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Turning Spreadsheets into Graphs: An Information Technology Lesson in Whole Brain Thinking

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ABSTRACT

WE HAVE CONCLUDED that teaching undergraduate students to use spreadsheet software to analyze, interpret, and communicate spreadsheet data through a graph is an information technology exercise in whole brain thinking. In investigating why our students have difficulty constructing proper graphs, we have discovered that graphing requires two different types of thinking: analytical, logical thinking for working with data and choosing the correct type of graph, and creative, holistic thinking to construct a graph that is aesthetically pleasing and accurately communicates the meaning of the data. Common graph types and their proper usage are discussed. To improve information technology graphing, we suggest instructors teach students to fully understand the data before deciding on a message to communicate, visualize the graph before using the software to create it, and focus on the "look and feel" of the graph.
(*Keywords: information technology, whole brain thinking, spreadsheet graphing, learner-centered knowledge, cognitive psychology*)

INTRODUCTION

GRAPHS ARE A VISUAL DISPLAY of statistical information and a powerful means of communication. Constructed well, a good graph enlightens and clarifies numerical information; executed poorly, a bad graph distorts and confuses it. Before the advent of the personal computer, creating graphs was largely an artistic exercise, requiring creative skills as well as an understanding of the data itself. Today, the PC, combined with spreadsheet and graphics software, has simplified the act of turning data into a graph. Unfortunately, as we have learned through over 20 years of teaching Information Technology (IT) to undergraduates, this ease has come with a price. We have found that sophisticated programs like Excel®, while giving our students an incredibly powerful, easy-to-use graphing tool, also provide an almost unlimited opportunity to produce inappropriate, confusing, perplexing, and, at times, amusing graphs.

GRAPHING LITERATURE

The vast majority of graphing literature is concerned with the proper selection, construction, and usage of graphs and is mainly found in the academic literature, such as texts by Cleveland (1985), Henry (1995), Schmid & Schmid (1979), and Wallgren, Wallgren, Persson, Jorner, & Haaland (1996). These texts take a fairly dogmatic, analytical approach to explain and illustrate the correct graph choice and construction for a particular array of data.

The body of literature concerned with the creative design aspects of graphing is much smaller and dominated by one author, Edwin Tufte. Tufte's three major works, *The Visual Display of Quantitative Information* (1983), *Envisioning Information* (1990), and *Visual Explanations: Images and Quantities, Evidence and Narrative* (1997) are seminal works in the aesthetic and communicative nature of graphing. According to Tufte, graphical excellence:

> . . . is the well-designed presentation of interesting data—a matter of substance, of statistics and of design . . . consists of complex ideas communicated with clarity, precision, and

> efficiency . . . is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest place . . . is nearly always multivariate . . . [and] requires telling the truth about the data. (1983, p.51)

The disciplines of technical communication and science education have come the closest to merging the technical, analytical side of graphing with the human factors of communication and design. Writing about the culture of computer graphing practices, Brasseur (2001) says, "it is important for technical communicators to know more about graphing itself—both as a design process and as an interpretive act" (p. 28). Mirel (1998), in a review of the literature on usability of data visualizations, suggests that students have problems designing and interpreting graphs on the computer, because programmers emphasize student cognition skills over social and cultural factors (p. 491). Roth and McGinn (1997), researchers in science and technology education, take a social cognition view of graphing, arguing that students' perception and experience play a major role in their ability to construct and interpret graphs. We can find no literature that specifically addresses IT graphing and whole brain thinking, the major focus of this article.

IT STUDENTS

Over 20 years ago, faculty in the College of Agriculture and Life Sciences (CALS) developed the first course in computer applications at the University of Vermont (UVM). Although this course has been constantly updated to reflect the rapidly changing field of IT, one assignment has remained constant throughout—the application of a spreadsheet program to display data in graphical form.

Like most American traditionally-aged college students, our undergraduates enter CALS with considerable experience using personal computers to access the Internet, play games, communicate with each other via e-mail and instant messaging, and utilize productivity software, especially Microsoft Office programs, including Word® and Excel®. At the beginning of each semester, students are given a "knowledge quiz" as a self-assessment tool to rate their computer experience. A quarter of the students enrolled in the Fall 2002 IT course indicated that they were not familiar with any spreadsheet and graphics software program, while almost 60% said they were familiar with Excel® (Leonard & Patterson, 2004). These summary statistics of first year students are similar to those reported by the University of Arkansas (Johnson, Ferguson, & Lester, 2002).

