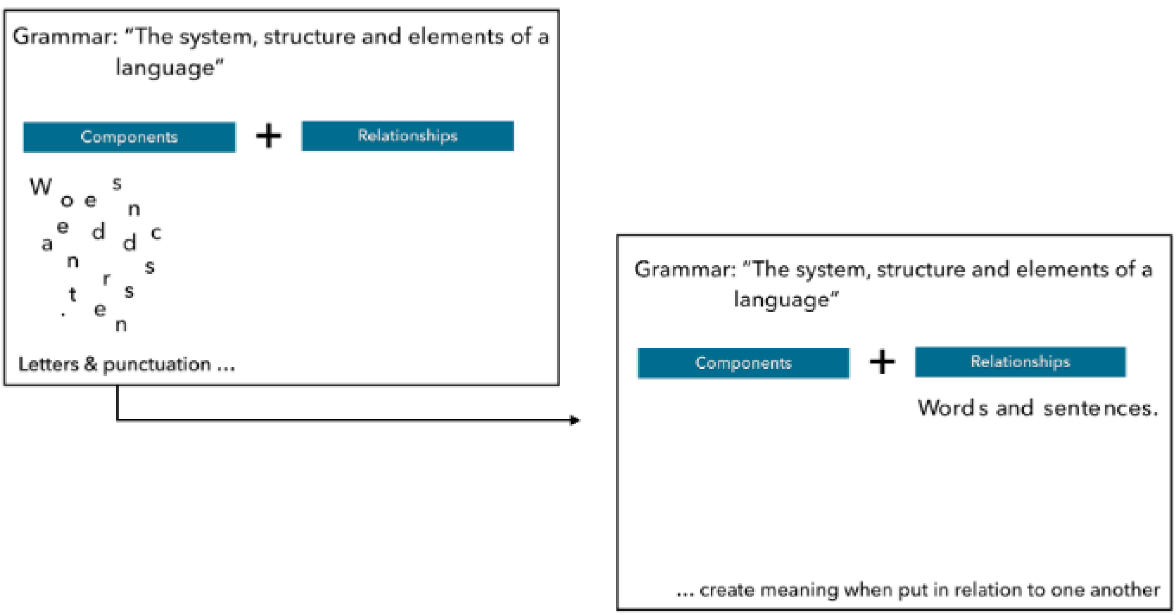
Visual Rhetoric: Making Arguments Visually Using Elements of Visual Grammar

Published on September 7, 2017

When designing visuals, we often neglect to identify a purpose beyond simply representing data. But visuals – particularly data visuals and infographics – are most effective when they are designed with a clear purpose in mind, particularly if they contribute to an argument. Melissa Clarkson's earlier post on The Elements of Visual Communication provided a good starting point for a discussion of how to use visual elements to communicate types of relationships: this post expands on those concepts in explaining how visual grammar can contribute to making an argument.

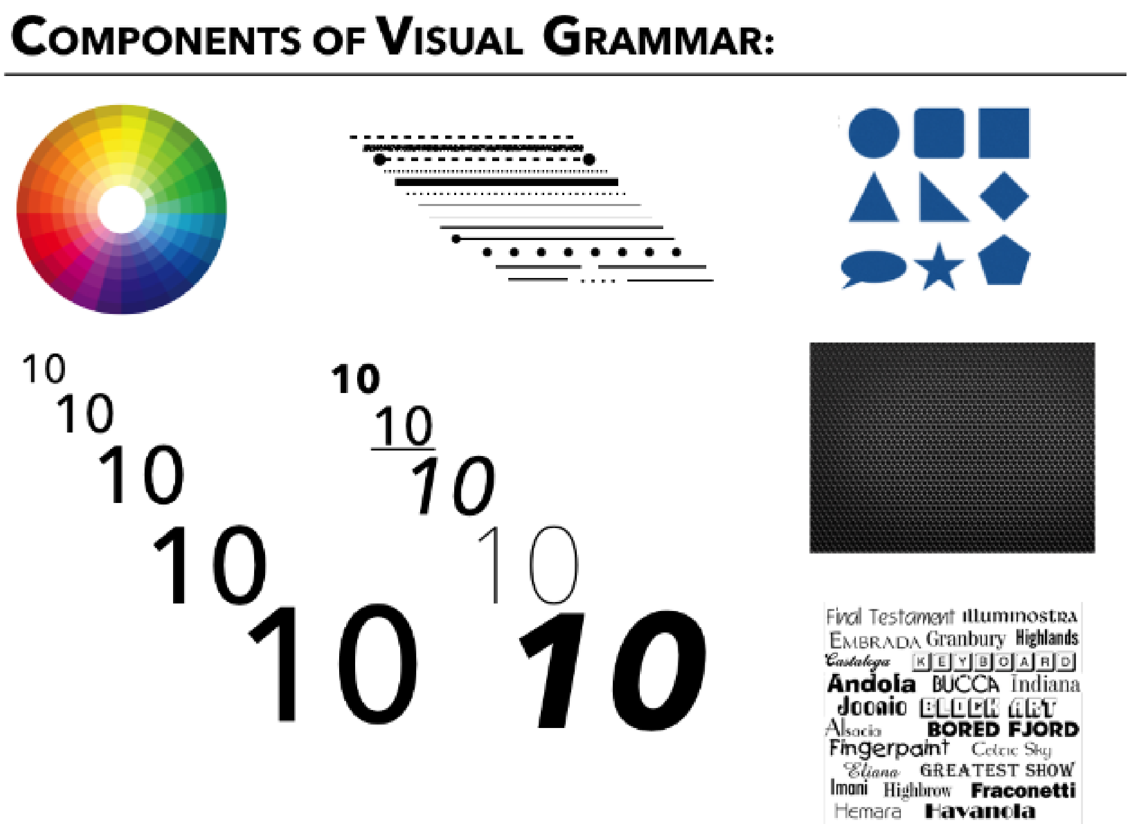
What is Visual Grammar?

