Using Numbers to Teach Critical Thinking

Many of the students who enroll in our statistics classes feel great anxiety about their ability to deal with mathematical concepts and numbers in general. When they see a number written on the board, their eyes glaze over or they begin to panic. Consequently, they are unable to use numbers as tools for dealing with concepts presented in class.

In speaking with such students, we find that they usually trace the origin of their math phobia to elementary or secondary school and the attitudes they developed about numbers there. They learned, either consciously or unconsciously, that dealing with numbers and mathematics was not fun, not practical, and not easy.

One of the major functions of elementary and secondary schools should be to develop in students an appreciation of how numbers (mathematics) function in society and how they can be used as a tool in problem solving. At the same time, students can learn techniques for critical thinking. Mathematics is especially appropriate for teaching critical thinking, because of the precise nature of the content and the possibility of building logical arguments for and against certain points of view using measurable data.

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Why Do We Believe as We Do?

Most people make decisions on the basis of what they believe to be true in a given situation. The philosopher Charles Peirce has outlined four sources commonly used as the basis for truth.[1] These can be described as tenacity/folklore, authority, intuition, and the scientific approach. An additional basis could be called absolute truth. For some people a basis for arriving at truth may not be observation or reasoning but impressions or revelations from God, which are accepted by faith.

Tenacity/Folklore

Many people feel that what they and other people in their culture have always done is the correct thing to do. They drive the same make of car as their friends and support the same political party as their parents. For people who make decisions based on tenacity or folklore, numbers

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have little value except as a reinforcement for what they already believe. Such people use numbers "in much the same way that an inebriate uses a lamp pole: more for support than for illumination."[2]

Authority

Authority is a powerful word in most societies. If someone wearing a doctor's coat in a TV commercial tells viewers to take a certain brand of aspirin for a headache, many of them will do so. This method works well if the authority is trustworthy, but in many cases competing authorities offer different recommendations. In such cases, people's chances of choosing correctly depend on which authority they believe. Frequently it is difficult to identify the proper authority to use for a given decision.

Intuition

Many people feel that they are capable of arriving at truth if they give adequate thought to the problem. They believe God has given human beings minds that can find self-evident truths without relying on experience.

Each of the methods described above has its place in decision-making. For example, the decision to eat with chopsticks or a fork is probably best decided by tenacity/folklore. Whether or not a child should watch the late movie on a school night is probably best decided by listening to an authority (the parent). Decisions in which feelings or attitudes are important, such as the color of a new car, might best be left to intuition. However, in modern society a fourth method has come into increasing prominence, largely because of its reliability as a basis for making many types of decisions.

Elementary and secondary schools should develop in students an appreciation of how numbers (mathematics) function in society and how they can be used as a tool in problem solving.

Scientific Approach

The scientific approach is basically a method of developing questions or hypotheses, collecting data that relate to the questions being asked, and drawing a logical conclusion based on the data. In many, if not most situations, the scientific approach depends on data that are collected and reported in terms of numbers. Intelligent consumers in today's society are bombarded by results of research studies reporting data that try to convince them to believe something to be true. Statistics are cited to influence people to vote for a certain political candidate, shape public opinion on the effects of acid rain, or promote the nutritiousness of one brand of breakfast cereal over another.

Since so much of what we believe is based on the scientific approach, we—and our students—need to understand how numbers are used to describe the information that has been collected. Critical thinking skills are especially important in analyzing the data presented.

We cannot avoid using numbers in a search for truth or as a basis for decision-making in many areas of society today. Teachers in all subjects can help students develop the mathematical tools and critical thinking skills needed to deal with the information explosion.

Reactions to Numbers

People react improperly to numbers in one of three ways: faith, anxiety/confusion, or distrust.

Faith

Some people are convinced that numbers are exact and "scientific." Therefore they think that any use of statistics by an authority figure such as a television reporter should be accepted as true, without evaluation, especially if the numbers are based on research.

Anxiety/Confusion

Another group of people cannot understand the meaning of numbers cited in television and popular magazines, so they act as though the figures do not exist. Attempting to deal with the information rationally would cause them anxiety or confusion, so they try whenever possible to minimize their exposure to any kind of statistics or numbers.

Distrust

Others feel that politicians, the media, advertisers, or researchers—anyone who uses numbers—is trying to trick or mislead them. One particular book title has captured the hearts of the critics of numbers: *How to Lie With Statistics*.[3] Such people use this phrase to buttress their distrust of numbers by saying, "You see, numbers can be used to say anything

you want them to say."

However, the same logic could be used to arouse distrust of words. Someone could write a book entitled, *How to Lie With Words,* but it probably would not sell very well because it is so obvious that most lies use words. Few people would suggest that we avoid using words or become paranoid about their meanings simply because they can be used for lies.

