LITERATURE

Expressing Human Thoughts, Emotions, and Cultural Context

Introduction

As a field of learning, literature differs from other disciplines in that the goal of a writer is not so much to acquire knowledge as it is to express human thoughts and emotions. Literature is the record of things worth saying. Literature rises above communicating the facts that it may contain. Thus, it goes beyond the writing found in other fields in which texts may do no more than encapsulate findings of historical research or scientific experimentation.

Literature does not stand or fall on whether the facts that it relates are true or not, but this does not mean that Merlin the Magician did not really exist. Stories about Merlin are not “true.” However, in other senses, we can speak about whether the characters, plot, and other features of a piece of literature appear to be true or false. Is what the author says about Merlin true to the rules of the character’s universe as the author and the reader understand them? Or does what he says flop about confusingly and murky? To succeed, the piece of literature must be truly something that people might want to read and feel wiser for having done so.

Goals

Great pieces of literature are those that have stood the test of time and communicate to people on many levels, including behavioral, psychological, scientific, cultural and aesthetic. Literature along with the “arts” is included in the broader category of the humanities. They are “works of the imagination and self-reflective scholarship based on carefully gathered evidence to illuminate enduring human concerns as well as present problems and possibilities” -- General Education Goals adopted by the SDSU Senate, November 6, 2001.

Writers might explore the human psyche or propose to excite and entertain. A writer may exaggerate and make fun of people and institutions, perhaps provoking new behavior on their part. Sometimes writers explore social conditions, which they may approach satirically or realistically, inviting social change. They may help explain the world symbolically, in the form of a traditional story. Writers may report true facts but with a careful or even an artistic use of language, resulting in the production of fine essays and works of literary nonfiction. Whatever their specific goal, writers want to express, explore, or explain human concerns and behaviors.

Products

Literature can include any carefully crafted or expressive piece of communication, whether written or oral. Literature may be either complete in itself or acted out as in a play or a film. Plays can be considered to be both literature and theatre. (In Liberal Studies, we generally categorize plays as part of the performing arts.) In novels, stories, essays, and plays, texts can be in regular language (prose) or in special, concentrated language, called verse.
Process

How an author creates is difficult to determine. Sometimes writers are not completely aware of their processes themselves. Different writers approach their work in different ways. Some may develop their themes and messages from personal experiences, others may focus on external demands or issues, and others may do extensive research. Some write at specified times every day; others write in long uninterrupted sessions and then take days or weeks off from writing. Some outline the entire work before fleshing it out; others allow the characters and situations to determine the outcome. Those with long careers may use more than one method and write in more than one style or genre. In learning to write, many children learn a “writing process” that includes: brainstorming, outlining, drafting, editing, revising, and publishing.

Academics in the process of analyzing literature, in particular novels or short stories, often use the following terms and ask the types of questions listed. Authors must deal with all these issues while planning their novels. They may try one approach and then change their minds and try a different one; however, ultimately they have to create an imaginary world in which the various parts work together convincingly.

Theme: Is there one central idea the author explores and develops? Are there less important ideas (minor themes) or parallel themes that enrich or conflict with the central theme?

Plot: Is there a plot? Is it familiar or is it new? Is it central to the writer’s purpose or an excuse for descriptive language, social activism, or philosophical speculation? What is the conflict at the heart of the plot?

Character: Are the characters believable? Are they meant to be?

Setting: Why here? Why then? What is the author trying to get across by making these decisions?

Tone: Is the work serious or funny, obvious or subtle?

Imagery: What pictures do the phrases or the words conjure in your mind?

Symbolism. What culturally significant meanings lurk below the text, plugging into the reader’s preexisting ideas or mental images?

Point of view: Is the narrator omniscient? Is he or she flawed in some way? Is the narrator one of the characters, knowing only what that character would know? Are there multiple narratives and points of view? Is the piece (whether fictional or not) in the first person, the second, or the third?

Audience: For whom is the work intended? Does the audience see the world new and fresh and in more detail through this writer’s eyes?

Style: Is the literary work smooth and flowing? Is it unclear, despite the author’s best efforts? Is the work deliberately tortuous and challenging? Is the lack of clarity a deliberate and well-controlled case of ambiguity, in which the author has constructed the work to function on different levels at the same time?
Outcomes

Outcomes are on a continuum. What is a best seller today may disappear tomorrow. If writing is to be considered literature in an academic sense, it must stand the test of time. Humans do not change very much. Thus, writing that reflects real human concerns and behaviors such as love, greed, economic and physical well-being, or fear is likely to be read by different generations and in different countries with diverse cultural perspectives. Great literature has “universal appeal.”

Literature takes readers out of themselves for a while and transports them to worlds otherwise unknown. If the new world brings pleasant experiences, then the reader may be entertained. If it brings understanding of deplorable social or political situations, then the reader may be moved to action. When readers connect with how a story’s characters experience and value life, they may come to appreciate, understand, and deal with their own experiences. When reading literature, readers work their way through an assortment of worlds.

Quality Control

How can individuals tell whether a written work is likely to be worth their time? They might ask themselves these questions: If the text is old, is it easy to get?

Have other people found it worth reprinting?
Also, have people found it (or its author) worthy of criticism?

If so, that piece of literature may become part of a “canon,” garnering attention from one generation to another, rather than being left only for specialists in research libraries.

Finally, does the work have style, readability, or other compelling features? If it is a new work, is there something entertaining or stirring about it? Would readers of different cultural backgrounds expect it to be in the canon someday? How is the canon determined, anyway? Who makes the determinations and what are the criteria?

