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A Course of Study in Analytical Thinking

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Most of the fundamental skills that one needs as a foundation for analytical thinking have nothing to do with data analysis in particular. Analytical thinking skills must be developed as a foundation for many professions. Surprisingly and unfortunately, many of the people whose jobs involve data analysis—perhaps most—have never developed these fundamental thinking skills. Most have only learned to use one or more data analysis tools without first learning the concepts, principles, and practices of analytical thinking that must be developed before those tools can be used effectively. Organizations cannot make up for this lack in thinking skills by throwing technologies at the problem. Technologies cannot do our thinking for us; certainly not the kind of thinking that is required for data sensemaking. Where do we go to learn these skills? They're rarely taught at universities, except in bits and pieces fragmented across several departments and courses, and they're certainly not a part of most corporate in-house training programs. My purpose in this article is to describe the fundamental analytical thinking skills that all data sensemakers must develop to do their jobs effectively and to recommend a list of books that provide this knowledge.

The impetus to write this article was an email from my friend and colleague Ron Rensink, a cognitive psychologist who teaches at the University of British Columbia in Vancouver, Canada. Ron's work has contributed a great deal to information visualization research. He sends me examples of his work from time to time, and recently, he sent an article about a course that he teaches to undergraduates to help them prepare for work in visual analytics (VA). In the article, he stated that this course "focuses on 'VA unplugged'—that is, on developing investigative abilities prior to training on the VA systems themselves." When I read his course syllabus, I became excited because I've long recognized the need for such courses. However, I'd love to see similar courses made accessible to people who are already in the work world, not just at universities.

After reading Ron's article, I spent several days imagining a curriculum that I could teach in public workshops to address this need. It was fairly easy to outline the content, inspired in part by Ron's syllabus, but I quickly encountered a snag regarding the logistics of teaching a course of this type to people who are already working. Unlike my data visualization courses, fundamental analytical thinking skills cannot be taught as a series of consecutive days. This is because a great deal of reading, thinking, discussion, and practice must occur for each of several topics, which would require at least a week between each lesson. Most organizations would not be willing to fly their employees to a public workshop that's organized as several daylong sessions spread across multiple weeks. I considered making this an online course, but face-to-face discussions and group exercises are critical to learning these skills, which online courses cannot yet support effectively. Although I'm still stumped by these logistical challenges, I haven't given up on the workshop idea, but in the meantime I thought I'd share the curriculum that I have in mind, along with suggested readings. This will give those of you who might benefit from this material a chance to get to it now by doing the reading and thinking on your own.

I have one other purpose for proposing this curriculum now: to get your suggestions. Please consider the curriculum below and let me know if you think additional topics or readings would be helpful. I would also be interested in hearing your personal take on the need for these analytical thinking skills and the current lack of them in most organizations.

Proposed Curriculum for Analytical Thinking

What I have in mind as a complete workshop consists of the following nine topics:

1. Whole-Brain Thinking
2. Critical Thinking

3. Logical Thinking
4. Scientific Thinking
5. Statistical Thinking
6. Systems Thinking
7. Visual Thinking
8. Ethical Thinking
9. Data Sensemaking

Each of these topics could be introduced (not deeply taught) as a day's worth of coursework composed of lectures, discussions, exercises, and tests, assuming that the required reading for each was done in advance.

Here's a brief description of each topic's contents, along with suggested readings:

1. Whole-Brain Thinking

   Human thinking can be divided into two basic types: 1) the fast, unconscious, intuitive, and emotional thinking that is handled by the more primitive parts of our brains, and 2) the slow, conscious, deliberate, and rational thinking that takes place in the parts of our brains that evolved more recently. Daniel Kahneman refers to them as System 1 and System 2 thinking. Both types are critical and useful, but they are best suited for different cognitive tasks. Our thinking can be improved if we understand their differences and learn to appropriately match the right type of thinking to the task at hand. Data sensemaking often requires System 2 thinking, so all data analysts must understand when to use it and how, as well as when, to trust their intuitions.

