INFUSING CRITICAL THINKING INTO CURRICULUM

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Some critical thinking materials copied or adapted from the Foundation for Critical Thinking

TRUE OR FALSE?

All humans use their thinking to make sense of the world.

Our students have to understand that this is

- *(a) true and*
- *(b) necessary in order to understand the importance and value of not just learning material to make an A on an exam or in a class.*

OPINIONS, FACTS AND CRITICAL THOUGHT

"A public opinion poll is no substitute for thought." Warren Buffet

"Too often we enjoy the comfort of opinion without the discomfort of thought." John. F. Kennedy

"Everyone is entitled to their own opinion, but not to their own facts." Daniel Patrick Moynihan

"The majority have no other reason for their opinions other than that they are in fashion." Samuel Johnson

"Opinion is the exercise of the human will which helps us to make a decision without information." John Erskine

What is the general theme or message of all of these quotes?

What is the difference between an informed and uninformed opinion?

How can you tell when an opinion is based on facts? On emotions? On personal experience?

Which type of opinion is easier to argue against, an informed or uninformed opinion? Why?

WHY CRITICALLY THOUGHT OUT OPINIONS?

The ability to form and articulate opinions is extremely important in all facets of life.

As citizens, people need to form opinions about political issues and leaders in order to vote responsibly.

We must form opinions about social issues, and we form opinions about the people we work and interact with on a daily basis.

However, simply having an opinion about a given topic is not enough. We must be educated about the topics we are discussing.

Presenting an informed, educated opinion is much more effective than sharing one based on emotion or personal experience alone.

In presenting our own opinions and work or thinking about those of others – we need to use critical thinking skills to develop a deeper understanding of the topic.

WHAT IS CRITICAL THINKING?

The ability to think clearly and rationally. It includes the ability to engage in reflective and independent thinking.

Someone with critical thinking skills is able to do the following :

- understand the logical connections between ideas
- identify, construct and evaluate arguments
- detect inconsistencies and common mistakes in reasoning
- solve problems systematically
- identify the relevance and importance of ideas
- reflect on the justification of one's own beliefs and values

Clarity and rationality constitute the common core across the different conceptions on critical thinking.

WHAT ISN'T CRITICAL THINKING?

Accumulating information

Having a good memory/knowing a lot of facts

Being argumentative

Being critical of other people

Do not believe in anything simply because you have heard it. Do not believe in anything simply because it is spoken and rumored by many. Do not believe in anything merely on the authority of your teachers and elders. - Buddha

WHY DO WE CARE AS EDUCATORS IF OUR STUDENTS CAN CRITICALLY THINK…

Using a sports analogy…

We're the basketball coach and you're the athlete…

- What if you came to practice and could only take notes and watch your coach instead of getting in there and trying it out yourself then…

…on gameday…

- You have to be on the court – you can't watch the coach play but you've never held the ball or tried to shoot a basket because all you've done is watch and listen to your coach. You will have learned *some* things but not as much as if your had the opportunity to practice yourself with the help and guidance of your coach.

moral of the story – students need to do their own thinking and their own work

"I want to play on Sunday" – Roger Federer (Tennis slams have finals on Sundays after two weeks of play)

- Everyone wants to be there (play on Sunday, get an A in class, be an expert, get a job) but what did he (Federer) do to get there? And what do you need to do to get there (get an A, become an expert, get a job)? These are what students need to be thinking about – what do you need to do to get there?
- You cannot move through life getting lines on a resume – there has to be substance behind those lines – when you're faced with situations when you don't have Google and don't have notes and don't have a book – you are responsible for what the meaning behind those (resume) lines is.

THE FUNDAMENTAL PURPOSE OF TEACHING IS TO PASS KNOWLEDGE ON TO STUDENTS SO THEY MAY APPLY THAT KNOWLEDGE IN THEIR FIELD

So we have to examine content in depth

- Like peeling back the parts of an artichoke until you get to the heart

- When students are working with course content – they should have questions and topics of discussion. If they do not – they need to be asking themselves

  - Am I engaging my mind in this?

    - They have to bring something to the table too!

WITH COURSE MATERIAL, WE WANT STUDENTS TO APPLY THE 5 LEARNING MODALITITES.