Note that the answers to these questions are, in part, up to the reader. If readers peruse a book, attend a play or poetry reading, watch a movie, or even view a television program, they help keep literature alive. Literature justifies itself if people read it, listen to it, or see it performed. The test is whether a reader connects, sees something of himself or others in it, and is enriched by the experience.

Readers can also look at how literary critics evaluate a piece of literature. Academic literary critics publish journals and peer-review each other’s books and articles, just as historians and scientists do, so there is also a body of “expert” opinion that can be consulted regarding what various critics have written about specific pieces of literature. Readers can read reviews to determine whether this or that interpretation or biographical work about an author is thought to be well written, well-researched, entertaining, and worth reading.

Historically, literary critics have argued from divergent perspectives. In the 19th century, realistic criticism was quite popular. Psychological criticism arose with psychology as a field of study, especially after Sigmund Freud published his works. Social criticism evaluated the social
constructs of literary pieces. In the 20th century, several new forms of criticism arose. “New criticism” began to look at the value of imaginative literature. Feminist criticism was one result of the feminist movement. Deconstructionist critics (late 20th century to the present) take apart or “deconstruct” in order to examine what may be hidden or ambiguous to the ordinary reader. Some critics argue from a cultural viewpoint, asking what the work reveals about the time in which it was written, including the cultural values of the society and of the author.

When researching the criticism of any piece of literature, one must be aware of the point of view of the critic and consider what values are reflected in that criticism. For example, one might want to ask: What does this type of criticism value? What are the goals of the critic in evaluating the work? Does this point of view help the reader understand the work better? Does this type of criticism seem fair or far-fetched for this particular piece of literature?
HISTORY
A FORM OF INQUIRY INTO THE PAST

Introduction

"History" comes from the Greek "historia," or "inquiry." Historians make inquiries into the past, grounding their inquiries in evidence. They look at records from the past such as letters, documents, diaries, and even paintings, selecting the details necessary to address major issues or questions about humanity. Historians ask questions of the evidence in order to bring the past to life, questions that typically address "Who are we?" and "How did we get here?" However, one should not assume there was no communication about the past or inquiry into the past before the Greek scholars.

Goals

Asking questions about the past distinguishes history from “antiquarianism.” Most historians reject antiquarianism, which means collecting random details about the past for their own sake. Historians, for example, reject the idea of obsessively collecting bottle caps or matchbooks or obsessively memorizing dates. History is not a random collection of bottle caps or dates. If history does not take the form of a list of dates or a display case of random memorabilia, what is it? History is an intellectual inquiry that enhances our understanding of people and places.

Products

Books and articles usually have an explicit argument, even if they also tell a story. Textbook presentations of history usually focus more on the story than on the argument, but the argument is still there under the surface. The reason there is always an argument, even in an apparently uncontroversial textbook written for use in elementary schools, is that even when a piece of historical text has no apparent argument, it is still written from a point of view. Someone had to decide what was worth mentioning and what could or should be left out. Should the next page of an historical narrative analyze the speech of a great politician or present a piece of iconic art? These are practical questions behind any piece of historical writing, from a seemingly non-argumentative text. Every piece of history is somebody's selection and representation of an argument. There is no pure history, only diverse selections—varying histories written by individuals who have different concerns or agendas.

Some historical arguments are written for general-interest and are sold in “mainstream” bookstores. Historians also write specialized books and articles for each other and for students. Some historians conduct research and write reports for organizations or historical societies. Their work may also lead to the production of informative documentaries.

Process

When creating an argument, there is a great deal of historical evidence to examine. The problem is selecting key pieces from it and then arranging them to make sense. Evidence that comes from people directly involved in an event is especially valuable. First-hand sources of information are called "primary sources." People without direct first-hand knowledge of an event write “secondary sources.” Historians pursue primary sources, trying to get as close as possible to what really transpired. However, secondary sources can be valuable in establishing a broader picture or a general set of questions for later research. Individual primary sources can be untrue or misleading.
Secondary sources can serve as a check on primary sources. Comparing sources to check for and eliminate biased points of view is an important part of creating an argument.

There are two principles that guide most historians when deciding what to include or emphasize. The first is “chronology.” It helps to present history in chronological order, because it is how the human brain experiences life. Of course, there can be flashbacks, even whole changes of scene that mean going back in time to pick up another strand in the story. Chronology usually helps readers understand contexts of events. Presenting arguments in chronological order can help make them more convincing.

In addition to chronology, historians use one more tool to shape their narratives. It is called "interconnectedness" or "context." This is the principle that separates history from the social sciences, just as the constant appeal to evidence separates history from the creative arts. An example of context being utilized by the historian is when a particular event or period of time being studied includes a description of other things happening at the same time and connections are made for the reader between the primary topic being studied and conditions, events or personalities that helped characterize or shape the sequence of events that occurred. The ‘context’ often provides the ‘color commentary’ that brings the historical topic to life and helps the reader to have more of a three-dimensional understanding of what is being studied. Context also helps provide the ‘tone’ or psychological climate of the topic being studied.