   This topic focuses on the following:

   - The brain's two thinking systems
   - System 1 thinking: how it works and when to rely on it
   - System 2 thinking: how it works and when to rely on it

   Reading:

   Daniel Kahneman, *Thinking, Fast and Slow*

   Ted Cadsby, *Closing the Mind Gap*, Parts I-III

2. Critical Thinking

   Critical thinking recognizes the ways in which our minds often mislead us and seeks to correct those thinking flaws. Common thinking flaws usually involve the use of System 1 thinking for situations that require System 2 thinking. System 1 thinking relies on unconscious rules of thumb, called heuristics. These heuristics evolved to handle the simpler world that we lived in before the cultural revolution that occurred when our brains developed language and abstract thought. They work great for most decision making, such as deciding to duck when an object is flying at high speed toward your head. They don't work well for most of the decisions that we make in response to complexity. Data sensemaking requires the basic skills of critical thinking, which are by no means common sense.

   This topic focuses on the following:

   - Knowing versus believing
   - Common flaws in thinking and how to avoid them

   Reading:

   M.N. Browne and S.M. Keeley, *Asking the Right Questions: A Guide to Critical Thinking*

3. Logical Thinking

   Logic is a set of formal principles for reasoning deductively. Deduction begins with one or more premises and ends with conclusions that are consistent with those premises. Logical thinking is a part of critical thinking, but it deserves separate study because it is a long, well-developed, coherent, and distinct set of principles. Every data sensemaker should be able to reason logically and construct a valid argument.

   This topic focuses on the following:

   - Logical argument
   - Common flaws in logic

   Reading:

   > Mark Zegarelli, *Logic for Dummies* (Despite being a part of Wiley Press' *Dummies* series, this book goes more deeply into formal logic and the use of its symbols than is needed for our purposes, but no simpler introduction that's worthwhile seems to be available.)

4. Scientific Thinking

   Although the roots of scientific thinking extend back to the time of the ancient Greeks and to some extent before then, what we now call science emerged in the 16th and 17th centuries and has led to an exponential increase in our knowledge of the world and the quality of that knowledge. Scientific thinking adheres to a particular method, which includes the following:

   - Knowledge is acquired empirically, through observation and measurement.
   - Knowledge is validated by forming hypotheses about phenomena and then making observations or running experiments to determine if they are false or potentially true.
   - Knowledge is always contingent, never certain, and always open to correction as new observations call existing knowledge into question.
   - Knowledge involves positions that are potentially falsifiable.

   Effective data sensemaking benefits greatly from the methods of science, including the formulation and testing of hypotheses and the conducting of experiments.

   This topic focuses on the following:

   - Scientific method
   - Observational vs. experimental studies
   - Experimental design

   Reading:

   > Stephen S. Carey, *A Beginner's Guide to Scientific Method* (Note: I have not yet read this book—it's been on order for two weeks—but it appears to be the best resource for this purpose based on the author's description and readers' comments. Colleagues have recommended *The Art of Scientific Investigation* by W.I.B. Beveridge, but it is terribly dated.)

5. Statistical Thinking

   Statistical thinking is the use of mathematics to determine the validity and significance of quantitative findings. It is integral to science, data sensemaking, and even more broadly to many of life's decisions.

This topic focuses on the following:

- Basic statistical concepts
- Probabilistic thinking

Reading:

Charles Whelan, *Naked Statistics*

6. Systems Thinking

Systems thinking is based on Systems Theory, a relatively new discipline that studies complex systems that initial emerged from cybernetics. It recognizes that with complex systems, which are composed of many interacting parts, the whole is greater than the sum of its parts. We cannot understand complex systems, such as the weather or even something simpler, such as a sales organization, by following the standard scientific approach of focusing on specific things independent of their context. Systems thinking is in many ways the opposite of analytical thinking: rather than breaking information down into its components parts (analysis), it seeks to understand the whole that is comprised of those parts (synthesis). Systems thinking has much in common with the dialectical thinking that emerged long ago in East Asia, embodied in Confucianism and Taoism, which has dominated those cultures for as long as logical thinking has dominated the West. Systems thinking and eastern dialectical thinking focus on contexts and relationships. Like science, systems thinking seeks to understand causation, but it does this differently because effects are illusive when mediated by multiple, dynamical interactions that sometimes separate causes and effects by large gaps in time. It is not difficult to see that data sensemaking benefits from this holistic perspective.