Familiarity, however, doesn't mean competency. When asked how "proficient" they were at creating spreadsheets and communicating through graphs, the majority of our students rated themselves between "beginner" and "intermediate." This self-rating was confirmed as students did very poorly when asked specific questions about proper graphing techniques in the knowledge quiz.

COMMON GRAPH TYPES

GRAPHS GIVE LIFE TO INERT SPREADSHEET TABLES and make data more interesting by illuminating trends and patterns that are not readily apparent in a spreadsheet format. According to Tufte, "(g)raphs reveal data. Indeed graphics can be more precise and revealing than conventional statistical computations" (1983, p. 13). Whereas a table of numbers can be hopelessly perplexing, even to the experts, a graph will oftentimes highlight trends and relationships among the data, thus communicating a clear message to the most inexperienced reader. *USA Today*'s novel and colorful approach to displaying data using graphs is a prime example of the power of visual communication through graphs and is a defining characteristic of the best selling paper in America.

The kind and amount of data selected to be graphed and the story the graph constructor wants to tell will determine the best type of graph to create. What follows is a brief summary of common graph types and their uses.

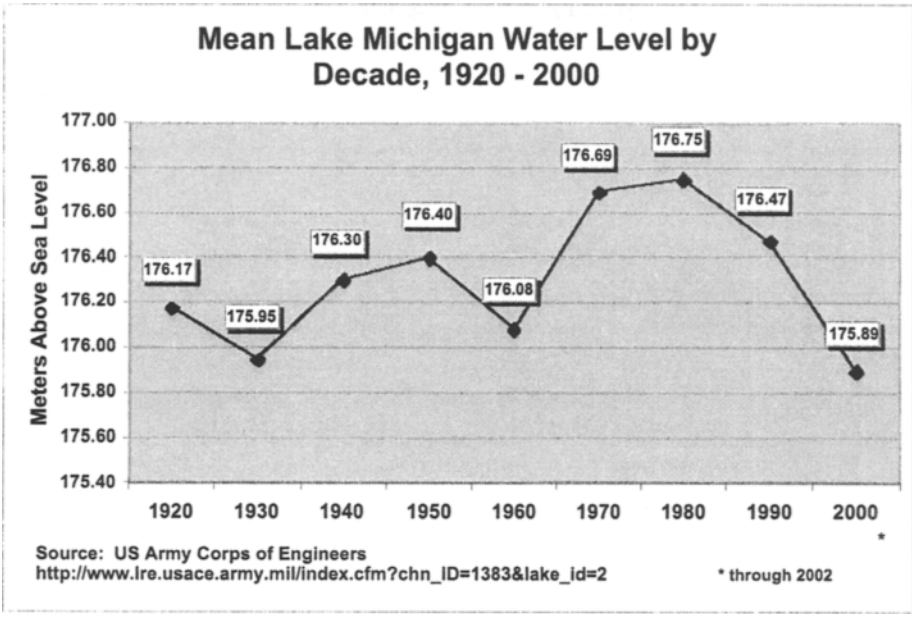

Figure 1. Line Graph Example

Line graphs (Figure 1) are commonly used to show changes in data over time. Often, trends and relationships are revealed by plotting a set of time series data using a line graph. Each line represents a category of data, and each point along the line represents the data's value at a particular point in time. Time series data, such as changes in the value of the American dollar against the Euro over the year, should be graphed as a line graph.

