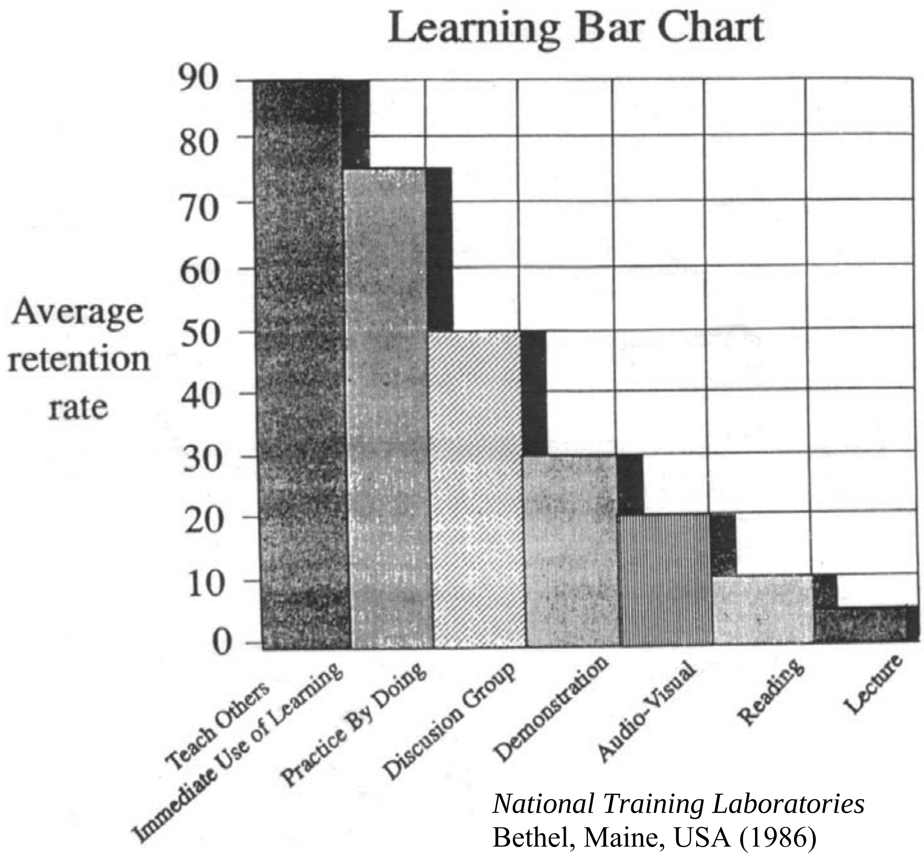
Table of Contents – TIK2OO Problem Solving, Logic and Design

MAXIMIZING YOUR LEARNING

Problem: How can I study in such a way that I can learn as much as I can in as little time as possible?



National Training Laboratories
Bethel, Maine, USA (1986)

Solution

Write a short paragraph outlining how the data presented above can help you to learn in an effective and efficient manner.

Some Windows Keyboard Shortcuts

Problem: How can I save time while using a computer?

Solution: One way of saving time is to learn to use keyboard shortcuts.

Keyboard Command	***Description***
Print Screen (PrtSc)	Capture image of entire screen (for pasting into a document)
Alt-Print Screen (Alt-PrtSc)	Capture image of active window (for pasting into a document)
Hold “Shift” while clicking on “×”	Close a window and ***all*** its parent windows
Shift - Del	Permanently delete the selected files (i.e. do not send the deleted files to the recycle bin)
Ctrl-C	Copy
Ctrl-X	Cut
Ctrl-V	Paste
Ctrl-Z	Undo
Ctrl-S	Save
Ctrl-O	Open a file
Ctrl-A	Select all
Ctrl-N	Open a new window
Ctrl-P	Print
Ctrl-Esc	Open the “Start” menu
Alt-Tab	Switch to the next open application
Alt-F4	Close the active window
Hold the “Shift” key while inserting a CD or DVD	Temporarily override “Autorun”
Hold the “Ctrl” key while selecting files	Multiple selection of files
Hold the “Shift” key while selecting files	Select all files in a contiguous block
Hold the “Ctrl” key while dragging an object	Copy and paste the object

For a complete list of Windows shortcuts, consult Keyboard Shortcuts for Windows , A List of the Keyboard Shortcuts That Are Available in Windows XP and Keyboard Shortcuts in Windows Vista.