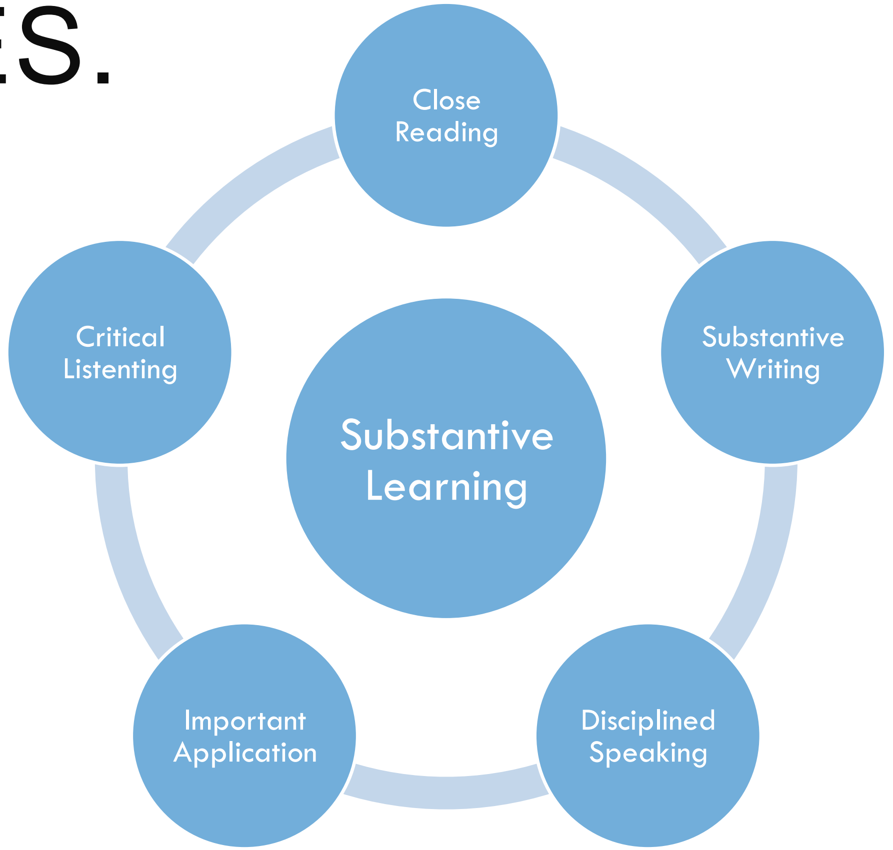
READ

THINK DEEPLY ABOUT

WRITE

LISTEN TO OTHERS SPEAK

SPEAK



SOME TIPS…

When students are working on in-class activities or small-group projects in class, use time hints

- Have a secondary task they can work on if they finish the first task that takes them deeper into thinking about/applying the materials so all students are engaged during the entire working time

Have them write down responses to discussion questions, write down their questions, come to class with 5 questions, etc.

With material, help them develop a seeing eye.

S – state essential idea → ____ to me is ____.

E – elaborate on statement → In other words, ____.

E – exemplify (bring from abstract to concrete) → For example, ___.

I – illustrate (metaphor/analogy) → To illustrate, ___.

- Critical thinking to me is active, thoughtful, evaluative thinking. In other words, it is examining information and making conclusions based on all of the knowledge available after considering alternatives and consequences. For example, taking the problems and situations of everyday life and come to a conclusion based on information and thought. It is like a baby learning how to walk – many trial and error situations until you come to the best conclusion of how to walk.
- If you have students working on things like this individually, they can stand or raise their hand as they finish → as soon as 2 finish, they can get together and begin a discussion on the topic. So, there is less waiting in class.

WE CANNOT THINK OF STUDENTS AS A BLANK SLATE

I talk – you listen

They listen to what we say through filters

- Bring assumptions regarding how people look/talk/act in addition to a lens about what we're learning and teaching

QUESTIONS YOU AND STUDENTS CAN ASK EACH OTHER OR RELATE TO MATERIAL TO THINK ABOUT IT MORE DEEPLY

CLARITY – Could you elaborate further? Could you give me an example? Could you illustrate what you mean?

ACCURACY – How could we check on that? How could we find out if that is true? How could we verify or test that?

PRECISION – Could you be more specific? Could you give me more details? Could you be more exact?

RELEVANCE - How does that relate to the problem? How does that bear on the question? How does that help us with the issue?

DEPTH – What factors make this a difficult problem? What are some of the difficulties we need to deal with?

BREADTH – Do we need to look at this from another perspective? Do we need to consider another point of view? Do we need to look at this in other ways?

LOGIC – Does all this make sense together? Does your first paragraph fit with your last? Does what you say follow from the evidence?

SIGNIFICANCE – Is this the most important problem to consider? Is this the central idea to focus on? Which of these facts are most important?

FAIRNESS – Do I have any vested interest in this issue? Am I sympathetically representing the viewpoints of others?

PICTURES AND RESOURCES

From Critical Thinking Books

GENERAL

Template for Analyzing the Logic of an Article

Take an article that you have been assigned to read for class, completing the "logic" of it using the template below. This template can be modified for analyzing the logic of a chapter in a textbook.

The Logic of "(name of the article)"

1) The main purpose of this article is ______________________.
(State as accurately as possible the author's purpose for writing the article.)

2) The key question that the author is addressing is ______________________.
(Figure out the key question in the mind of the author when s/he wrote the article.)

3) The most important information in this article is ______________________.
(Figure out the facts, experiences, data the author is using to support her/his conclusions.)

4) The main inferences/conclusions in this article are ______________________.
(Identify the key conclusions the author comes to and presents in the article.)

5) The key concept(s) we need to understand in this article is (are) ______________.
By these concepts the author means ______________________.
(Figure out the most important ideas you would have to understand in order to understand the author's line of reasoning.)

6) The main assumption(s) underlying the author's thinking is (are) ______________.
(Figure out what the author is taking for granted [that might be questioned].)

7a) If we take this line of reasoning seriously, the implications are ______________.
(What consequences are likely to follow if people take the author's line of reasoning seriously?)

7b) If we fail to take this line of reasoning seriously, the implications are ____________.
(What consequences are likely to follow if people ignore the author's reasoning?)

8) The main point(s) of view presented in this article is (are) ______________.
(What is the author looking at, and how is s/he seeing it?)