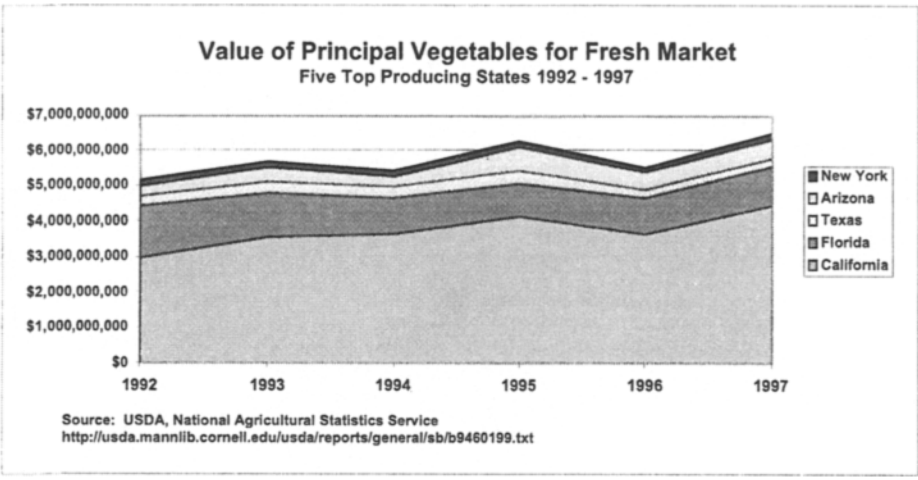

Figure 2. Area Graph Example

A variation on the basic line graph (Figure 2), area graphs utilize a series of stacked lines, each one representing a related category of data over time, with the areas between the lines filled with different colors, shades of gray, or hatch patterns. These graphs show the contribution of a set of values to the whole. The attendance at the 14 American League baseball parks over the last ten years would make an interesting area graph.

Bar graphs (Figure 3) consist of a series of columns or bars, each one representing the value of a particular category at a particular point in time. Because the length of the bar is the focus of comparison, the width of each bar should always be the same. Bar graphs are often used to compare related data and, unless there is an existing logical order to the bars, should be sorted in ascending or descending order to highlight trends and relationships. The ten longest bridges in the world as of January 2004 should be graphed as a bar graph.

Stacked bar graphs (Figure 4) are a variation of the bar graph and compare the contributions of different sub-sections of a whole, again, at a given point in time. For example, the relative size of voter turnout from each political party during presidential elections in the U.S. could be graphed as a stacked bar.