Outcomes

History’s questions often lead into moral or political issues. For example, the question “Why did the Industrial Revolution happen?” may lead to another question, one touching on the effectiveness of modern policies designed to bring economic equity and/or development to groups or nations who have historically been the victims of exploitative and discriminatory practices. A new question might be something like this: “Given what we know about the Industrial Revolution in England in the 18th and 19th centuries, why have certain countries not yet achieved a standard of living comparable to richer countries in such areas as education, living conditions, health, economic and political development?” That question, in turn, could lead to questions about the effectiveness of the particular policies of modern governments. Looking at evidence about the past can throw light onto such questions, history has been called "moral philosophy by example."

History, however, is even broader than that. People can visit the past simply for fun, not only for moral or political lessons. History takes individual human experience and adds to it some of the hard-won lessons, ideas, scenes, and enjoyments of those people whom the reader can not talk to face to face.

Frequently, historical writings contradict each other. The different points of view of historians is part of the historiography; historians from the same era or from different eras approach the study or interpretation of the same events from very different beliefs, values, and prejudices or biases.. Part of the enjoyment and challenge of studying history is appreciating and exploring how historians present different points of view; put together narratives out of contradictory or unlikely evidence; argue their cases, knowing how chancy or changeable current world patterns are; and simply inquire into the past for fun and profit. By studying history, people gaining understanding about how and why events happened in the past. In the best case, these lessons help them and the governments or organizations they lead avoid some of the same mistakes in the future; in the worst case, their readings helps them appreciate the richness and depravity of the human experience.

Quality Control
If a piece of history writing is easy to shape any way the historian wants, through selecting one set of details instead of another, is history fictional? To some degree history is an art. Perhaps it is subjective, but partial is a better word than fictional. It is partial because it is always only a “part” of the story, and it is “partial” in taking one side or another in an argument—that is, being partial toward one side or another. Since history is a compilation and representation of evidence, other historians might make a different set of decisions about what to emphasize or what evidence to use in bringing their stories to life. While the human imagination may generate many possible stories about a historical period or event, only a small proportion of those stories fit the evidence. True history fits the evidence that can be verified by other people.

Historians review each others’ books and read each others’ articles, providing peer review. Works of academic history are read by anonymous experts before they are published. These experts provide quality control; they suggest substantive and stylistic improvements. The stylistic improvements are important because historians often dismiss work that is poorly written. If the writing is not good, then the argument and the research are probably poor, too. Most likely, details were poorly selected and do not illustrate what they should or do not illustrate anything in particular. Since history is centered on finding, choosing, and arranging the details that further an inquiry into the past, flaws in logic and organization are very serious.

Flaws due to oversight or selective presentation of evidence are also serious. Historians must consider all known evidence; even it represents only specific examples. While historians can not avoid presenting a point of view, blatantly biased arguments are unacceptable.

While historians do check each other's work and try to write as clearly and as timelessly as possible, each piece of historical writing remains only a part of a whole story. Historians think about these limitations, but are not really bothered by them. They have a saying that “History must be rewritten by each new generation.” Each new generation will have new concerns and new arguments to make and will look at evidence in new ways.

While historians do check each other's work, and while they try to write as clearly and as timelessly as possible, each piece of historical writing remains only a part of the story, and it remains shot through with the point of view of its author. Historians think about these limitations a lot, but they are not really bothered by them. They have a saying that “History must be rewritten by each new generation.” Each new generation will have new concerns and new arguments to make. Each generation will look at the evidence in a new way, and emphasize certain details. For example, since the latter third of the 20th century, ethnic studies and some other departments in universities have contributed to the explosion of new knowledge and new perspectives on past events and historical interpretations related to the experience of certain populations. This has resulted in both the presentation of new evidence and new interpretation of old evidence related to the general topic of cultural studies both in the United States and throughout the world.

FURTHER READING


A short classic on how teaching history as an interesting progression toward *now* can distort things.

On recent controversies about the National History Standards, and the kinds of history that schoolchildren should learn.


On connections between history and other fields.


On how historical evidence is all around you.
Mathematics

The Study of Patterns and Structures

Introduction

“Mathematics” comes from the Greek work “mathematike,” which means scientific craft. Mathematics is defined as “the systematic treatment of magnitude, relationships between figures and forms, and relations between quantities expressed symbolically” (Stein 884). Many times mathematicians examine several cases looking for patterns or relationships and make general conjectures based on those cases. Once they have made a conjecture, mathematicians prove their conjectures by a detailed argument, showing that each step of the proof is justifiable. Mathematical theorems can be proven beyond all doubt using logical argument.

Goals

In non-technical terms, the goal of mathematicians is to find patterns in quantities and their interrelationships, patterns in shapes, patterns in uncertainty, and patterns in change. Hence, one short description of mathematics is sometimes "the study of patterns." Patterns are defined as a consistent arrangement of numbers, forms, or colors that constitute a recognizable design or relationship with each other such that the observer can ascertain the predictability of their occurrence. Mathematicians also develop symbolic languages to describe new kinds of structures and the ways in which structures interact. Patterns and structures in nature are fundamental to the sciences, so mathematics, as the study of patterns and structures, has also been given the label "queen and servant of the sciences." However, mathematics can go well beyond everyday life and the natural world, with the study of quantities giving birth to abstract structures and relationships, and with the study of shapes leading to ideas in four, five, or more dimensions.

Mathematicians who specialize in topics with obvious practical use are sometimes called "applied mathematicians,” whereas those whose main interests do not obviously relate to applications can be called "pure mathematicians." There are, of course, many mathematicians with interests in both the practical and the abstract aspects, so the labels describe the ends of a continuum rather than a dichotomy.

In each of the following disciplines, mathematicians have had to develop unique methods and approaches in order to recognize the underlying patterns and structures.