Whenever a large body of facts is summarized and presented, the facts can be distorted because of the ignorance of the receiver or the malice or carelessness of the presenter. This is no less (but also no more) true when the facts to be summarized are numbers rather than words. In dealing with both numbers and words, teachers should inform students about the traps for the ignorant receiver and the tools of duplicity used by the malicious or careless presenter.

Teaching about communication and the use of words is not just the job of the English teacher. Every teacher should help students learn to use words wisely and precisely to communicate ideas.

The same approach should be used in dealing with numbers. Like words, numbers are useful tools for conveying precise meanings. While the mathematics teacher will teach many aspects of the meaning of numbers, other teachers should encourage proper use of statistics and numbers as appropriate in their disciplines. In our information-based society, students must learn the function that numbers play in decision-making in many areas of life.

How Numbers Can Mislead

To help students avoid being misled by numbers, teachers should show them how this takes place. Two major ways numbers can mislead are through inaccuracy or improper interpretation.

Inaccurate Numbers

Inaccuracy can result from errors in calculation, deliberate falsification, or poor procedures for collecting the data used in calculating the reported numbers.

Inaccurate computations and deliberate falsification occur infrequently, but poor data collection procedures are fairly common. Teachers need to help students explore the source of the numbers that they deal with in any subject under discussion—whether it be history, home economics, English, science, or auto mechanics. It is helpful to discuss the ways the researchers arrived at the numbers to determine whether the figures are a trustworthy basis for decision-making.

Television ads provide excellent examples for discussion. When an announcer says that 8 out of 10 doctors, or 80 percent of doctors surveyed, recommend a certain product, you can probably assume that the statistic is accurate. However, you might ask your students whether more than 10 doctors were actually interviewed, and what method was used to select the doctors. If only 10 doctors were surveyed and all of them worked for the same hospital or research laboratory, you might decide to ignore this particular statistic in making a judgment about the product.

Mathematics is especially appropriate for teaching critical thinking.

Statistics can be used to dazzle consumers, while "fine print" nearly contradicts the claims being made. If 85 percent of those expressing a preference chose Silky Legs pantyhose, the unwary buyer may be so impressed by the percentages that she fails to wonder how many people had a preference. A gum that advertises it has more sticks per package doesn't mention that they are smaller than those of a competitor. All too many car buyers have experienced a rude shock when comparing their actual gas mileage to "EPA Estimates" advertised by the manufacturers, despite disclaimers that "Your mileage may vary."

Few people intentionally misinterpret information, for fear of lawsuits or other negative reactions. Commonly, however, certain cautions are left unsaid. These may relate to the interpretation of the data or the reporting of selective information. The reason for this manipulation of statistics is the hope that the listener or reader will interpret the numbers in a specific way. This might not happen if the cautions were given or if all the information were presented.

For example, a newspaper may report that test scores in the local public schools have fallen over the past four years and express concern that students may be receiving an inadequate education. They may even present a table or graph to make a dramatic impact.

What they may omit, however, is data showing that the school system still has the highest averages in the state, and had shown improvement for each of the previous 20 years before the current decline. They also may fail to specify whether the same percentage of students has taken the test over the course of the periods being compared. If only the top 25 percent of the county's scholars took the test until four years ago, and the test has recently been expanded to include 55 percent of the students, then the report does not use a valid basis for comparison.

In cases like this, teachers should help students understand the need to interpret the numbers before accepting or rejecting the conclusions or interpretations given with the numbers. They need to be aware that additional data might shed more light on an issue or expose a bias on the part of a reporter or politician. Teachers can suggest sources for students to pursue in trying to draw their own conclusions about the multitude of numbers they encounter in an information-oriented society.

Teaching Critical Thinking Using Numbers

Following are some examples of how numbers can be used to teach critical thinking in a variety of subject areas and grade levels.

Misuse of the Term *Average*

Most students are familiar with the term *average.* A simple demonstration of the difference between the mean, median, and mode to determine "average" family size may encourage critical thinking when encountering that term in advertisements and newspapers.

Select five students to role-play membership in a group for which the "average" number of children in a family is to be determined. Have the students come to the front of the room. Give each child a large card with a number (12, 12, 3, 2, or 1) written on it to indicate the number of children in his or her "family."

Have the students hold up the cards in numerical order. Tell the class that you would like to describe the "typical" family size in this group with one number (the average). Compute the "average" family size in three ways. First sum the numbers (30) and divide by the number

Continued on page 28

HELPING STUDENTS THINK CRITICALLY

Continued from page 6

support for the development of new ones.