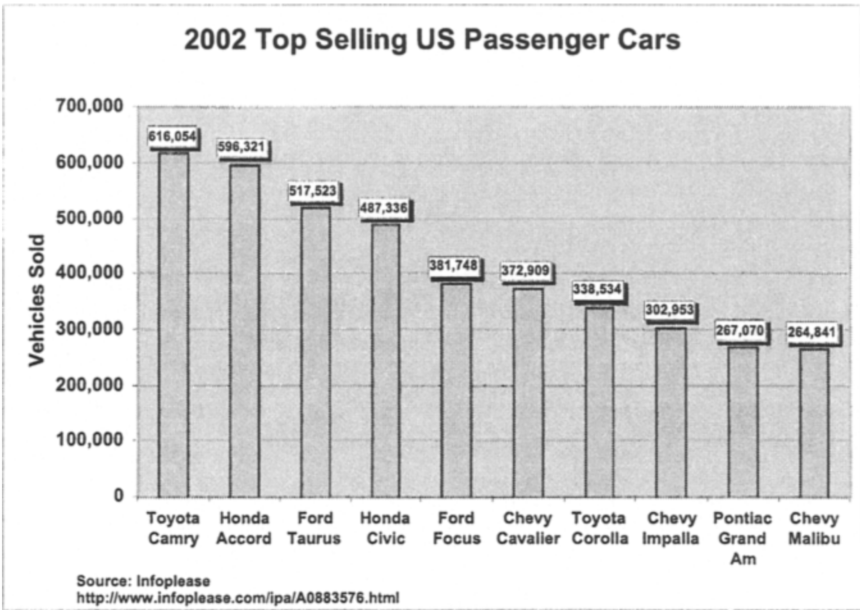

Figure 3. Bar Graph Example

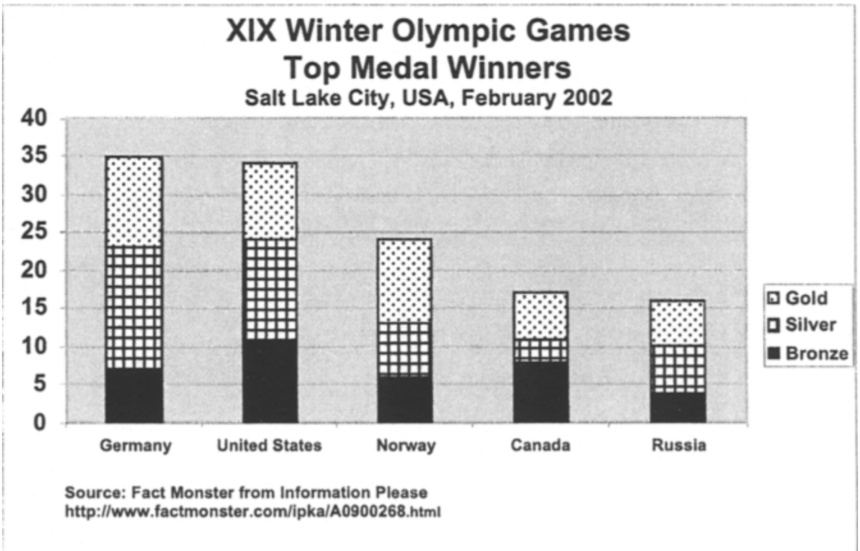

Figure 4. Stacked Bar Graph Example

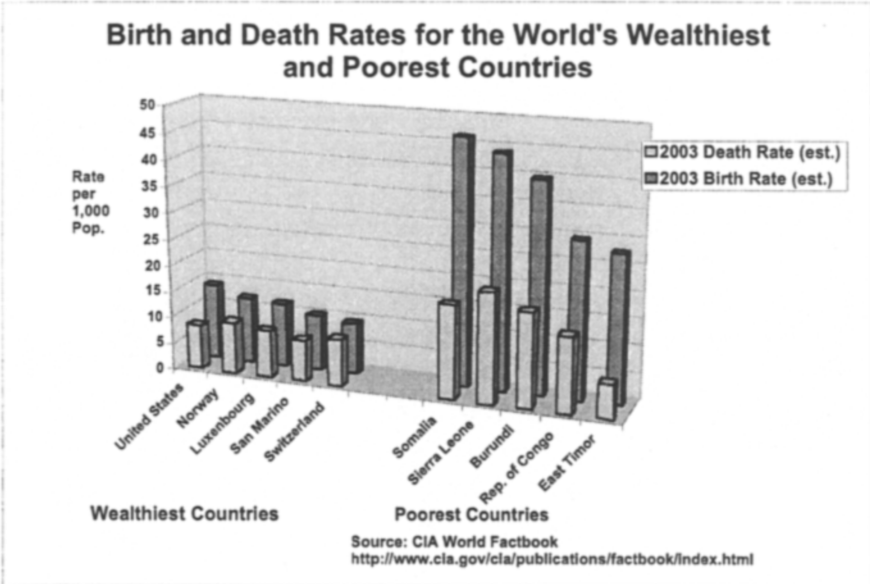

Figure 5. 3-D Bar Graph Example

Another variation of the bar graph, the 3-D bar graph (Figure 5) allows the graph maker to highlight comparisons by placing one row of bars in front of another. Comparing Winter 2003-4 accident rates at five Colorado ski areas between skiers and snowboarders would make for an interesting 3-D graph.

Pie graphs (Figure 6) compare the components of a set to each other and are used to show the percentage proportion of two or more values to a meaningful total. For example, the percentage of the human population that was distributed across the continents in 2003 should be graphed as a pie graph.

XY graphs (Figure 7), also called scatter plots, are used to show correlation or the relationship between two sets of data often with very different scales of measurement. A line of best fit will indicate the type and degree of relationship between the two sets. For example, an XY scatter plot should be used to show the correlation between birth rate and GNP per capita for selected countries.