• Arithmetic—the study of number systems and what can be done to numbers
• Geometry—the study of shapes; often taught largely as a system of proofs
• Algebra—the study and manipulation of unknown quantities in equations, and the study of how to solve those equations and find the unknown quantities
• Trigonometry (largely a high school rather than a university subject)—the study in which shapes (graphs) are turned into equations and equations into shapes (graphs), so that geometry and algebra can be brought together and used to advance each other
• Calculus—the study of the mathematics of the equations and graphs of unknown algebraic quantities that change from one moment to the next (like sounds waves and accelerating
objects) so that the equations, when graphed, do not make the clean simple lines and circles encountered in algebra, geometry and trigonometry

- Probability—the study of the relative possibility that an event will occur
- Statistics—the study of how to generalize from the numerical evidence about a small number of things or people (the “sample”) in order to say something about a larger group (the “population” or “parameter”)

**Products**

Mathematicians do their work in academic institutions, private research institutes, and even financial, technological, and other businesses. Academic mathematicians write mathematics proofs, propose new problems, and develop new methods. They write articles, which are published in professional mathematics journals and books. Mathematicians who work in financial and business settings use mathematics to enhance the productivity of their companies. Movies such as *A Beautiful Mind* and books such as *Journey through Genius* by Dunham help the public understand and appreciate that “beauty, truth, reality, and abstraction are not limited to painters and poets. These concepts occupy the minds of mathematicians, who often view their subject as an art as well as a science” (Selzer 11: 445).

**Process**

How mathematicians proceed varies from mathematician to mathematician:

- Many times mathematicians work almost exactly as a scientist may. They examine several cases (perhaps with the aid of a computer), make a general conjecture based on those cases, and then gather still more evidence in an effort to test the conjecture. Unlike scientists, mathematicians do not stop at this stage; they proceed to establish their conjecture beyond all doubt by creating a logical, step-wise proof based on previously proven postulates and theorems.

- Another mathematician may proceed quite differently. She may carry out thought experiments about elements in her abstract systems and deductively reason about them, creating new theorems, proposing new topics of investigation, and even creating new methods for working with the elements.

- Sometimes a mathematician will focus on making the mathematics more pleasing intellectually, as in establishing some known result with a simpler or more revealing argument or in relating it to some other area of mathematics in a clever way.

In whatever way they proceed, all mathematicians must first decide what is worthwhile to study. Some mathematicians get ideas from colleagues, others write review chapters or articles in order to become familiar with the literature, and others examine several cases looking for patterns. For example, consider the three triangles below, which are inscribed in the top half of the circle. Can you see a pattern? Hint: What kind of angle do the two sides of the triangle seem to form at the top of the circle?
A mathematician named Thales, who lived from about 640 to 546 BC, probably made drawings something like those above, noticed that the angle formed near the top of each circle was a right angle, and proposed the conjecture: “An angle inscribed in a semicircle is a right angle” (Dunham 7). (A conjecture is a tentative proposition formed without sufficient evidence for proof.)

As already stated, a conjecture is not enough. Since the time of Thales, and possibly earlier, mathematicians have used deductive reasoning to write mathematical proofs. (A proof is a step-wise argument built on careful, logical reasoning about the necessary consequences of already known, already proven facts.) In the above example, Thales might have used something like the proof shown below.

If you find the details of the proof hard to follow, just notice how it is set up: There are five steps. In each step something is done which depends upon definitions or previously proven theorems.

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**Step 1.** Draw the line (shown dotted and bold in Figure 1) from the top of the original triangle to the center of the circle. Notice the line (solid and bold), which forms half of the base of the triangle. Both of these lines are radii of the circle. Thus, they have the same length.

**Step 2.** Since the dotted, bold line and the solid, bold line are the same length, the little triangle on the left side of the figure is an “isosceles” triangle. Angles “a” and “a” are thus equal because Thales had previously proven that isosceles triangle have equal angles adjacent to their equal sides.
Step 3. Repeat steps 1 and 2 for the new triangle in Figure 2 to show that angles “b” and “\(b\)” are equal.

Step 4. The angle C in Figure 3b is the sum of angles “a” and “b.” See the top of the triangle in Figure 3a.

Step 5. From previously proven theorems, Thales knew that the sum of all three angles of a triangle equal two right angles. Thus, for the large triangle in Figure 3b,

\[
2 \text{ right angles} = C + a + b \quad \text{(sum of the three angles)}
\]

\[
= [a + b] + a + b \quad \text{(substituting for C)}
\]

\[
= 2 (a + b) \quad \text{(combining like terms)}
\]

\[
1 \text{ right angle} = a + b = C \quad \text{(dividing by two)}
\]

Thus, angle C is a right angle.

The statement “An angle inscribed in a semicircle is a right angle” has now become a theorem. (A theorem is a proposition that is proven via logical argument based on initial definitions and previously proven propositions and theorems.) The new theorem can be used in future mathematical proofs.

To summarize, mathematicians may or may not use the inductive reasoning of scientists to arrive at a conjecture, but they do not stop there. Mathematicians go on to use the type of logical, deductive reasoning shown above to establish theorems that are true for all time.

