

The Thinker's Guide
to

Engineering Reasoning

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Based on Critical Thinking Concepts & Tools

The Foundation for Critical Thinking

Foreword

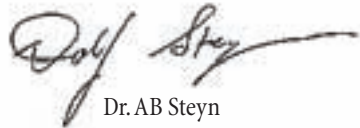
I am delighted to recommend *The Thinker's Guide to Engineering Reasoning* for engineering instructors, students, and engineers alike. This guide is a very useful addition to the arsenal of engineering education tools. I believe it fills a gap that has been largely ignored in engineering instruction. It covers an important area of competence that we so often presume students will acquire, but traditionally (and sadly) do not sufficiently address, if at all.

An isolated focus on technical skill delivery, or on one skill area, has not worked in the past, currently fails and will not meet tomorrow's needs. It is important for the field of engineering to be understood as systems of overlapping and interrelated ideas, rather than isolated and different fields of knowledge. Moreover, it is important to recognize and effectively deal with the multiple environmental, social and ethical aspects that complicate responsible engineering. Accordingly, it is time for engineering educators to realize that effective engineering instruction cannot be based in memorization or technical calculation alone. Rather, it is essential that engineering students develop the generalizable critical thinking skills and dispositions necessary for effectively and professionally reasoning through the complex engineering issues and questions they will face as engineers. The authors outline and detail these skills and dispositions quite effectively in this guide.

I am further delighted to note the level of detailed sub distinctions covered in the guide. I believe it is Dave Merrill who originally claimed that expertise is defined by the number of detailed sub-divisions clearly made and qualified. As such, the authors have proven mastery!

Growing industry dissatisfaction with deficient engineering education has led to the inception of the CDIO™ Initiative. This international design addresses engineering education reform in its broader context. Active student participation forms an integral part of this solution. While not the exclusive aim or application of this guide, its potential to compliment such institutional reforms by equipping the student to step up to the challenges of independent reasoning, is particularly beneficial.

The Thinkers Guide to Engineering Reasoning is not only a must-read publication for engineering educators, but a vital guide and career long companion for students and engineers alike.

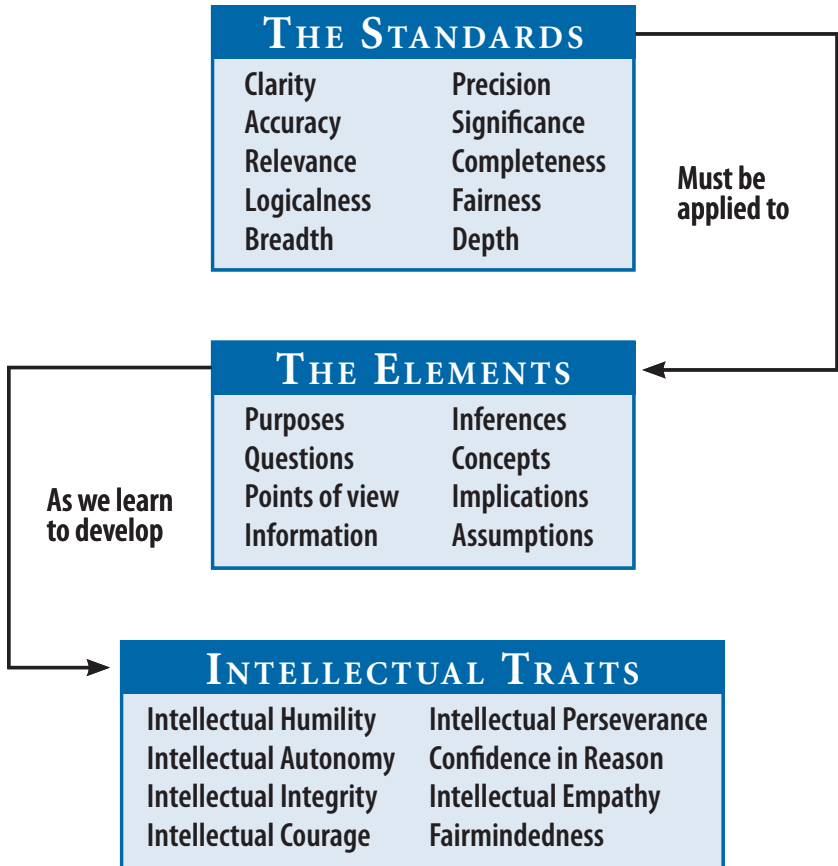


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Engineers concerned with good thinking routinely apply *intellectual standards* to the *elements of thought* as they seek to develop the traits of a mature engineering mind.