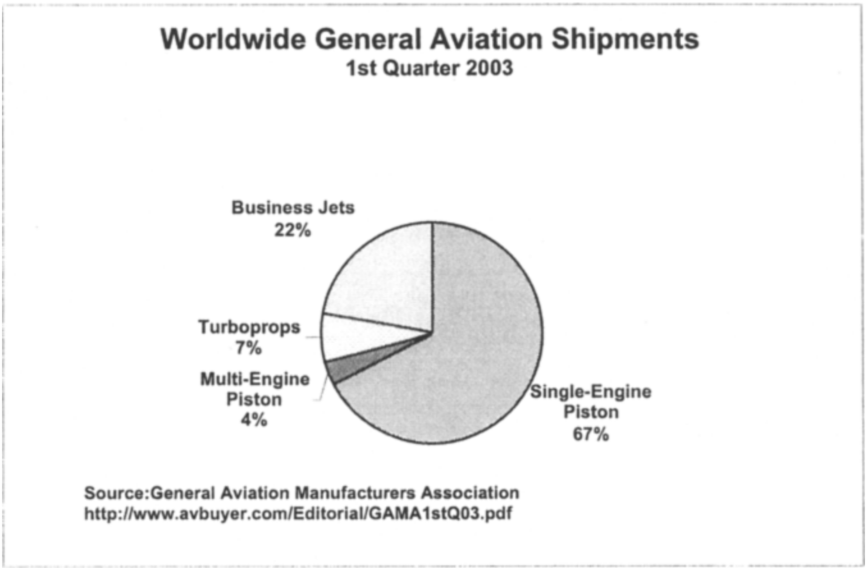

Figure 6. Pie Graph Example

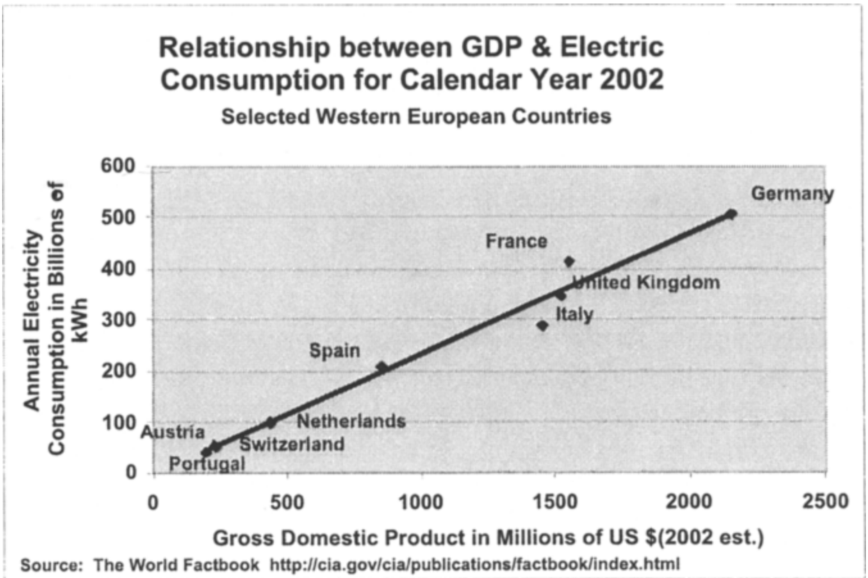

Figure 7. XY Scatter Plot Example

THE ASSIGNMENT

FOR THE IT GRAPHING ASSIGNMENT, students select, graph and then explain data found on UVM Web sites developed by the Center for Teaching and Learning (CSEQ—College Student Experience Questionnaire, CORE—Alcohol and Drug Survey, Residential Life Survey, Student Demographics, Student Government Association Opinion Poll), Institutional Studies (admissions and enrollment information, retention and graduation rates, surveys of recent graduates, UVM Sourcebook) and the Office of Financial Analysis and Budgeting (general income and expenses for UVM).

Upon close examination of completed undergraduate assignments, we have found that a very high percentage of our students make significant graphing errors using Excel®. These errors seem to cluster around two very different types of thinking. On one hand our students made analytical-type errors: selecting the wrong graph type, omitting an essential legend, forgetting to include a data source, making spelling errors, or drawing the wrong conclusion. We also observed that most of our students did not understand how to construct or correctly interpret an XY scatter plot graph. On the other hand, our students made errors in aesthetics such as: selecting too much data for one graph, adding unnecessary information or distracting embellishments, leaving pie slice labels overlapping, creating labels that were too large for the graph, or selecting colors or black and white shadings that are difficult to differentiate. Students would submit an assignment that may have been the correct type of graph for their data, but the visual presentation would be highly unusual at best or totally incomprehensible at worst.