**Outcomes**

Whatever field mathematicians study and however they study it, they want to understand it, and quite often the reasoning in a mathematical proof shows why the results hold and on what they depend. Hence, a mathematical proof can both verify a result and also give insight into what makes the result work. Since pure mathematicians have quite often found that results born in abstractions have eventually found applicability in surprising places, they are quite happy to study topics that seem to have relevance only within mathematics itself. Applied mathematicians, in contrast, seek to use the type of insight mentioned above to find ways in which mathematics can be applied in a whole range of different areas.
As stated by Brown and Porter, “It is not generally recognized how much of a part mathematics plays in our daily lives. Some of the mathematics is of course quite old: every day we use numbers, graphs, addition and multiplication. It is easy to forget that the invention of these was at one time a great discovery.” For example, bookkeeping systems were not possible before Arabic numerals replaced Roman numerals. (Think about how difficult it would be to add a column of numbers, such as 11, 8, and 23, if they were written XI, VIII, and XXIII.) Physics, statistics, and engineering depend heavily on modern mathematics, for example error correcting codes in CD players and imaging and category theory in design of the next generation of computer programs and software. Business and economics—from currency trading to budget making to the distribution of goods—are also highly dependent on high-level, often quite abstract mathematical reasoning.

Quality Control

How do mathematicians know that their reasoning is correct? While the following discussion focuses on proofs, the same type of verification, albeit less formally presented, is also used in problem solving and in applied math. In all cases, the key is a logical development of ideas.

How do mathematicians know the reasoning in a proof is correct? Mathematical proofs are written by humans, and humans are fallible. Proofs can be long, even hundreds of pages. If the work is directly related to an application, the proof has a sort of test by seeing whether its prediction holds for the application. Conjecture, like a scientific theory, is strengthened by confirming evidence, but not assured in a mathematical sense (or a scientific sense, for that matter). The result might not hold true for unexamined cases.

How, then, is a mathematical proof of a general result determined to be all right? Mathematical facts most often involve an infinitely large number of cases, so it is not possible to show that the proof is all right by checking even several cases. The usual procedure for evaluating proofs is to have other mathematicians examine the work. A mathematician might give a research talk to colleagues, inviting them to examine her reasoning. She might circulate the work to other experts in the field, who then examine the work quite critically, seeking errors in reasoning or looking for unstated assumptions that might not always be true. Eventually she would submit the work to a technical journal for consideration for publication. The journal editors then look for experts who review the work anonymously. The author-mathematician is not told who these reviewers are so that the reviewers can be critical without fear of damaging a relationship with someone they might know (most experts in a field know the other experts in that field). The hope is that all of this checking, even though it is done by other humans, catches every shortcoming in the reasoning. Even though it is certainly possible that several experts can miss some error, a mathematical result that survives this review process can usually be counted on to be correct.

While some proofs are very long and complicated, mathematicians ultimately strive for the most concise proof. “The highest compliment that a mathematician can receive about a theorem he has developed is, ‘It is beautiful,’ or ‘It is elegant’” (Selzer 11: 445).
Works Consulted

http://www.bangor.ac.uk/~mas010/methmat.html.


Science

Explanation of the Natural and Physical World

Introduction

“Science” comes from the Latin word “scientia,” which means skill, knowledge, or expertise. Science is defined as “the systematic knowledge of the physical and material world” (Stein 1279). Scientists believe that all basic rules of the universe are the same and constant. However, finding out these "rules" is a process of constant questioning, refining, modifying, and discarding of ideas based on evidence gained by observing the natural world.

Goals

Science disciplines differ from one another in what is studied, techniques used, and outcomes sought, but they share a common purpose and philosophy, and all are part of the same scientific enterprise. The primary goal of all scientists is to explain how the natural world works. While satisfying their own curiosity and earning professional recognition may be the primary driving forces, some scientists may also hope that their discoveries will ultimately lead to products or ideas that improve the quality of human life or protect the biosphere.

- Physicists usually study motion, energy, forces (including electricity and magnetism), waves and optics, nuclear forces and particles.

- Chemists study the interaction of electrons and electron fields, how atoms combine, how the atomic structure of materials relates to the physical and chemical properties, etc. They also carry out chemical reactions to produce chemical products.

- Biologists study living things. Their investigations range from subcellular biochemistry to the whole biosphere.

- Earth scientists study the Earth and its systems, including processes and materials. Their investigations focus on the solid earth, the oceans, the atmosphere, and other planetary bodies. (Stars, which are run by nuclear reactions, are usually the province of physics.)

Although each scientific discipline provides a conceptual structure for organizing and pursuing knowledge, all scientists study many problems using information and skills from many disciplines. Scientific disciplines do not have fixed boundaries; new ones are being formed where existing ones meet. Some sub-disciplines spin off to become new disciplines in their own right.

Students should note that some things cannot usefully be examined scientifically, including matters of morality and matters that cannot be tested objectively. Scientists deal with physical or natural phenomena, not philosophical or religious issues. However, science can inform ethical decisions by predicting likely consequences of actions.
**Products**

Basic research takes place at academic institutions (colleges and universities), other public or private research institutions (e.g., Los Alamos Laboratory, Carnegie Institute), and more rarely at corporate laboratories (e.g., Bell Labs). Academic scientific writing is very precise and usually concise. Most scientific results are published as short articles in scientific journals. Review articles, which summarize and evaluate earlier articles in the field, are also published periodically. (John has a different version of the

Applied science takes place in many different setting. Scientists who work for industries often combine science with technology to create new products or improve current products. Scientists working for industries, the government, and private environmental groups use scientific approaches to study and mitigate problems. Those working in medicine and biotechnology look for new medicines and treatments for human illness.