How to Evaluate an Author's or Experimenter's Scientific Reasoning

1. Focusing on the stated scientific **Purpose:** Is the purpose of the author well-stated or clearly implied? Is it justifiable?
2. Focusing on the key scientific **Question:** Is the question at issue well-stated (or clearly implied)? Is it clear and unbiased? Does the expression of the question do justice to the complexity of the matter at issue? Are the question and purpose directly relevant to each other?
3. Focusing on the most important scientific **Information** or data: Does the writer cite relevant evidence, experiences, and/or information essential to the issue? Is the information accurate and directly relevant to the question at issue? Does the writer address the complexities of the issue? Does the experimenter clearly delineate the scientific data to be collected?
4. Focusing on the most fundamental **Concepts** at the heart of the scientific reasoning: Are the key ideas clarified? Are the ideas used justifiably? Does the experimenter clarify the theories behind the experiment?
5. Focusing on **Assumptions:** Does the scientific reasoner clearly delineate the scientific assumptions? Does s/he show a sensitivity to what s/he is taking for granted or assuming (insofar as those assumptions might reasonably be questioned)? Or does the reasoner use questionable assumptions without addressing problems inherent in those assumptions?
6. Focusing on the most important scientific **Inferences** or conclusions: Do the inferences and conclusions made by the scientific reasoner clearly follow from the information relevant to the issue, or does the reasoner jump to unjustifiable conclusions? Does the reasoner consider alternative conclusions where the scientific issue is complex? In other words, does the reasoner use a sound line of reasoning to come to logical scientific conclusions, or can you identify flaws in the reasoning somewhere? Does the experimenter clearly separate data from conclusions?
7. Focusing on the scientific **Point of View:** Does the reasoner show a sensitivity to alternative relevant scientific points of view or lines of reasoning? Does s/he consider and respond to objections framed from other relevant scientific points of view?
8. Focusing on **Implications:** Does the reasoner display a sensitivity to the implications and consequences of the position s/he is taking?

SCIENCE

The Logic of an Experiment

(Attach a detailed description of the experiment or laboratory procedure.)

The main goal of the experiment is ______________________________

____.

The hypothesis(es) we seek to test in this experiment is(are) ______________

____

____.

The key question the experiment seeks to answer is ______________________

____.

The controls involved in this experiment are ______________________

____.

The key concept(s) or theory(ies) behind the experiment is(are) ______________

____

____.

The experiment is based on the following assumptions ______________________

____

____.

The data that will be collected in the experiment are ______________________

____

____.

The potential implications of the experiment are ______________________

____.

The point of view behind the experiment is ______________________

____.

Post Experiment Analysis

The data collected during the experiment was ______________________________

____

____

____

______________________________.

The inferences (conclusions) that most logically follow from the data are ______

____

____

______________________________.

These inferences are/are not debatable, given the data gathered in this study and the evidence to this point.

The hypothesis (or hypotheses) for this experiment was/was not (were/were not) support by the experiment results.

The assumptions made prior to this experiment should/should not be modified given the data gathered in this experiment. Modifications to assumptions (if any) should be as follows ______________________________

____

____

____

The most significant implications of this experiment are ______________________________

____

____

____

Recommendations for future research in this area are ______________________________

____

____

____

____

The Logic of Science

Goals Scientists Pursue: Scientists seek to figure out how the physical world operates through systematic observation, experimentation, and analysis. By analyzing the physical world, they seek to formulate principles, laws, and theories useful in explaining natural phenomena, and in guiding further scientific study.

Questions Scientists Ask: How does the physical world operate? What are the best methods for figuring things out about the physical world? What are the barriers to figuring things out about the physical world? How can we overcome those barriers?

Information Scientists Use: Scientists as a whole use virtually any type of information that can be gathered systematically through observation and measurement, though most specialize in analyzing specific kinds of information. To name just some of the information scientists use, they observe and examine plants, animals, planets, stars, rocks, rock formations, minerals, bodies of water, fossils, chemicals, phenomena in the earth's atmosphere and cells. They also observe interactions between phenomena.

Judgments Scientists Make: Scientists make judgments about the physical world based on observations and experimentation. These judgments lead to systematized knowledge, theories, and principles helpful in explaining and understanding the world.

Concepts that Guide Scientists' Thinking: The most fundamental concepts that guide the thinking of scientists are 1) physical world (of nature and all matter); 2) hypothesis (an unproved theory, proposition, or supposition tentatively accepted to explain certain facts or to provide a basis for further investigation); 3) experimentation (a systematic and operationalized process designed to figure out something about the physical world); and 4) systematic observation (the act or practice of noting or recording facts or events in the physical world). Other fundamental concepts in science include: theory, law, scientific method, pure sciences, and applied sciences.

Key Assumptions Scientists Make: 1) There are laws at work in the physical world that can be figured out through systematic observation and experimentation; 2) Much about the physical world is still unknown; 3) Through science, the quality of life on earth can be enhanced.

Implications of Science: Many important implications and consequences have resulted from scientific thinking, some of which have vastly improved the quality of life on earth, others of which have resulted in decreased quality of life (e.g., the destruction of the earth's forests, oceans, natural habitats, etc.). One important positive implication of scientific thinking is that it enables us to replace mythological thinking with theories and principles based in scientific fact.

The Scientific Point of View: Scientists look at the physical world and see phenomena best understood through careful observation and systematic study. They see scientific study as vital to understanding the physical world and replacing myth with scientific knowledge.

The Logic of Biochemistry

Biochemical Goals: The goal of biochemistry is to determine the biological foundations of life through chemistry. Its aim is to use chemistry to study events on the scale of structures so small they are invisible even with a microscope.

Biochemical Questions: How do small-scale structures and events underlie the larger-scale phenomena of life? What chemical processes underlie living things? What is their structure? And what do they do? How can we correlate observations made at different levels of the organization of life (from the smallest to the largest)? How can we produce drugs that target undesirable events in living creatures?

Biochemical Information: The kinds of information biochemists seek are: information about the kind of chemical units out of which life is constructed, about the process by which key chemical reactions essential to the construction of life take place.

Biochemical Judgments: Biochemists seek to make judgments about the complex process of maintenance and growth of which life basically consists. In short, they seek to tell us how life functions at the chemical level.

Biochemical Ideas: There are a number of ideas essential to understanding biochemistry: the idea of levels of organization of life processes (molecular, sub-cellular particle, cellular, organ, and total organism), the idea of life structures and life processes, the idea of the dynamics of life, the idea of the unity of life processes amid a diversity of life forms, etc.