This topic focuses on the following:

- Systems theory
- The importance of considering context and relationships

Reading:

Ted Cadsby, *Closing the Mind Gap*, Part 4

Donella H. Meadows, *Thinking in Systems: A Primer*

7. Visual Thinking

Vision is by far our dominant sense. Our brains have the ability to represent abstract information visually, which makes it possible for us to understand relationships and detect meaningful patterns in data. When words and numbers are not enough, pictures of data are often needed to understand relationships and patterns. This is especially true today because of the many complex problems that we face. In fact, systems thinking, the previous topic in this list, can only be examined and understood through the use of visual representations. Data sensemakers must understand the potential of visual thinking and know when and how to represent information visually in ways that allow our brains to see, compare, and understand meaningful patterns and relationships.

This topic focuses on the following:

- Benefits of visual thinking
- Representing abstract information visually

Reading:

Colin Ware, *Visual Thinking for Design*

8. Ethical Thinking

   Our thinking is not complete without first considering the effects of our knowledge, decisions, and actions on others, including other creatures, and on the larger world. We are engaged in ethical thinking when we consider these effects to pursue justice, fairness, and the wellbeing of others. It involves our values. Most people consider themselves relatively ethical in behavior, but how that translates into action differs considerably, and how we can support the greatest benefits for all in a culturally diverse world is one of our great challenges. Ethical thinking can be improved through study, experience, and practice. The work of data sensemakers results in decisions and subsequent actions that should be shaped by ethical thinking.

   This topic focuses on the following:

   - An ethical compass
   - Utilitarianism
   - Ethics and data

   Reading:

   Joshua Greene, *Moral Tribes*

9. Data Sensemaking

   This final topic brings together all the types of thinking that have been covered and shows how they can be applied specifically to data sensemaking. This topic directly addresses the unique challenges of using digital data as the repository of facts from which we derive knowledge.

   This topic focuses on the following:

   - Unique challenges of digital data
   - A scientific approach to data sensemaking
   - Separating signals from the noise

   Reading:

   Richard Heuer, *The Psychology of Intelligence Analysis*

   Nate Silver, *The Signal and the Noise*

   Stephen Few, *Signal* (introduction only)

This completes the curriculum, at least for now. The necessity of these thinking skills, however, might not yet be obvious to you. Let's think a bit more about their importance.

The Necessity of Fundamental Analytical Thinking Skills

We live in a time of specialization. During the industrial revolution, specialization was needed to build an industrial workforce. Knowledge work, however, now dominates our current age, and it benefits from broader knowledge and thinking. If you're involved in the sciences, you've no doubt read about or personally experienced the benefits of interdisciplinary knowledge and collaboration. Knowledge is often transferable, with some modification, from one discipline or domain to another. Our universities are still too specialized in their approach, often locking students into isolated domains that restrict their thinking, but this is changing.

The work of data sensemaking is most effective when we approach information and problems from multiple perspectives. As data sensemakers, we cannot afford to be myopic. We cannot focus our studies, interests, and skills too narrowly. Our thinking must be built on a broad and sturdy yet flexible foundation. In my work, I focus on the use of data visualization for exploring, making sense of, and then communicating quantitative information. Essentially, I try to help people think and communicate more effectively. The data visualization

concepts, principles, and practices that I teach cannot be fully understood or applied by people who have not already built a foundation for analytical thinking.

I'm fortunate in that the broad foundation for analytical thinking that has served me well personally and professionally is one that I encountered quite naturally during my 20s. I owe this good fortune, in part, to an unusual journey. My work today is quite a departure from my early life and aspirations. My first profession, beginning when I was still a teenager, was the ministry. My early perspective was that of a religious fundamentalist: narrow-minded and anti-intellectual. My world expanded, however, during my undergraduate studies. Back then, undergraduates were required to fulfill a broad range of "general education." My General Ed, as we called it, featured courses in the natural sciences and social sciences that quite literally rocked my world. During this period I was introduced to the scientific method. I soon withdrew from the ministry as the fabric of my religious mindset unraveled. I went on to major in Communication Studies, which drew its contents primarily from psychology, but also included a bit of rhetoric, including the study of logic and argumentation. Like many students in the social sciences, I received introductory exposure to statistics. It wasn't until many years later that I approached statistics with wonder. During this same period, my critical thinking skills were developing, which were forged by fire as I struggled with the flaws in my religiously based mindset.