Over the centuries, the work of scientists has become more and more specialized with the result that today it is very difficult for lay persons, and even scientists in different fields, to understand new developments. Popular scientific magazines, such as *Scientific American*, and books, like *The Panda's Thumb* by Stephen J. Gould, help the public understand and, in a democracy, vote on issues affected by science and technology.

**Processes**

The “scientific method” that most students study in their introductory classes is generally thought to have been developed at about the time of Sir Isaac Newton. The method comes from the interplay of two forms of reasoning: inductive and deductive. If a person performs a set of observations, organizes them, and comes to a generalization, we say he used inductive reasoning. If instead a person proceeds from a few basic principles and argues logically to a conclusion, we say he used deductive reasoning. The most successful scientific ideas have arisen when a combination of both forms of logic is used.

All peoples make sense of their world by asking questions, making observations, drawing simple inferences from their observations, and predicting what will happen in new, but related, situations. Professional scientists, however, typically carry out these inductive activities at a more sophisticated level and also use deductive reasoning to design and carry out formal investigations with carefully controlled variables. As you read the following section, try to define each of the underlined terms; then, when you read the subsequent section, check your definitions.

The formal scientific method involves creating a hypothesis, designing one or more investigations to test the hypothesis, carrying out the observations required by the investigation, and finally deciding whether the data support or refute the hypothesis. Usually, scientists predict the results they expect to see in their investigation if their hypothesis is correct and, in some cases, if an alternative hypothesis is correct. They redesign their investigation if their predictions suggest there will be inadequate observable differences to distinguish between the two hypotheses. There is a lot of trial and error, recycling back to make extra observations, repetition to obtain reproducible data, etc. If a hypothesis is shown to be correct, it and other related, correct hypotheses may ultimately lead to a theory. The development of a theory is usually a collective endeavor, rarely if ever due to
one individual's efforts. To be fully accepted as a scientific explanation, most theories include an explanation of how something occurs; i.e. a mechanism. Scientists frequently help their reader understand a complex theory by creating a conceptual model; i.e. a somewhat simplified, visual representation of the processes occurring.

In order to understand the scientific method, students need to differentiate between scientific terms, some of which have only subtle differences. The following definitions and example should help.

Hypothesis: A hypothesis is a testable conjecture put forth as a possible explanation of certain phenomena. It serves as a basis of argument and further observation and experimentation. For example, in studying how people perceive light, a person doing preliminary work may observe that the eye perceives a “yellow” spot on a screen when red and green beams of light are overlapped. The investigator might hypothesize that the structure of the eye is responsible for this result.

Investigations and Experiments: Investigations will be defined as situations where a single specific observation or series of observations is made. Experiments will be defined as situations where comparative observations are made. In testing the above hypothesis, researchers would probably determine what colors are perceived when pairs of two different colored lights are overlapped. They would observe that red plus green is perceived as yellow, red plus blue is perceived as magenta, and blue plus green is perceived as cyan. They would also observe a large body of other observations, such as red plus yellow is perceived as orange.

Inference: An inference is a conclusion based on logical analysis of all available observations and previously formed theories. Inferring is the most challenging and creative aspect in scientific investigation. The investigators need to recognize and predict patterns. They need to create generalizations based on all the evidence. In the above example, if they are clever they would draw an inference that red, green, and blue beams can be used to create all the other colors merely by overlapping beams of different intensities. They would try to include a mechanism as a part of their explanation.

Mechanism: A mechanism describes the underlying molecular structure, force interactions, etc. that explain how something occurs. In our example, the scientists would have to research the published scientific literature or collaborate with biologists to discover that the retina in the eye has three distinct receptor cells, one of which absorbs light in the red region of the spectrum, one of which absorbs light in the green region, and the third of which absorbs light in the blue region.

Theory: A theory is a well verified explanation that accounts for all known observations and well-verified hypotheses. Ideally, a theory allows predictions in new situations. In the above example, the theory would state that the eye includes only three types of color receptors: one for red, one for green, and one for blue. The theory would explain the perceived “yellow” color by saying that the red-type receptor and the green-type receptor receive equal intensity light and send equal signals to the brain, which perceives “yellow.”

Conceptual Model: A conceptual model is a descriptive representation of how or why a phenomenon occurs. Investigators might draw a diagram of the retina showing equal numbers of red-type, green-type, and blue-type receptors lining the retina of the eye. They could draw equal
size arrows reaching the red-type and green-type receptors, but nothing reaching the blue-type receptor, to indicate that the same intensity light is hitting only the red-type and green-type receptors. They could also show the two receptors sending equal signals to the brain and a light bulb with “yellow” in the center to represent the color perceived. The drawing would show diagrammatically the processes described verbally in the theory.

**Prediction:** A prediction is what scientists expect to see in a given situation if their hypothesis or theory is correct. In the above example, scientists would predict that equal intensity green light and blue light shown on a screen would be perceived as cyan light. (If tested, this is indeed what they would observe.)

Understand that creativity in science comes both from being able to design an investigation that has never been done before, sometimes with new technology, as well as the insight to draw inferences from and explain what is observed. Robert Pirsig makes the following insightful comment: "The formulation of hypotheses is the most mysterious of all the categories of scientific method. Where they come from, no one knows. A person is sitting somewhere, minding his own business, and suddenly—flash!—he understands some thing he didn't understand before" (113). He goes on to say, "The data stays the same but the explanation changes dramatically" (136). Creation of scientific explanations requires not only organization of observations but also flashes of creative insight. The truly great ideas may even have an aesthetic quality—they so beautifully and concisely explain phenomena that heretofore had been unexplainable.