Based on the above analysis, we have come to the conclusion that constructing an appropriate and effective graph using spreadsheet software is, in fact, an assignment in whole brain thinking.

WHOLE BRAIN THINKING

BASED ON PIONEERING WORK by Nobel Prize winner Roger Sperry, who conducted split-brain experiments with people whose corpus callosum (the connection between the two hemispheres of the human brain) had been severed by surgery, ". . . it is now widely held that the two sides of the human brain represent different modes of thinking. Each side is characterized by dominant or preferred group of functions representing a defining way of interpreting the world and reacting to it" (Trevarthen, 1990, pp. xxxi-xxxiii).

Called the brain of language and information, the left side of the brain is characterized by logic, facts, words, and language; being detail-oriented, reality based, and practical. The right side is called artistic and creative and is characterized by feelings, imagination, symbols and images and by being "big picture" oriented and spatially perceptive. People whose thinking is mainly logical and analytical are sometimes referred to as left-brained dominant, and those who are creative and artistic are called right-brained dominant (Connell, 2002). Those rare individuals who exhibit thinking and achievements equally in both realms (Leonardo da Vinci is often used as an example.) are called whole brain thinkers (Wonder & Donnovan, 1984). Subsequent attempts to incorporate additional brain models into a more comprehensive theory of thinking (Herrmann, 1996, 1990) still rely on the basic model of left and right brain thinking.

This brain dichotomy has received a great deal of attention from the popular press, which, predictably, has led to a backlash from brain researchers (Gardner, 1982; Searlman 1977, 1983; Sergent 1981; Springer & Deutsch, 1998; Young, 1983). According to Gordon (1990),

> Applications of hemispheric differences are undertaken prematurely in countless courses and books purporting to teach how to improve both hemispheres of the brain, how to compensate for a "weak" hemisphere, or how to use a left-hemisphere mode for a right-hemisphere task. So far, none of these attempts have been properly validated by adequate tests or methodology . . . . On the other extreme are the critics who

> feel right/left dichotomies are not only too simple and overrated, but are also fictitious. If researchers took these dichotomies at face value, the critics would be right. But specialists in the field recognize the dichotomies to be qualitative differences in basic functions of the brain . . . . What may be a semantic disagreement turns into a questioning of the foundations themselves. (p. 262)

Recent brain research suggests that certain functions, predominately found in one hemisphere in the majority of people, have been discovered to be dominant in the opposite hemisphere or to be evenly split between the two in a minority of people. For example, language, the brain's most lateralized function, " . . . resides predominantly in the left hemisphere in 90 percent of the population. About five percent have their main language areas in the right hemisphere, and another five percent split language fairly evenly between hemispheres . . . " (Ratey, 2002, p. 274).

Rather than categorizing the two brain hemispheres as possessing dichotomous functions, it is easier to imagine them metaphorically as clusters of functions or "cognitive styles" (Iaccino, 1993, p. 29) that are more strongly embodied in one hemisphere than the other. The concept of whole brain thinking, then, embraces the functions of both cerebral clusters, *regardless of where the individual brain functions are assigned.*

Teaching that engages whole brain thinking by stimulating logical, analytical brain functions as well as aesthetic, creative ones, would be called whole brain education, while teaching that does not reach both clusters equally would be considered skewed and deficient in the eyes of whole brain thinkers. American education has been accused of being too oriented to the analytical, fact-based functions of the brain, with scant attention paid to the creative, artistic functions (Cherry, Godwin, & Staples, 1989; Springer 1987; Springer & Deutsch, 1998). Conversely, art education that only includes the aesthetic and imagination would be just as deficient (Unsworth, 1996).

We believe that the act of turning an Excel spreadsheet into a graph is a unique IT application requiring whole brain thinking by requiring a balance of creative, artistic brain functions as well as analytical, logical ones.