Understanding visual grammar – the components and relationships that contribute to meaning – in visual language – is key to developing effective visuals. As in linguistic grammar, we rely on a shared, often culturally specific, set of patterns and expectations in building and interpreting visual texts. We can start to understand this term by examining something we are already familiar with: linguistic grammar. This is the set of rules or principles that govern the composition of language in order to make shared meaning. In other words, grammar involves: (1) the components of language (letters, words, clauses, phrases) and (2) their relationships that contribute to meaning.



Visual grammar is the same, except that we are working with different components and relationships, alongside less well defined rules about how they go together. [Clarkson's post](#) has already identified some of these components, but this is a more expansive list:

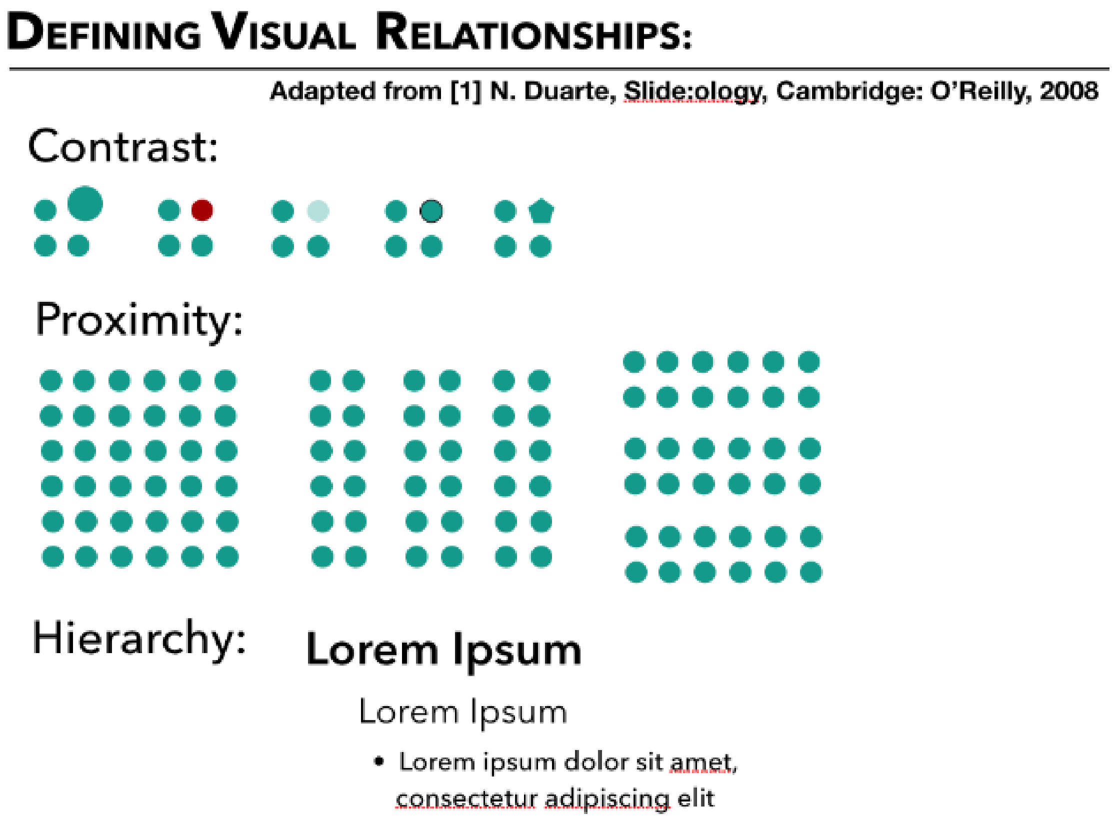
- Size
- Shape
- Line
- Color
- Tone
- Position
- Orientation
- Texture
- Background
- Type
- Style
- Point
- And others ...