Biochemical Assumptions: Some of the key assumptions behind biochemical thinking are: that there are chemical foundations to life, that the techniques of chemistry are most fitting for the study of life at the level of molecules, that it is possible to use chemical ideas to explain life, that it is possible to analyze and discover the key agents in fundamental life process, and that it is possible, ultimately, to eliminate unwanted life processes while strengthening or maintaining desirable ones.

Biochemical Implications: The general implications of biochemistry are that we will increasingly be able to enhance human and other forms of life, and to diminish disease and other undesirable states, by application of chemical strategies.

Biochemical Point of View: The biochemical viewpoint sees the chemical level as revealing fundamental disclosures about the nature, function, and foundations of life. It sees chemistry as solving the most basic biological problems. It sees life processes at the chemical level to be highly unified and consistent, despite the fact that life process at the whole-animal level are highly diversified.

The Logic of Biology

Biological Goals: Biology is the scientific study of all life forms. Its basic goal is to understand how life forms work, including the fundamental processes and ingredients of all life forms (i.e., 10,000,000 species in fragile ecosystems).

Biological Questions: The questions biology is concerned with are: What is life? How do living systems work? What are the structural and functional components of life forms? What are the similarities and differences among life forms at different levels (molecule, organelle, cell, tissue, organ, organism, population, ecological community, biosphere)? How can we understand the biological unity of living matter?

Biological Information: The kinds of information biologists seek are: information about the basic units out of which life is constructed, about the processes by which living systems sustain themselves, about the variety of living systems, and about their structural and functional components.

Biological Judgments: Biochemists seek to make judgments about the complex processes of maintenance and growth of which life basically consists.

Biological Concepts: There are a number of essential concepts to understand to understand the logic of biology: the concept of levels of organization of life processes (at the molecular level, at the sub-cellular particle level, at the cellular level, at the organ level, and at the level of the total organism), the concept of life structures and life processes, the concept of the dynamics of life, the concept of the unity of life processes amid a diversity of life forms, etc…

Biological Assumptions: Some of the key assumptions behind biological thinking are: that there are foundations to life, that these foundations can be identified, studied, described, and explained; that it is possible to use biological concepts to explain life; that it is possible to analyze and discover the structure and dynamics of living systems and their components; that all forms of life reproduce, grow, and respond to changes in the environment; that there is an intricate and often fragile relationship between all living things; that all life forms, no matter how diverse, have common characteristics: 1) they are made up of cells, enclosed by a membrane that maintains internal conditions different from their surroundings, 2) they contain DNA or RNA as the material that carries their master plan, and 3) they carry out a process, called metabolism, which involves the conversion of different forms of energy by means of which they sustain themselves.

Biological Implications: There are specific and general implications of the present logic of biology. The specific implications have to do with the kind of questioning, the kind of information-gathering and information-interpreting processes being used by biologists today. For example, the state of the field implies the importance of focusing questions and analysis on the concepts above, of seeking key answers at all levels of life systems. The general implications are that we have the knowledge, if not always the will, to understand, maintain, and protect forms of life.

Biological Point of View: The biological viewpoint is focused on all levels and forms of life. It sees all life forms as consisting in structures and understood through describable functions. It sees life processes at the molecular level to be highly unified and consistent. It sees life process at the whole-animal level to be highly diversified.

The Logic of Geology

Goals of Geologists: The purpose of geology is to understand the earth and all its aspects—its origin, its varied features, the composition and structure of the material that composes it, and its impact on the life upon it. It is concerned with all the forces that have acted upon the earth and the effects of those forces. It attempts to reconstruct the history of the earth, particularly as it is recorded in the rocks of the outer crust.

Questions Geologists Ask: What is the earth made of? How has the earth changed over time? What causes the earth to change? How can we predict changes in the earth? How can we use what we know about the physical environment in making decisions?

Information Geologists Use: Geologists primarily study rocks and derivative materials that make up the earth's crust, as well as information about physical forces that affect the earth's development. For example, they use information about the earth's water in relation to geological processes. They use maps of the earth, as well as knowledge from geodesy (the branch of applied math concerned with measuring, or determining the shape of the earth, or with locating points on the earth). Geologists gather information about landforms and other surface features of the earth, as well as information about minerals within the earth. Geologists study the geomagma field, paleomagnetism in rocks and soils, heat flow phenomena within the earth, chemicals within the earth, sediments, oil, coal, fossils, and geothermal energy.

Judgments Geologists Make: Geologists make judgments about the physical properties of the earth and its internal composition. They make judgments about the causes of change in the earth, the chemical makeup of the earth, the origin, structure, history and composition of rocks and minerals. They make judgments about prehistoric life, about how the earth is altered due to external forces, about how best to utilize and exploit the earth's natural resources, about how to design human-made structures given the earth's processes and makeup, and about problems caused by human use and exploitation of the physical environment.

Concepts that Guide Geologists' Thinking: Key geological concepts include: the geological time scale (obtained from four major rock types, each produced by a different kind of crustal activity; endogenetic processes (processes originating within the earth) exogenetic processes (those that originate externally); and the plate tectonics hypothesis; (that the earth's crust is divided into a number of plates that move about, collide, and separate over geological time). In addition, geologists use principles from other sciences to understand the earth. For example, biology is needed to explain life records of the past; the remote history of the earth's beginnings are interwoven with astronomy; theories in physics must be used to explain tides, earth heat, interior rigidity and many other phenomena; chemistry is needed to analyze the materials within the earth; theories in meteorology and climatology are needed to explain how external forces impact the earth's surface.