A BALANCE OF ANALYTICAL AND ARTISTIC THINKING

Constructing a graph requires analytical thinking for the graph maker to accurately analyze a set of data, draw a reasoned and logical conclusion, and select, construct, and correctly label an appropriate graph. An equal amount of artistic, holistic, and creative thinking is required in that the amount of data to be displayed and the visual "look and feel" of the graph are decisions that follow mostly general aesthetic, subjective, intuitive guidelines. The graph designer must use whole brain thinking to find a balance between analytical details and the subjective whole, keeping in mind it is what the reader perceives which is important, not how much can accurately be included in the graph. Additionally, graphs speak directly to the eye and create a compelling picture of the data in the reader's mind. It takes artistic skill to bring out the meaning and patterns in the data most effectively. Just as a good graph conveys correct information, a bad graph misleads the reader (Wallgren et al., 1996).

TEACHING TO THE WHOLE BRAIN

Our review of student graphs pointed out a number of shortcomings that we are addressing in our instruction. In the past, by focusing on what the graphing software can do, we have spent too much time teaching to logical brain functions and not enough time looking at the visual, aesthetic side of graph construction. We now believe that students need instruction and practice in both modes of thinking or whole brain thinking. They need to able to draw a reasonable conclusion from a set of data and construct an appropriate graph that creates a clear and compelling visual message for the reader.

To promote whole brain thinking, students first need to select a set of data and fully understand its implications. "Lurking behind the inept graphic," writes Tufte (1983), "is a lack of judgment about quantitative evidence" (p. 79). Once the statistics are understood, then the students need to visualize the graph before using the IT graphing program to construct it. It is important that the students learn to utilize the software program to draw their envisioned graph, rather than allowing the program to make the graph for them by accepting the step-by-step graph wizard defaults of Excel®.

One way to do this is to give students practice where the instructor supplies the data and the students have to: (a) explain the statistics, (b) develop a message they want to communicate and (c) draw by hand what the graph should look like (Appendix A). Ideally, this should be done before introducing them to the graphing software. Also, students should be given the opportunity to critique good and bad graph examples, so they learn to recognize and correct errors in their own graphs. We believe that having students identify what's wrong with incorrect, inappropriate, or confusing graphs is as powerful a teaching technique as showing them good ones.

We also need to increase the amount of time spent choosing data sets, selecting the most appropriate graph type for the selected data set, focusing on the "look and feel" and the visual message of the graph, and establishing aesthetic criteria for graph construction. Adding a checklist for students to use in their graphing assignment may help to cut down on carelessness and simple omission mistakes as well as remind them to pay attention to graphing aesthetics and design (Appendix B).

Our experience in teaching to the whole brain is limited to one semester, but the results are encouraging. Student graph assignments were markedly improved: The number of graphs without errors rose from 3 out of 134 or 2.2%, using the old method of teaching, to 31 out of 119 graphs or 26.1%, using the whole brain method. Careless errors like forgetting to include a data source were reduced, fewer mistakes were made in data selection and graph choice, and the aesthetics of the graphs were better. In addition, the diversity of graph types was higher with some students creating complicated graphs such as XY scatter plots where none was attempted the previous year. Many students demonstrated a deeper understanding of graph construction and showed an enthusiasm for our emphasis on the visual message of graphing in addition to the mechanics of the software.

SUMMARY

A GRAPH is a visual communication medium that gives life to data by displaying patterns and relationships that are often hidden in a spreadsheet format. As IT instructors, we have been inclined to underestimate the importance of the visual, subjective nature of graph construction. Focusing instruction solely on logical brain functions, such as what the graphing software can do, has led to a large number of student errors. We have come to believe that the seemingly simple task of teaching undergraduate students how to construct a graph is actually a sophisticated assignment in whole brain thinking. Students not only have to draw conclusions from a data set and construct an appropriate graph, but they have to pay attention to the aesthetics and visual message of graph construction. Instructors should capitalize on the IT assignment to turn spreadsheets into graphs as an opportunity to teach whole brain thinking.

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Appendix A.
Graph Practice 1

1. Imagine you are interested in the religious affiliations of UVM students. You randomly sample 300 students and ask them their religious affiliation and tabulate the results as in the table below. What kind of graph would best communicate these data? Draw a picture of what the graph would look like.