After I left the ministry, I developed an interest in studying religion from a social science perspective and did graduate work in Comparative Religions, including the psychology, sociology, and history of religions. This deepened my scientific perspective and also introduced me to East Asian dialectical thinking, which sowed the seeds for the systems thinking that I would encounter years later. Although my previous religious perspective was replaced with that of science, I retained the sense of mission and deep commitment to ethics that were formed during my time in the ministry. After completing a master's degree (MA) in religious studies, I went on to do doctoral work in the field, but after a while I took a leave of absence that turned into a lifelong detour.

It was then time that I took my first job in information technology (IT). I had only taken a single computer course in college, but I learned how to use an IBM PC in the early 80s when it was brand new and nobody was yet an expert. This allowed me to quickly develop computer skills that were rare at that time. This was the basis of my IT career, which began as a short-term means of making money after living many years as a starving student. From the beginning, I helped people use computers to derive value from data. I dabbled in programming for a while, which strengthened my logic skills, but mostly I focused on using computer-based tools to augment human intelligence. My initial full-time IT position was in a group called "Decision Support" at a large semiconductor company in Silicon Valley, but my work eventually led to data warehousing, then business intelligence, and eventually to data visualization as my area of focus. It was only then that I began to learn about and develop visual thinking skills and to deepen my knowledge of statistics and systems thinking.

Put simply, I was fortunate in that I developed a foundation for analytical thinking quite organically during this journey, without intention, which has helped me enormously. I'm grateful that this broad foundation in analytical thinking skills was mostly in place already before I began my IT career, because this has enabled me to approach problems more flexibly than most of my professional colleagues who prepared specifically for jobs in IT.

I know through experience that relatively few of the people who work as data sensemakers today have developed the broad foundation of analytical thinking skills that I propose in this article. In addition to many years of observing people who do this work, I still get to know them regularly in the courses that I teach and in consulting engagements. These folks also express their opinions and concerns in my blog and discussion forum. I've found that, despite good intentions, few of them have developed the analytical thinking skills that they need to fully succeed in their jobs and provide optimal benefit to the organizations that employ them. Most have developed what they know on the job, with little opportunity for anything but training in the use of specific analytical tools.

Even though I've been aware of this sad fact for many years, I'm still often surprised by the ways in which people whose jobs involve data sensemaking frequently fail to think critically, cannot construct a logical argument, cannot formulate and test hypotheses, and rarely shift from System 1 to System 2 thinking when its needed. When I taught at U.C. Berkeley, I encountered MBA students who were already working as data analysts who could not reason logically, even in basic ways. You can see for yourself ways that many people lack critical thinking skills by reading some of things that they write in response to my blog articles. I'd like to believe that most of my readers are already well-rounded analytical thinkers, but a few who post comments

in my blog definitely are not. (Perhaps they're not regular readers.) Two flawed forms of arguments arise again and again: (1) the popular personal attack (e.g., "you're a jerk therefore you must be wrong"), which is a favorite among politicians, especially during presidential campaigns, and (2) the "I'm right because I said so" argument, lacking reason and evidence, which is a favorite among frazzled parents. This kind of reasoning arises from our reptilian brains.

Here's one more example that stands out vividly in my experience. Two years ago I taught a visual data analysis course at a conference for people who do data warehousing and analytics work at universities. After teaching all day, I stuck around to attend the opening keynote address that evening and was shocked and infuriated when I realized that the speaker was a "face reader," not in the scientific sense of reading micro-expressions to detect someone's mood or truthfulness, but in the pseudo-scientific sense of judging a person's personality and character based on facial attributes, such as the length of their earlobes. It was a parlor trick, pure and simple, no more valid than astrology or handwriting analysis. I sat in my seat fuming as some of the people who had attended my course earlier that day volunteered to have their faces read and bought into everything that that the charlatan said. (By the way, he performs for birthday parties and bar mitzvahs in addition to giving keynote presentations at conferences.) This poignantly pointed out what little effect my books and courses in data visualization could have on people who lack a foundation in analytical thinking.

Effective data sensemaking skills are built on a broad foundation of fundamental analytical thinking skills. If you've jumped ahead and are trying to make sense of data without first learning these fundamental skills, you needn't despair; you can learn them now.

I would like to see these fundamental analytical thinking skills taught as general education courses to all college-level students, no matter what they pursue as their primary fields of study. It would also benefit organizations to help their knowledge workers develop the foundational thinking skills that they lack. Until then, however, we must take responsibility for our own development and acquire these skills. Until this foundation in analytical thinking is routine rather than exceptional, the "information age" will remain the realm of a few and the delusion of most.

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