Key Assumptions Geologists Make: That geology is interwoven with many other branches of science and therefore, that geologists must rely on theories and laws from other scientific branches to think geologically; that the history of the earth is best interpreted in terms of what is known about geological processes at work in the present, rather than supposed processes in the past (principle of uniformitarianism); that the structures and forces within the earth, as well as those affecting the earth, are interrelated and must be understood in relationship to one another; that the physical structures of the earth and the ways in which they function are predictable, though there is much about the earth that we cannot yet predict.

Implications of Geology: There is almost unlimited practical value in applying geological knowledge. By studying geology, for example, there are implications for determining and predicting water, coal, and oil supply, stone quarrying, and locating ore. Geology aids in identifying geologically stable environments for human constructions. It can also help in forecasting natural hazards associated with geodynamic forces including volcanoes and earthquakes. Geologists can make a significant contribution in illuminating the effects of human exploitation on the earth's surface and resources.

The Point of View of Geologists: Geologists see the earth as a physical structure containing predictable structures, influences and forces which, when systematically studied, can improve the quality of life.

The Logic of Chemistry

The Goal of Chemistry is to study the most basic elements out of which all substances are composed and the conditions under which, and the mechanisms by which, substances are transformed into new substances. Chemists study pure substances, elements and compounds, molecules, atoms, and sub-atomic particles. They study chemical reactions, classes of chemicals, and uses for chemicals. Chemistry, like physics, conducts its study of the physical properties of chemical substances insofar as the properties of these substances can be measured, expressed in mathematical formulas (or approximations), and explained by chemical theories. Its goals may be roughly contrasted with those of physics (which focuses on physical properties, on the physical nature of matter and energy).

Its Key Question is: What are the chemical properties of pure substances insofar as they can be measured, expressed in mathematical formulas, and explained by chemical theories?

Its Key Concepts: Chemical theory is based on a conception of atoms, their electronic structures, and their spatial arrangements in molecules. Other key concepts include matter, energy, gravity, physical property, chemical property, pure substance, element, compound, molecule, reaction, electron, electron transfer, electron sharing, chemical bonding, atomic weight, molecular weight, specific gravity, valence, catalysis, qualitative analysis, quantitative analysis, organic compound, and inorganic compound.

Its Key Assumptions are: That the universe is controlled by laws, that the same laws apply throughout the universe, that the laws guiding the universe can be expressed in mathematical terms and formulas, that physical properties can be distinguished from chemical ones, that all (or most) of the changes in identity of substances, as they react with other substances, can be accounted for by the theories and laws of modern chemistry.

The Data Chemists Gather result from their observations of the physical and chemical properties of matter. They observe matter as divided into elements and compounds. They seek to gather information about pure substances, molecules, atoms, and subatomic particles. They compare the behavior of different molecules. They observe the speed of chemical reactions within plants and animals. They observe the extent to which helping agents are necessary for these reactions to take place.

Inferences, Generalizations, or Hypotheses are made regarding the scope of chemical phenomena. When possible, chemists seek general hypotheses or chemical theories that they can test, modify, and perfect through extended study and experimentation. When successful, they predict new chemical phenomena in line with a given theory and then conduct further experiments to verify or falsify it.

Implications. The huge growth in knowledge and understanding of the chemical world as a result of advances in chemistry carries with it important implications for quality of life in many dimensions of human existence. Chemical knowledge has had significant implications in medicine, agriculture, engineering, and biology. Many new substances and materials have been produced through chemistry. Our knowledge of chemistry has also been misused in the building of weapons of mass destruction (biochemical weapons), in our polluting of the environment, and in creating chemicals harmful to people, other animals, and plants.

The Point of View. Chemists see the physical world as containing basic elements whose structures can be studied and transformed in accordance with various chemical laws and principles.

The Logic of Physics

The Goal of Physics is to discover the physical forces, interactions, and properties of matter, including the physical properties of the atom and sub-atomic particles. In pursuing this end, physicists study gravitation, motion, space, time, force, and energy. This entails the study of mechanics, heat, light, sound, electricity, magnetism, and the constitution of matter. Physics conducts its study of the physical properties of matter and energy insofar as these properties can be measured, expressed i mathematical formulas, and explained by physical theories. Its goals may be contrasted with thos of chemistry (which focuses on chemical properties, on the composition and transformations of matter) and those of biology (which focuses on living matter).

Its Key Question is: What are the physical properties of matter and energy insofar as both can be measured, expressed in mathematical formulas, and explained by physical theories? (Physical properties can change without changing the identity of the matter; chemical properties cannot change without changing the identity of the matter.)

Its Key Concepts include: matter, energy, mass, space, time, light, work, entropy, motion, volume, density, weight, magnitude, direction, displacement, velocity, acceleration, momentum, inertia, equilibrium, friction, gravitation, mechanics, heat, sound, electricity, magnetism, chaos theory, quantum, and relativity.

Its Key Assumptions are: that the universe is controlled by laws, that the same laws apply througho the universe, that the laws guiding the universe can be expressed in mathematical terms and formulas, that physical properties can be distinguished from chemical ones, that the velocity of light is constant throughout, that space and time are interrelated, that all motion is relative, and tl the forces of inertia, gravitation, and electromagnetism are different manifestations of a single forc

The Data or Information Physicists Gather are all focused on the causal relations or statistical correlations of physical occurrences or phenomena. Physicists use information from many physical sources such as heat, light, sound, mechanics, electricity, and magnetism to come to conclusions about the physical world. They study atoms, particles, neutrons, and electrons. They observe the ways in which moving bodies behave and stationary bodies react to pressure and other forces. They observe waves and small particles. They observe how physical forces affect living things. In short, the physical world provides a virtually unlimited store of data for the various types of physicists to observe.