Affiliation	Number of Students in sample
No affiliation	127
Catholic	56
Jewish	43
Rastafarian	2
•	•
•	•
Toaist	4

Would your graph choice be any different if you had data from all UVM students, instead of just a sample of 300?

2. You are interested in the effects of global warming. You have read that one of the potential effects of global warming is an increase in the frequency of tropical storms (hurricanes, typhoons). You decide to test this hypothesis by finding and graphing some data. You go to the National Oceanic and Atmospheric Administration's web site and World Watch's *Vital Signs* database and get the average global temperature and number of tropical storms for the years 1950-2000. What kind of graph would display the relationship (if any) between global temperature and storm frequency for the years 1950-2000? Draw a picture of what the graph should look like.

Year	Global Temp °C	Number of Storms
1950	13.87	52
1951	13.86	57
1952	13.89	63
•	•	•
2000	14.31	78

3. You get a summer job working for the Grey Fox Bluegrass festival. There are 5432 tickets sold. Along with the ticket infomation, the attendees send in a survey that includes what their primary instrument is. What kind of graph would best communicate the distribution of primary instrument of the festival attendees? The data are tabulated below. Draw a picture of what the graph should look like.

Continue on next page

Appendix A. (Continued)

Primary Instrument	Number of attendees
Guitar	2856
Banjo	968
Mandolin	1567
None	654
.	.
.	.
Washtub bass	27
TOTAL:	8432

4. You are interested in how the snow depth at Smuggler's Notch upper ski lift area changes during a typical winter. You go to their website and download the following table:

Date	Snow Depth (in.)
Oct 1	2
Oct 2	1
Oct 3	5
Oct 4	5
.	.
.	.
March 5	171
.	.
June 1	0

What would be the most appropriate type of graph to display how the snow depth changes over the winter? Draw a picture of the graph.

5. You are interested in how people have voted in the past three US presidential elections. You gather the following data from the US Census Bureau:

Year	Party	Millions of votes
1994	Democrat	57
1994	Republican	54
1994	Independent	2
1996	Democrat	62
1996	Republican	59
1996	Independent	12
2000	Democrat	63
2000	Republican	63
2000	Independent	4

What type of graph or chart would best communicate the total number of voters each year and how the party affiliations fared in the elections from 1994-2000? Draw a picture of the graph.

Appendix B.
Graphing Checklist

What is the message (description, comparison, pattern, relationship, etc.) you are trying to communicate through your graph:

Graph Choice and Construction

_____ **Graph Type** is the correct choice for message to be communicated and data selected.

____ **Title** clearly indicates what the graph is about, when and where the data were collected.

____ **Data Source** clearly indicates where the data came from.

____ **Axis Units** of the data are clear and labeled correctly. (For example: miles, liters, seconds, bits per second, births per 1000.)

____ **Axis scales** are appropriate for data variability (For example, log scale may be best for data that vary over many magnitudes)

____ **Totals omitted** where unnecessary (Pie & Bar graphs especially).

____ **Labels** appropriate for size for graph. Labels horizontal where possible.

____ **Data** are not too few or too numerous for chosen graph type. Each data point is easy to read.

____ **Text** is clear and concise. No unnecessary text to clutter graph.

____ **Legend** is only present if there are two or more series of data.

Graph Aesthetics and Design (Tufte, 1983, p. 13)

____ **Glitz** such as bright colors, distracting fonts, backgrounds, 3-D, and borders kept to absolute minimum. Simplicity rules.

____ **Graph communicates** with clarity, precision and efficiency

____ **Graph induces** the viewer to think about the substance rather than methodology, graphic design, technology of graphic production, or something else.

____ **Graph avoids** distorting what the data have to say.

____ **Graph presents** many numbers in a small space and/or makes large data sets coherent.

____ **Graph encourages** the eye to compare different pieces of data

____ **Graph reveals** the data at several levels of detail, from a broad overview to the fine structure.

____ **Graph serves** a reasonably clear purpose: description, exploration, tabulation or decoration.

____ **Graph is closely integrated** with the statistical and verbal descriptions of the data set.

____ **Graph** makes sense when shown to someone not familiar with subject or study.

____ **Graph** communicates the message you wish to convey.