And the relationships we work with in the visual domain are also different:

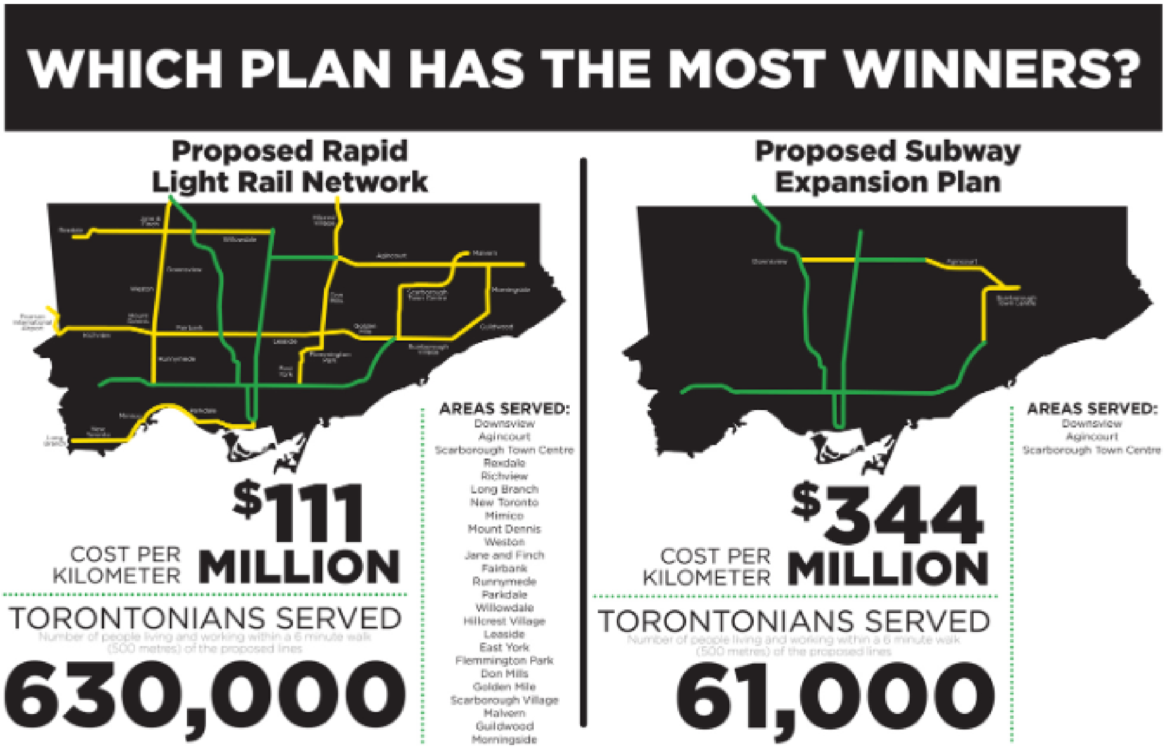
- Contrast
- Proximity
- Hierarchy
- Balance
- Flow
- Similarity
- Closure
- Symmetry
- Unity
- And others...

Below, see how we can use these relationships in designing visuals using different components, such as color, line, size, position, and shape.



Visual Rhetoric:

Understanding those components can also help us to understand how to form effective visual arguments, as in the poster below, which uses components such as line shape, colour, size, typeface, style, and even whitespace. But it relies primarily on relationships between elements to create a clear and effective answer to the question it poses, even without stating it directly. This case study in visual rhetoric helps us to understand how arguments can be constructed by components and their relationships.



[2] Toronto Environmental Alliance

This poster, produced by the Toronto Environmental Alliance, became a prominent part of the debate around transportation planning and engineering in the city of Toronto in 2011, as residents debated plans for new investments in transportation infrastructure. The poster compared plans to develop a new rapid light rail network with plans to extend the existing subways with limited city and provincial funds allocated for the city, asking "which plan has the most winners?" Without giving an explicit answer, and by making use of elements of visual grammar and developing important relationships between the two sides, this post provides a strong argument for the Light Rail Network.

The poster uses a variety of different visual grammar components. The unique ***shape*** of the Greater Toronto Area forms the blank map on which ***lines*** show the routes for the different plans, with ***color*** signifying the difference between old and new. While a consistent ***font*** is used, various ***styles*** and ***sizes*** *(bolding, all caps, different colours and shades)* differentiate between types of information provided. ***Line*** is also used to create separation between the two versions, and types of information.

But the argument the poster makes relies on the relationships between the components on either side of the major dividing line: in part, it relies on the structural ***similarity*** of the two sides, but it also relies on the ***contrast*** between the two sides of the visual. These relationships between the information are emphasized by the use of ***proximity***, which creates this juxtaposition. By creating similar summaries of the key features of each potential project, the visual highlights the advantages of the proposed Rapid Light Rail Network. The question is answered when the costs, numbers of Toronto areas and people served are compared with one another.

When we examine the way this argument is constructed visually, we can start to see that ***blank space*** – an component we hadn't identified above – in the map and the list of areas served also helps to construct the argument in the visual.

Summary:

Conceiving your visuals in terms of components and their relationships that contribute to making an argument can help you to plan visuals more effectively. By developing an understanding of how to use line, color, shape, and other components that create relationships, you'll have a strong toolbox for making effective visuals with clear messages.