Inferences, Generalizations, or Hypotheses are made regarding the scope of the phenomena. Whe possible, physicists seek general hypotheses or physical theories that they can test, modify, and perfect by extended study and experimentation. When successful, they predict new physical phenomena in line with a given theory and then conduct further observations or experiments confirm or falsify it.

Implications. The huge growth in knowledge and understanding of the physical world as a result c advances in physics carries with it important implications for quality of life in many dimensior of human existence. It has provided the foundations of engineering. It enables us to build powe plants, trucks, airplanes, trains, televisions, and telephones. Most machinery and tools, for example, are dependent on knowledge of physics. Most construction of buildings, irrigation and sewer systems, solar power alternatives, and the instrumentation of modern medicine are products of modern physics. Our knowledge of physics has also (arguably) been misused in th building of weapons of mass destruction, in our polluting of the environment, and in our use c mechanisms by which to invade the privacy of citizens.

The Point of View: Physicists see the universe, as well as the physical world and everything in it, a ultimately explainable and understandable through physical theories and laws. Many physicist see the universe as open to almost unlimited exploration and discovery.

ENGINEERING

Analyzing Engineering Tools: Modeling and Simulation

Purpose. Modeling and simulation can either be a direct engineering product or a development tool used to design other complex systems. It provides a representation of the physical world for purposes such as operator training, development trade studies, component development, prototype testing, and test and evaluation where full-scale live testing is impractical, dangerous or cost-prohibitive.

Key Questions. How can the features of the real world be practically simulated to provide accurate insight into physical interactions and behaviors in order to design physical systems for specific purposes? What level of detail is required for accurate portrayal of the systems behavior?

Point of View. Simulation and modeling takes the point of view that the physical world submits to mathematical and computational modeling to such an extent that the behaviors observed in simulation reliably imitate or predict a system's performance in the real world.

Key Concepts. Concepts span all domains of engineering, but also notably include concepts such as numerical methods, equations of motion, man-the-loop and hardware-in-the-loop testing, batch simulation, virtual reality, display latency, systems identification and computational throughput.

Key Assumptions. Simulation depends upon simplifying assumptions; real world detail remains beyond our reach. Simple simulations entail lengthy lists of assumptions. Improving simulation fidelity entails adding details to physical models that are assumed negligible in more simple models. Enhancing fidelity to the real physical world means removing assumptions, and consequently building complexity.

- When using modeling and simulation, engineers assume that they can design models that accurately represent the physical world to a sufficient level of detail.
- Simulation and modeling typically assumes that a relationship exists between cost and complexity, value and fidelity.
- Engineers assume that there are situations in which modeling and simulation provides vital insight (note that simulation may be employed throughout the product life, from conception to operation), while simultaneously recognizing that unmodeled phenomena may indeed be significant (limiting the simulations value).

The Data or Information. The information upon which simulation and modeling depends includes math models for the interaction of simulated systems, plus specific attributes of physical systems provided by analysis, physical testing, legacy designs, or systems identification.

Inferences. Simulation conclusions include design decisions as well as training and educational practices.

Implications. Simulation can reduce the risk or expense of engineering development and testing, or provide insight into a system's response to conditions which cannot practically or safely be tested in realistic conditions (e.g., failure states or emergency conditions). However, if a simulation product or process is flawed, negative implications might exist for the use of the actual product when used in the real world.

Analyzing Disciplines: Mechanical Engineering

Purpose. Mechanical engineering develops mechanical systems and materials for public, commercial, and consumer markets. It is tremendously broad, spanning transportation, mechanisms, architecture, energy systems, materials, and more.

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

Point of View. Commonly, the point of view is that of the design and manufacturing tear Other relevant points of view include the customer, stockholders, marketing, maintainer or operators.

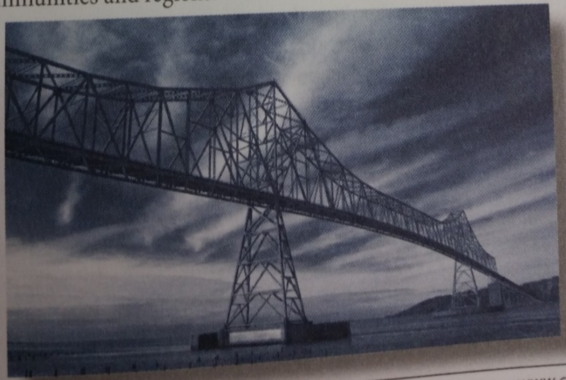
Key Concepts. These concepts include materials science, stress, strain, loads, friction, dynamics, statics, thermodynamics, fluid mechanics, energy, work, CAD/CAM, machine and so on.

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 mechanical systems. Mechanical engineers assume that market needs can be met with mechanisms and materials. Additionally, mechanical engineers frequently must integra their work with other engineering disciplines (such as automotive, aerospace, electrical computer, chemical, and so forth) in the design and implementation of a product.

Data or Information. Mechanical engineers require experimental and computational legacy designs, regulatory requirements, market studies or mission need statements.

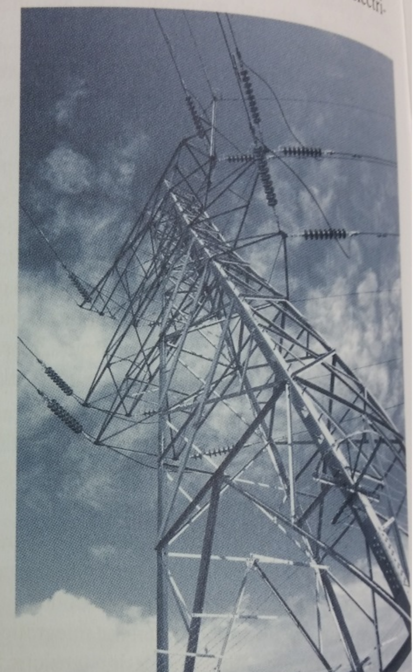
Inferences, Generalizations, or Hypotheses. The conclusion of most mechanical eng neering activity is a product ready for delivery to a customer, or integration into a larg system.