A Checklist for Engineering Reasoning

- All engineering reasoning expresses a *purpose*.** Take time to state your **purpose clearly**.
 - Distinguish your purpose from related purposes.
 - Check periodically to be sure you are still on target.
 - Choose realistic and achievable purposes.
- All engineering reasoning seeks to figure something out, to settle some *question*, solve some engineering *problem*.**
 - Take time to state the question at issue clearly and precisely.
 - Express the question in several ways to clarify its meaning and scope.
 - Break the question into sub-questions.
 - Determine if the question has one right answer, or requires reasoning from more than one hypothesis or point of view.
- All engineering reasoning requires *assumptions*.**
 - Clearly identify your assumptions and determine whether they are justifiable.
 - Consider how your assumptions are shaping your point of view.
 - Consider the impact of alternative or unexpressed assumptions.
 - Consider the impact of removing assumptions.
- All engineering reasoning is done from some perspective or *point of view*.**
 - Identify your specific point of view.
 - Consider the point of view of other stakeholders.
 - Strive to be fair-minded in evaluating all relevant points of view.
- All engineering reasoning is based on *data, information, and evidence*.**
 - Validate your data sources.
 - Restrict your claims to those supported by the data.
 - Search for data that opposes your position as well as alternative theories.
 - Make sure that all data used is clear, accurate, and relevant to the question at issue.
 - Make sure you have gathered sufficient data.
- All engineering reasoning is expressed through, and shaped by, *concepts and theories*.**
 - Identify key concepts and explain them clearly.
 - Consider alternative concepts or alternative definitions of concepts.
 - Make sure you are using concepts and theories with care and precision.
- All engineering reasoning entails *inferences* or *interpretations* by which we draw *conclusions* and give meaning to engineering work.**
 - Infer only what the data supports.
 - Check inferences for their internal and external consistency.
 - Identify assumptions that led you to your conclusions.
- All engineering reasoning leads somewhere or has *implications and consequences*.**
 - Trace the implications and consequences that follow from your data and reasoning.
 - Search for negative as well as positive implications (technical, social, environmental, financial, ethical).
 - Consider all possible implications.

Analyzing Disciplines: Electrical Engineering

Purpose. Electrical engineering develops electrical and electronic systems for public, commercial, and consumer markets. It is tremendously broad, spanning many domains including recreational electronics, residential lighting, space communications, and electrical utilities.

Key Questions. What are the detailed design features of the system that best satisfy the stated mission or market requirements? How will we conceive, design, implement, and operate electrical and electronic products and systems?

Point of View. The point of view is commonly that of the design and manufacturing team. Other relevant points of view include the customer, stockholders, marketing, maintainers, or operators.

Key Concepts. These concepts include electromagnetism (Maxwell's equations), electrochemical properties of materials, discrete and analog mathematics, resistance, current, charge, voltage, fields and waves, and so on.

Key Assumptions. Assumptions are in part shared by all scientists and engineers. One assumption is that the universe is controlled by pervasive laws that can be expressed in mathematical terms and formulas, and that those principles can be used to model electrical systems. Electrical engineers assume that some important market needs can be best met through electrical and electronic products. Additionally, electrical engineers frequently assume that their work must be integrated with other engineering disciplines (such as mechanical, chemical, and so forth) in the design and implementation of a product.

Data or Information. Electrical engineers employ experimental and computational data, legacy designs, regulatory requirements, market studies or mission needs statements.

Inferences, Generalizations, or Hypotheses. The conclusion of most electrical engineering activity is a product ready for delivery to a customer.

Implications. Electrical engineering products and services have wide-ranging implications that span global, national, and local economics, public infrastructure, health care, and communications, with potential for positive and negative quality of life impacts on communities and regions.