Be aware that there is no rigid sequence of steps that all scientists take. Scientists are people and, like all people, tend to follow exciting leads and interesting problems. They have human motivations, interests, and emotional attachment to their work. Furthermore, scientific problems are different from each other. Progress requires a variety of approaches and techniques—and sometimes new technology. To some extent, success in science is based on luck. However, luck is usually informed by intuition and skill. Scientists must be able to ask the right questions at the right time and then be able to follow through by designing an investigation that will help answer their questions.

**Outcomes**

The value of science, to a large extent, is its power in allowing people to make correct predictions as to what will happen, or be observed, in new situations where similar scientific ideas are expected to apply. All societies, from the modern and technological to traditional to hunter-gatherer, survive based on their abilities to observe, infer, and predict effectively.

Everyday people make observations and draw inferences. This process is the essence of science. The generalizations and rules they create allow them to predict what will happen in new situations and, thus, to live better lives. Professional scientists go beyond simple generalizations to discover fundamental scientific ideas that can be used to explain why and how phenomena occur. The body of scientific knowledge that is continually expanding has facilitated the development of a wide variety of technologies and products that influence every aspect of modern life. While most scientists pursue basic explanations of physical and natural phenomena, some of these ideas are
sooner or later developed into new medicines, treatments for disease, solutions to environmental problems, and technologies.

**Quality Control**

Scientific ideas, to be any good, must be based on reproducible, reliable observations and must provide a valuable explanation of the phenomenon, an explanation that is useful in predicting and explaining future observations.

**Valid observations.** Researchers always repeat their experiments (usually 3-4 times once they get the method working consistently) and/or make additional observations until they are convinced that their data is reliable. In LS courses, comparisons of the data obtained by the various lab groups serve this same purpose. If data from one group disagrees with that of all the others, that group is asked to check its procedures and repeat the activity. Usually, the problem that caused the spurious data is discovered.

**All the data.** Scientific ideas must satisfactorily explain all the data, not just that which is consistent with a proposed scientific idea! In LS courses, students learn to challenge other groups’ ideas based on observations that may have been overlooked.

**Simplicity.** Ideally, scientific ideas and models should be aesthetically pleasing. Occam's razor states that if two ideas equally account for all the data, then the simpler idea should be chosen.

**Mechanisms.** To be really useful, a model needs to include a mechanism. Mechanisms provide a means for understanding the unseen features that allow a phenomenon to occur. For example, Darwin’s theory of natural selection describes how preferential reproduction of individuals best suited to a given environment can account for evolution. (Note that the idea that species evolved and changed was widely accepted before Darwin—there was fossil evidence showing this; what Darwin added was the mechanism or explanation: natural selection.) The domains model for magnetism provides a mechanism that depends upon the behavior of the atoms in ferromagnetic materials. The plate tectonic model explains how movement of plates past each other can account for the past and current features of the Earth’s surface.

**Predictive Power.** The best scientific ideas and models are so powerful that they provide a way to make accurate predictions in new situations.

Before submitting a paper, scientists ask colleagues for feedback and revise the paper based on their comments. They then submit the paper to a journal. The editor of the journal sends the paper anonymously to two or three experts in the same field for review. They may accept it, ask for revisions, or reject it. Once the paper is accepted by a journal and published, the scientists' work is open to evaluation by other scientists throughout the world. Science is, therefore, a collective and social task.

Evaluation and revision are an essential part of the scientific method. "Accepted" theories come about by a continual back and forth discussion among scientists, each carrying out investigations that produce evidence that either is inconsistent or consistent with the current theory. Scientists don't ever "prove" theories; they gather enough evidence to support a theory. All available data
(evidence) must at least be consistent with the theory. Constant addition of new knowledge (data, evidence) and, if necessary, correction and revision of ideas is the means by which scientists understand more and more about the basic rules of the universe.

Scientists are not considered "good" or "bad" based on whether they first thought up the idea that becomes an accepted theory. However, a scientist may be considered a better scientist if he/she is associated with a theory that elegantly explains all available data. A scientist is criticized by his/her peers (and /sometimes censured) for things such as: coming to conclusions not based on "valid" data, poor design of an investigation/experiment, use of "faked" or manipulated data, and plagiarism. The success of science and technology in the world arises from the constant self-correction that is built into the scientific process.

Works Consulted


The Visual and Performing Arts
The Illumination of Enduring Human Concerns and Possibilities

Introduction
The word “art” is derived from the Latin *ars*, which means skill, craft, technique, practice. However, there is more to art than skillful construction. To be art, something must be well done, but it must also communicate some kind of beauty or emotion in addition to the world of everyday life and ordinary things. Not everything that is skillfully done is art. Well-crafted, mass-produced tract houses are not “art,” no matter how skillful the carpentry is. Art reflects above-the-ordinary attention on the part of the maker, the user, and the viewer.

Goals
Art is more than an artifact of merely emotional, subjective expression. Pre-20th century painting, for example, was an attempt to depict visually scientific truths as seen by the artists of that time. Thus, their goal may have been to create a record of their time. Artists may strive to evoke emotion, communicate ideas, present unique perspectives on reality, or portray alternate realities. They use various media to relate their thoughts in ways that they hope will affect their audiences.