Improving your Basic Problem Solving Skills

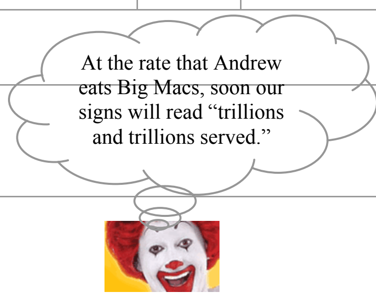
Instructions

The basic mathematical problems that we encounter in everyday life can often be solved by applying the four basic operations of arithmetic +, −, × and ÷. Unfortunately, for a variety of reasons, many students have difficulties choosing the appropriate operation(s). The purpose of this section is to help you to recover the skills that you probably possessed in elementary school but have since lost due to ***overuse*** of calculators, cell phones, digital audio players, video game systems and a plethora of other electronic distractions.

The Meaning of the Operations

Operation	Meaning	Answer Called	Example
+	When two or more groups of objects are combined, what is the total number of objects altogether?	Sum	Andrew E. ate six Big Macs for breakfast, twelve for lunch and nineteen for dinner. How many did he eat altogether? ***Solution*** 6 + 12 + 19 = 37 Andrew ate thirty-seven Big Macs altogether.
−	If one or more objects are removed from a group of objects, how many remain?	Difference	On a test worth 57 marks, Alysa lost only three marks. What was her mark? ***Solution*** 57 − 3 = 54 Alysa's mark was 54/57.
×	If there are *m* groups of *n* objects, how many objects are there altogether?	Product	Each day, Mr. Nolfi drives a total of 72 km to get to work and to return home. Given that there are about 40 weeks in a school year, how far does he drive each year just going to and from work? ***Solution*** 5 × 40 = 200 = approximate # of school days in one year 200 × 72 = 14400 Mr. Nolfi drives about 14400 km each year just to go to and from work.
÷	If a group of objects is to be divided into a number of smaller groups of equal size, how many objects will there be in each group? OR If a group of objects is to be divided into groups of equal size, how many groups will there be?	Quotient	One day, Mr. Nolfi was so pleased with his TIK2O0 students that he decided to bring a huge bag of miniature "Oh Henry" chocolate bars to school. If there were 500 miniature chocolate bars in the class, how many "Oh Henry" bars did each student get? ***Solution*** 500 ÷ 20 = 25 Each student got 25 "Oh Henry" bars.

The Operations in Pictures



	2+3=5	For a Valentine's day present, Aruna gave \$2.00 to Maleeka and \$3.00 to Halisha. Altogether, she gave \$5.00.
	6−4=2	After paying \$4.00 for a Big Mac, Andrew E. was left with \$2.00.
	4×2=8	Four friends each contributed \$2.00 to a charity for a donation of \$8.00 altogether.
	10÷5=2	Jonathan decided to share \$10.00 of his winnings with five friends. Each friend got \$2.00.

Very Important Problems

For each of the following problems, remember to ask yourself the following questions:

- Which of the four operations (i.e. +, –, × and ÷) makes the most sense?
- Would a diagram help to solve the problem?
- Are any unit conversions necessary?
- If a percentage is given, has it been properly converted to fraction or decimal form?
- Does the final answer make sense?

1. A machine that fills soft drink bottles can fill each bottle at a rate of 375 mL/s. How long would it take to fill a 2 L bottle? How long would it take to fill 10000 bottles?

2. Approximately 2.4 million students attend public elementary and secondary schools in Ontario. The average cost to the taxpayer is about $7000 per student, per year. What is the yearly cost of the Ontario public education system?

3. On average, the distance from the Earth to the sun is about 150000000 km. Given that light travels at about 300000000 m/s, how long does it take a ray of light to travel from the Sun to the Earth?

4. The sale price of a computer system is 15% *off* its original price. If the original price was $1199.99, what is the sale price?

5. A digital audio player has a storage capacity of 30 GB (thirty gigabytes). If an average song requires 4 MB (four megabytes) of storage space, approximately how many songs can be stored? (Note that 1 GB = 1024 MB.)

6. Express 28300 seconds in the form hours:minutes:seconds.

7. You need to paint the walls and the ceiling of a rectangular room whose dimensions are 6 m (length) by 4 m (width) by 3 m (height). The brand of paint to be used has a coverage of 6 m^2 (square metres) per litre. If each can contains 3.79 L of paint, how many cans would you need to buy to apply ***two*** coats of paint to the walls and ceiling?

8. A room has a rectangular floor with dimensions 4.8 m by 5.3 m. You need to install square ceramic tiles that are each 20 cm by 20 cm. If the tiles come in boxes of 25, how many boxes would you need to buy?