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



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.

ADDITIONAL INFORMATION

Critical Thinking

Critical thinking is not a matter of accumulating information.

A person with a good memory and who knows a lot of facts is not necessarily good at critical thinking.

A critical thinker is able to deduce consequences from what he know, and he knows how to make use of information to solve problems, and to seek relevant sources of information to inform himself.

Critical thinking should not be confused with being argumentative or being critical of other people.

Although critical thinking skills can be used in exposing fallacies and bad reasoning, critical thinking can also play an important role in cooperative reasoning and constructive tasks.

Critical thinking can help us acquire knowledge, improve our theories, and strengthen arguments.

We can use critical thinking to enhance work processes and improve social institutions.

Good critical thinking might be seen as the foundation of science. Science requires the critical use of reason in experimentation and theory confirmation.

4 REASONS TO STUDY CRITICAL THINKING

1. ***It is a domain-general thinking skill.*** The ability to think clearly and rationally is important whatever we choose to do. If you work in education or research then critical thinking is obviously important. But critical thinking skills are not restricted to a particular subject area. Being able to think well and solve problems systematically is an asset for any career.

2. ***It enhances language and presentation skills.*** Thinking clearly and systematically can improve the way we express our ideas. In learning how to analyze the logical structure of texts, critical thinking also improves comprehension skills.

3. ***It promotes creativity.*** To come up with a creative solution to a problem involves not just having new ideas. It must also be the case that the new ideas being generated are useful and relevant to the task at hand. Critical thinking plays a crucial role in evaluating new ideas, selecting the best ones and modifying them if necessary.

4. ***It is crucial for self-reflection.*** In order to live a meaningful life and to structure our lives accordingly, we need to justify and reflect on our values and decisions. Critical thinking provides the tools for this process of self-evaluation.

ATTITUDES THAT WILL NOT HELP YOUR CRITICAL THINKING…

I prefer being given the correct answers rather than figuring them out myself

I don't like to think a lot about my decisions as I rely only on gut feelings

I don't usually review the mistakes I have made

I don't like to be criticized

I ALREADY KNOW HOW TO THINK

Yes but…

Just like any skill – practice and education can improve it

How can thinking critically help you improve your thinking?

- Hold ideas at arm's length and examine it before accepting it into your mental framework
- A habit of cautious evaluation

CRITICAL THINKING ≠ FINDING FAULT

Not on a fault finding mission

Sometimes information will be bad

Sometimes information will be good

Critical thinking should not teach you to be cynical and negative just to evaluate the world in which you live with more of an "open eye".

- It is meant to be constructive and helpful. It's meant to separate ideas from their vehicles – to separate true from false – accurate from distorted – complete from incomplete.
- A good critical thinker will be open to opposing arguments and ideas, carefully considering the merit and weight of each one, recognizing that he or she can always learn something form others, and might even be wrong in a current position.

PAY ATTENTION!

Critical thinkers pay attention!

- Having a lazy attitude toward incoming information is grounds for deception by those who would wish to deceive you.

If you were hungry for some Old Chicago Style pizza – you might go "to your local grocer's freezer" and look for some. Let's say you saw two boxes – one said Old Chicago Style frozen pizza and the other said Old Chicago frozen pizza. Old Chicago Style frozen pizza is actually made in California. Its sausage flavor variety is sausage flavor variety, not sausage variety. The "sausage" is really textured vegetable protein – not sausage. Here's an example where you could use critical thinking in your everyday life – not just taking information at face value.