Products
Truly great pieces of visual and performing art, like great pieces of literature, are those which have stood the test of time, communicate to people on many levels, including behavioral, psychological, scientific, cultural and aesthetic. The “arts” are included with literature in the broader category of *the humanities*. There are two broad categories into which the arts are divided. They are:

- **The Plastic Arts**
  Plastic artists work with tangible things that can be manipulated or changed. Some artists make two-dimensional works, such as paintings, mosaics, or photographs. Other artists make three-dimensional objects, such as sculptures, mobiles, pottery, jewelry, or textiles. Sometimes artists create especially fine versions of things that ordinarily are not art, such as furniture and clothing. Furniture and clothing exemplify objects that can be raised to the level of art if they are extraordinary in their conceptualization or execution.

- **The Performing Arts**
  Performing artists create above-the-ordinary *experiences*, such as musical sounds, dances, or dramatic performances. They can rise above mere background elevator MUZAK (in the case of music); they can rise above merely moving and jumping around (in the case of dance); and they can rise above merely pretending and mimicking (in the case of drama). Music, dance, and drama can incorporate each other or include the plastic arts. However, fundamentally the performing arts *are* the performances; that is, the set of transitory sights and sounds experienced once in time. If one writes a musical score, that itself is not the music; it is a set of clues for talented musicians and conductors to use in trying to recreate it. The same thing is true with a play, which needs to be performed if it is to be really appreciated. Dance is even more clearly the performance and not the record of clues about how to recreate that performance. Dances have to be performed continually by people who remember them, or they have to be filmed or videotaped.
Process

Art has to be made from something. A plastic artist’s above-the-ordinary skill in physically changing the material with his own hands is thought by many people to be a vital part of making “art.” The artist’s talent in manipulating the material makes the object above-the-ordinary. Most artists employ similar habits that writers have in that they first develop a “rough draft” of what they want to create. They must also consider types of media that will best portray what they want to express. Painters, for example, must consider the type and size of canvass, the type of paint mixtures to use, and the shades of color. They are also mindful of how viewers will “see” their work and how to best present it. However, there are some kinds of artists who do not make finished products with their own hands; they rely upon other people to actually make the objects. Architects, product designers, and interior designers work in this way; they work with what other people will manufacture or have manufactured. Composers, playwrights, and choreographers also fit into this category.

Artists approach their work in different ways using different media. What artists have chosen to communicate has varied during different historical eras. While the visual and performing arts are very different from one another, they exhibit certain basic distinctions that tend to occur during certain eras. Being aware of these styles helps viewers understand the works of art they study and enjoy.

The process an artist employs depends on the media through which s/he chooses to communicate with his/her audience. Principles in visual arts include: balance, repetition, contrast, emphasis, and unity. Works of art are organized in terms of line, color, value, space, texture, shape, and form. A musician chooses particular instruments and considers pitch, rhythm, and timbre in creating music and must know how to make appropriate notations so that others can bring his/her creation to life. In theater, the process of lifting a script to life includes: acting, directing, design, and scriptwriting. In dance, dance, space, time, levels, and force/energy are counterparts of production. These are the elements that painters, sculptures, photographers, composers, musicians, playwrights, directors, actors, choreographers, and dancers work with in creating their works of art.

Outcomes

Perhaps a way of defining the extraordinariness of art is to say that the world would be boring without it; the world would be too ordinary. Humans’ natural tendencies to beautify and transcend the ordinary, both in what they make and in what they want to elicit from other people, naturally lead to art.

The utility of art is hard to define or capture. It is what we do not need to do for reasons of utility but find worth doing anyway for reasons that we don’t really understand. We can stand back and say, “Wow, imagine someone having the skill to do that!” We can wonder how an artist, composer, playwright, or choreographer could have the insight and ability to excite a certain feeling or response in us, sometimes even years after we experienced it. In art, we can lose track of time. We seem to escape mortality for a while, becoming part of a larger set of human talents and appreciations linked together across the centuries. Of course, not everyone likes every kind of art and not everyone is able to produce every kind of art.
Art may give people a reality check as it did for Goya’s viewers in the nineteenth century when he created his etchings of the Spanish Civil War. Originally a court painter, he created idealistic renderings of the Spanish royal family until, subsequently, he used his talents to depict the horrors of humanity at a time when Spaniard fought Spaniard in utter brutality.

Quality Control

A question we might ask in evaluating art is: “Does this do it for me, or am I simply going through the motions in trying to make (or appreciate) this thing?” This is a subjective question but a real one nonetheless. The evaluation of art may be subjective and vary from one person to another, but it is still real. Doubtful cases, where someone’s opinion is definitely “yes, this is good art” and someone else’s is “no, it is bad art” are usually infrequent. This is especially true among people who have analyzed a particular genre of art for years, in large part because they like it and have a special affinity for it.

Art experts may or may not be able to produce art themselves, but they know what they like. They have thought through the relevant questions of “aesthetics” (the theory of beauty). The experts are able to give informed aesthetic judgments, and they usually have some fairly detailed knowledge of production techniques and of what is special about a particular art genre. For example, experts on opera know that it is unique because the audience can hear and easily follow the contradictory thoughts inside multiple peoples’ heads simultaneously.

In forming their judgments, art critics rely not only on aesthetic theories about the nature of the genre in question but also on a good working knowledge of earlier examples of art and of the achievements of different artistic schools—“the best that has been thought and said,” in the words of Mathew Arnold. Critics keep these examples in mind for purposes of comparison and because they love them.

Further Reading