9. Ontario's provincial government has a debt of approximately 150 billion dollars. If that debt were to be divided equally among all residents of Ontario, how much would each Ontarian owe? (Ontario's population is approximately 13 million.)

Problem Solving According to George Polya

George Polya was a mathematician who wrote a definitive work on problem solving. He concluded that there are **four** fundamental steps (listed below) in the problem solving process. Try to classify each step as logical or creative and state whether you think that each step is easy or difficult. Be aware that for some, or perhaps all of the steps, you may wish to write, "It depends!" This is a perfectly acceptable answer as long as it is well supported.

Polya's Four Steps	Logical or Creative?	Easy or Difficult?
1. Understand the Problem	______________	______________
2. Choose a Strategy	______________	______________
3. Carry out the strategy	______________	______________
4. Check the Solution.	______________	______________

Questions

1. Which step (or steps) above do you consider the most difficult?

2. For the step that you chose in question one, why is it the most difficult step for you?

3. Why do so many students find solving problems so difficult?

4. Why are problem solving skills so important?

LOGIC VERSUS *CREATIVITY*

Both logic and creativity play vital roles in most facets of life. In particular, when solving problems (the problems do not necessarily have to be mathematical), we rely on both of these very important qualities. Each, however, has its own unique function. Below we shall examine each of these roles in detail.

THE ROLE OF LOGIC

Logic allows you to be

1. exact, consistent, precise
2. disciplined, industrious
3. analytical
4. focused
5. realistic
6. mature
7. serious
8. rational

Limitations of Logic

Logic does not help very much with generating new, original ideas. Logic is more useful in the analysis of ideas and putting ideas into practice. People who rely too heavily on logic tend to be better critics than creators.

THE ROLE OF CREATIVITY

Creativity allows you to be

1. *approximate, ambiguous, metaphorical*
2. *playful*
3. *inventive, imaginative*
4. *meandering*
5. *dreamy, full of fantasies*
6. *childish*
7. *humorous*
8. *intuitive*

Limitations of Creativity

Relying too heavily on your creative side can cause you to become undisciplined. While your mind will be overflowing with brilliant ideas, the lack of discipline will make it difficult for you to put your ideas into practice. You may begin working on many projects but very few are completed because you are so easily distracted.

The point is that you need to rely on both logic **and** creativity. If you keep this in mind while solving problems, you will find that you will quickly improve your ability to solve problems. To help you remember the difference between logic and creativity, I have provided you with a simple analogy from the world of movies.

LOGIC Movie Critics → They analyze and criticize the movies.

CREATIVITY Script Writers → They create the great ideas.

Questions

1. Which side of your brain is the so-called creative side? Which is the logical side?

2. Why are sleep and nutrition so important for the proper functioning of your brain?

A Detailed Description of Polya's Four steps of Problem Solving

1. Understand the Problem (Define the Problem)

- ***Carefully read*** the problem ***several times***.
- ***Identify*** what you are being asked to ***find***.
- ***Ensure*** that you ***understand all terminology***.
- ***Highlight*** all ***given information***.
- ***Identify*** all the ***information*** that ***is required*** to solve the problem.
- ***Identify*** the ***given information*** that ***is required*** to solve the problem.
- ***Identify*** any ***extraneous information*** (information that is not needed).
- ***Identify*** any ***missing information***.
- ***Do research*** to ***find*** or ***estimate*** any ***missing information***.
- ***Keep*** an ***open mind***.
- ***Do not make*** any ***unnecessary*** or ***incorrect assumptions***.
- ***Think logically*** and ***creatively!***
- ***Consult colleagues, peers, experts,*** etc.
- ***Do not worry*** about ***possible strategies yet***.
- ***Predict*** what a ***reasonable answer*** or ***range of answers*** would be.

2. Choose a Strategy

- ***Unleash your creative powers! Be imaginative!***
- ***Do not be afraid to take risks!***
- ***Do not dismiss any ideas*** at this stage. Feel free to be ***whacky!***
- ***Avoid*** feelings of ***frustration*** or ***inadequacy***.
- ***Do not give up quickly!***
- If you have the desire to quit, ***take a break*** and ***try solving the problem later***.
- ***Do not be afraid*** to be ***unconventional***. Perhaps you are correct and everyone else is wrong!
- ***Draw*** a ***diagram*** or ***visualize***.
- ***Compare*** the problem to an ***equivalent*** or ***similar problem*** that you have already solved.
- ***Compare*** the problem to a ***simpler*** but ***related problem***.
- ***Solve*** a ***specific example*** of the problem.
- ***Look for patterns***.
- ***Write*** a list of ***as many possible strategies*** as you can.
- ***Do research*** to discover if ***anyone else*** has solved the problem.