PAUL & ELDER BOOK

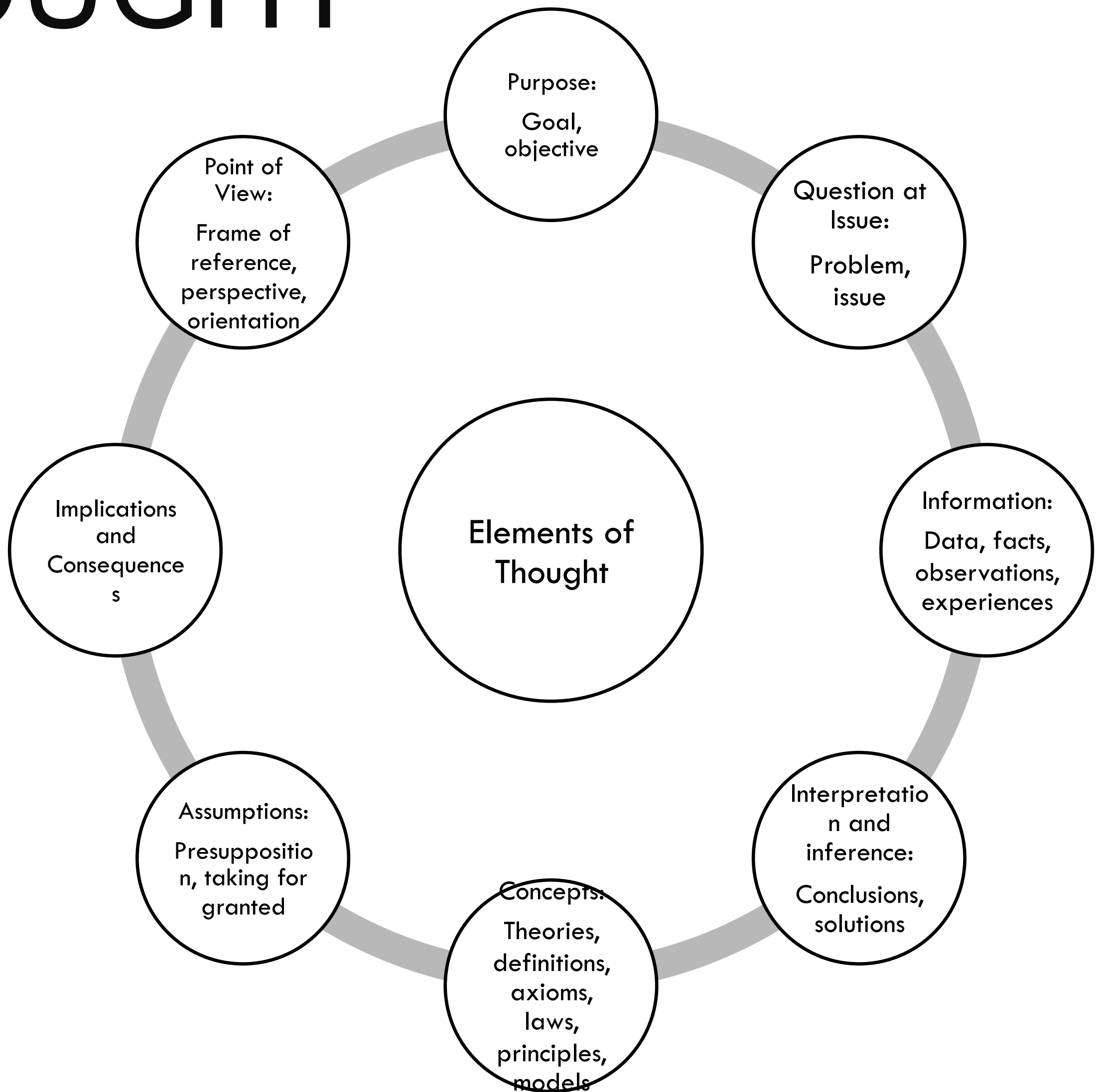
Critical Thinking definition:

- The art of analyzing and evaluating thinking with a view to improving it.

Critical Thinking is:

- Self-directed
- Self-disciplined
- Self-monitored
- Self-corrective

THE ELEMENTS OF THOUGHT



A CHECKLIST FOR REASONING

All reasoning has a PURPOSE

All reasoning is an attempt to FIGURE something out, to settle some QUESTION, solve some PROBLEM

All reasoning is based on ASSUMPTIONS

All reasoning is done from some POINT OF VIEW

All reasoning is based on DATA, INFORMATION & EVIDENCE

All reasoning is expressed through, and shaped by, CONCEPTS and IDEAS

All reasoning contains INFERENCES or INTERPRETATIONS by which we draw CONCLUSIONS and give meaning to data

All reasoning leads somewhere or has IMPLICATIONS and CONSEQUENCES

HOW CAN YOU APPLY CRITICAL THINKING TO YOUR WRITING?

- Purpose
- Questions
- Information
- Inferences/Conclusions
- Concepts
- Assumptions
- Implications/Consequences
- Points of View

You can ask yourself questions related to the 8 elements of thinking.

Purpose: What am I trying to accomplish?

Questions: What question am I raising?

Information: What information am I using to come to this conclusion?

Inferences/Conclusions: How did I reach this conclusion?

Concepts: What is the main idea here?

Assumptions: What am I taking for granted?

Implications/Consequences: What am I implying?

Points of View: From what point of view am I looking at this issue?

PURPOSE

All reasoning has a purpose

State your purpose clearly

Distinguish your purpose from related purposes

Check periodically to be sure you are still are target

Choose significant and realistic purposes

QUESTIONS

All reasoning is an attempt to figure something out, to settle some question, solve some problem

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

Distinguish questions that have definitive answers from those that are a matter of opinion and from those that require consideration of multiple viewpoints

INFORMATION

All reasoning is based on data, information, and evidence

Restrict your claims to those supported by the data you have

Search for the information that opposes your position as well as information that supports it

Make sure that all information used is clear, accurate, and relevant to the question at issue

Make sure you have gathered sufficient information

INFERENCES/ CONCLUSIONS

All reasoning contains inferences or interpretations by which we draw conclusions and give meaning to data

Infer only what the evidence implies

Check inferences for their consistency with each other

Identify assumptions that lead you to your inferences

CONCEPTS

All reasoning is expressed through, and shaped by, concepts and ideas

Identify key concepts and explain them clearly

Consider alternative concepts or alternative definitions of concepts

Make sure you are using concepts with care and precision

ASSUMPTIONS

All reasoning is based on assumptions

Clearly identify your assumptions and determine whether they are justifiable

Consider how your assumption are sharing your point of view

IMPLICATIONS/ CONSEQUENCES

All reasoning leads somewhere or has implications and consequences

Trace the implications and consequences that follow from your reasoning

Search for negative as well as positive implications

Consider all possible consequences

POINT OF VIEW

All reasoning is done from some point of view

Identify your point of view

Seek other points of view and identify their strengths as well as weaknesses

Strive to be fair-minded in evaluating all points of view

WHAT IS EGOCENTRIC THINKING?

People who are egocentric thinkers are convinced that their understanding of things is the absolute truth.

- Innate Egocentrism: It’s true because I believe it
- Innate Sociocentrism: It’s true because we believe it
- Innate Wish Fulfillment: It’s true because I want to believe it
- Innate Self-Validation: It’s true because I have always believe it
- Innate Selfishness: It’s true because it is in my selfish interest to believe it