4. Arrange the classroom space to encourage interaction with you, the teacher, and among the students. Place the chairs, desks, or tables in a circle, semicircle, or rectangle, so that everyone will be able to see everyone else. Allow students to ask one another questions dealing with the topic under discussion. Guide the exchanges by clarifying issues, questioning assumptions, and encouraging less-articulate students to participate.

5. On occasion, arrange the desks in clusters and provide opportunity for students to work in small groups to solve specific problems. Then request one spokesperson from each group to present a brief report.

Written Assignments

As important as oral participation is to stimulate student involvement and articulate concepts, it cannot replace writing as a fundamental mode of learning. Writing allows thought to become visible to ourselves and to others, while facilitating the analysis and evaluation of our own ideas. In today's classrooms, however, most tests, reports, term papers, and examinations tend to emphasize information recall rather than critical thinking.

Since critical thinking is a skill that can be developed and mastered through practice, teachers should design writing assignments that will require students to perform tasks of increasing difficulty. This progression will guide them through specific steps: summarizing ideas, outlining basic issues, identifying key concepts, asking appropriate questions, recognizing assumptions and biases, critiquing arguments, proposing theories, and defending conclusions.

When teachers request more short written assignments, rather than fewer, longer ones, they can better guide the students' learning and provide them with immediate feedback. Assignments should focus on real problems and issues; ideally, topics should relate to the student's own experience. It is essential that instruction for the assignments be clearly spelled out, including the subject, the materials to be read or researched, the overall approach, length, format, and deadline.

Here are some types of written assignments that will progressively foster critical thinking:

1. *Brief summaries.* Have students compile an abstract of a chapter of assigned reading, a lecture, a classroom discussion, a film, or a videotape shown in class. This involves identifying the central concepts and arranging them in order of importance.

2. *Short analytical papers.* Ask students to read one or more essays dealing with a subject, then summarize the authors' respective positions, evaluating their validity.

3. *Critiques.* Provide students with a newspaper editorial or an article written by a columnist and ask them to summarize the position presented, identify the point of view of the author, critique it, and offer a rebuttal.

The evaluation of these assignments must be prompt and explicit. Teachers should clearly indicate by writing on the margins or at the end of the paper the weak and strong points, and suggest specific ways of making improvements in future assignments.

Personal Commitment

Few teaching tasks can be more demanding than helping students develop their critical abilities. In this process, learners usually progress through four steps: (1) *dualism,* a viewpoint that sees the world neatly divided between right and good versus wrong and bad; (2) *multiplicity,* when students realize that there is uncertainty regarding the specific solution to many problems in all disciplines; (3) *relativism,* a position that acknowledges the existence of many points of view that seem equally valid; (4) *commitment,* when in the face of growing complexity of viewpoints, the student carefully chooses one position on the basis of his or her own personal values and accepts responsibility.

Happy is the teacher who has led his or her students through the process of developing their God-given abilities to think critically and to make conscious ethical choices. Such teachers are invaluable both to their nation and their church. □

FOOTNOTES

[1] Ellen G. White, *Education* (Mountain View, Calif.: Pacific Press Publishing Association, 1903), p. 17.

[2] Chet Meyers provides a useful review and a bibliography of current approaches and techniques in his book *Teaching Students to Think Critically* (San Francisco: Jossey-Bass, 1986). In this article I will summarize several of his concepts. Available selection of papers, with a wider scope, was recently edited by Arthur L. Costa, *Developing Minds: A Resource Book for Teaching Thinking* (Alexandria, Va.: Association for Supervision and Curriculum Development, 1985).

[3] *How Children Fail,* rev. ed. (New York: Dell, 1982), p. 161, quoted by Meyers, p. 9.

[4] Meyers, p. 39.

[5] Ibid., p. 42.

[6] Two helpful books on this subject are Norris Sanders, *Classroom Questions: What Kinds?* (New York: Harper and Row, 1966), and William F. Hill, *Learning Through Discussion* (Beverly Hills, Calif.: Sage, 1969).

USING NUMBERS TO TEACH CRITICAL THINKING

Continued from page 9

of students (5). This is the *mean,* which gives 6 children per family. Then compute the *average* family size by selecting the number that is the most common, 12, which is the *mode.* Then calculate the average family by selecting the middle score, 3, which is the *median.* At this point you can discuss which measure of "average" best describes the "family size" of the group or the "typical student" in the group and point out that numbers must be interpreted with care.

After the discussion, you can make up examples and let the students develop develop their critical thinking skills in deciding what the "average" might or might not mean. For example, you might clip out a newspaper article that says your community has an average of 1.78 children per family and ask where a TV reporter could find an "average" family to interview.

Misleading Graphs

Graphs and charts are good sources of information for teaching critical thinking in social studies classes. *U.S. News and World Report* is an especially good source for such illustrations.

In showing how graphs can mislead,

choose a characteristic for one of your students, such as weight, that has stayed relatively constant over a one-week (or longer) period, with slight variations. Plot the scores using the time dimension as the horizontal axis and the characteristic (weight) as the vertical axis. Make the chart appear to have a large fluctuation during the time period as shown in Figure 1.

For the initial discussion, do not put the numbers on the vertical axis of the chart. After discussing what occurred over the time period, insert the numbers, and note the different interpretation.

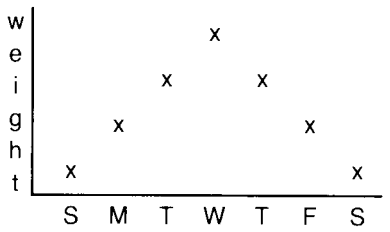

Figure 1

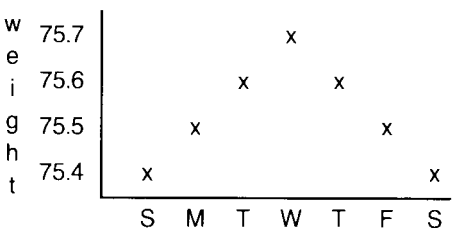

Figure 2

You can use these two charts to illustrate the importance of looking at numbers critically when interpreting graphs and charts to get the true picture of what the information is saying.

Use of Percentages

A good way to teach the importance of understanding percentages correctly would be to take some event that happens very rarely in your school or community and report changes that have occurred in it over the past two years. For example, if last year one person caught pneumonia and this year, three persons became ill with the disease, you could tell the class that there has been a 300 percent increase in the incidence of pneumonia and discuss whether public health authorities should be concerned about this trend.

In a general business or social studies class you could cite a newspaper account that reports a corporation's profits as increasing 300 percent in the past year, and discuss what this means. It may be that on $5 billion sales, last year the profit per share was 25 cents and this year it was 75 cents.

Both of these examples could be used to emphasize the importance of knowing the base number in interpreting a report that uses changes in percentages as the basis for its conclusions.

In Summary

For teachers to use numbers to teach thinking they should have (or develop) these four characteristics:

1. Appreciation for the value of numbers in decision-making;
2. A desire to use numbers when they naturally appear in the subject being taught;
3. A commitment to learn the meaning of numbers with which they will deal; and
4. A desire to include in the curriculum various techniques of interpreting data.

Of course, expertise in mathematical calculations and the background of having completed a statistics course that emphasized the practical use of numbers would also be a help. □

FOOTNOTES

[1] J. Buchler, ed., *Philosophical Writings of Peirce* (New York: Dover, 1955), chapter 2.

[2] Audrey Haber and Richard P. Runyon, *General Statistics*, 3rd ed. (Reading, Mass.: Addison-Wesley, 1977), p. 12.

[3] Darrell Huff, *How to Lie With Statistics* (New York: W. W. Norton and Co., New York, 1954).

CRITICAL THINKING AND THE MEDIA

Continued from page 11

to defend their opinions.

Teach logical thinking. Show students how to recognize hasty generalizations and biased commentary. Teach them to seek the information on which conclusions are based.

Analyzing Advertising

Explain to your students that Madison Avenue lives or dies by emotional appeals. Teach them that emulation is not always good, that fear is not always warranted, that the bandwagon is not always a sturdy place on which to stand, that status is not always a worthy target.

Bring an ad for a new car with a sexy person smiling from the front seat or draped over the hood. Then ask, "What's really on sale in this picture?" Help students see that they are shaped by the media barrage.

Looking at TV

I think we can safely assume that our students, at least in the United States, watch a minimum of 10 to 15 hours of television each week. (If you're a boarding academy teacher, your students probably make up for lost time when they're on home leave.)

Another safe assumption is that a majority of our students watch movies, either in the theater or on VCRs in the family room.

Given the above statistics, what criteria do our students use in deciding which programs and movies to watch? I suspect that frequently the main criteria is exciting entertainment value. It if titillates, watch it.

Are we willing to allow that to be the only criteria? Are we going to surrender our students' minds to a jungle for 15 hours a week without giving them some self-defense techniques?

Why not teach evaluative critique? Talk about morality, or the lack of it, and the callousing of the spirit that comes from seeing too much crime, evil, murder, and mayhem. Talk about the overdose of fantasy, the problem of too much unreality, the 30-minute solutions to complex problems.

Discuss with your students the effect of a two-minute news report about a complicated major issue, say disarmament, on our perception of that issue.

Critiquing Art

Analyze beauty in art. Help your students decide what makes a work of art praiseworthy. Help them establish criteria based on balance, variety, intricacy, vitality, universality. . . .

The arts and media offer a multitude of opportunities for teachers of any discipline: Use *Star Trek* as a case study on speed, time, distance, and space. Discuss