3. Carry out the Strategy

- ***Check*** your list of strategies and ***select one*** that you think is likely to work.
- ***Carry out*** your strategy ***logically*** and ***carefully***, paying close attention to ***detail***.
- If your strategy ***fails***, return to ***steps 1*** and ***2***.

4. Check the Solution

- Is your answer ***reasonable*****?**
- Does your ***answer agree*** with the ***prediction*** you made in ***step 1***?
- Does your ***answer agree*** with the ***answers obtained by others***?
- Is there a ***better way*** to solve the problem?
- Ask ***peers, colleagues,*** etc to check your solution.

STRETCHING YOUR PROBLEM SOLVING SKILLS

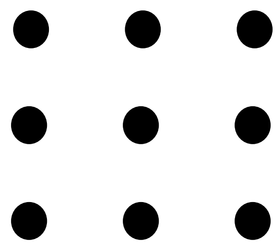
Problem: How can I improve my problem solving skills? How can I break through mental barriers?

Solution: Try to solve a wide variety of challenging and interesting problems?

The problems listed below can help you to improve your problem solving skills. Be forewarned, however. Many of the problems are quite tricky and require ***creative interpretations!*** Most importantly, don't be surprised if you aren't able to solve many of the problems. This is quite normal and should not be a source of frustration. If you find a particular problem frustrating, move on to a different one. What matters most about these problems is what they can teach us about ***breaking through mental barriers***!

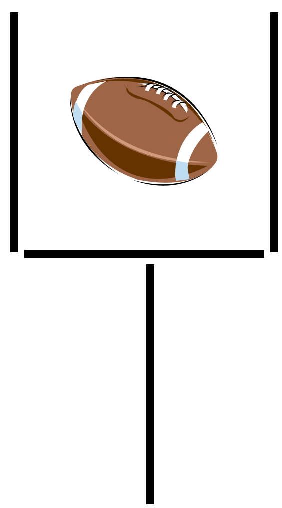
Questions

1. Use ***exactly four straight lines*** to connect the dots shown below. As you connect the dots, you ***may not*** lift your writing utensil from the paper and you may pass through each point ***exactly once***. In other words, the four straight lines must form a ***continuous*** (not broken) path through all nine dots.



Think outside the box!

2. Shown below is a football "upright" (i.e. football goal posts) with a football in the "middle." Move ***only two*** of the four posts so that the football is no longer in the middle, but the ***shape*** of the upright remains unchanged.



Sometimes, you may need to stand on your head to get a different point of view.

3. Shown below is the Roman numeral "seven." Add a single line to turn it into an "eight."

VII

This one is very easy!

4. Shown below is the Roman numeral "nine." Add a single line to turn it into a "six."

IX

You need a creative interpretation of the word "line" here!

5. Reveal a common ***word*** by removing "six letters."

BSAINXLEATNTEARS

Quotation marks make a huge difference in this question!

6. Five figures are shown below. Select the one that is ***different from all the others***. Explain your choice.

Many problems have more than one correct solution!

7. The following is an ***incorrect*** equation. Turn it into a ***correct*** equation by moving ***exactly one*** line segment.

II = VI

Don't get trapped in the mindset of Roman numerals!

8. How many grooves are there on one side of a $33\frac{1}{3}$ rpm long playing vinyl record? (For those of you who are too young to know what a vinyl record is, use the Internet to find out!)

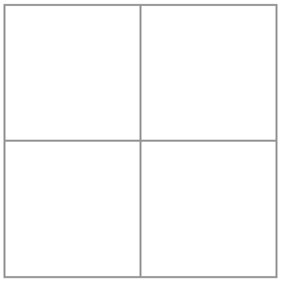
Sometimes you are given extraneous information! (That is, you are given information that is not needed.)

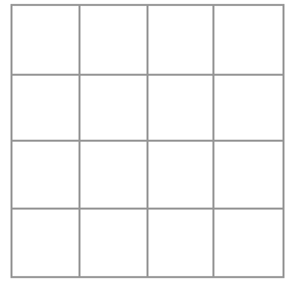
9. Arrange 16 dots in such a way that you have 10 rows with 4 dots in each row.

You need a creative interpretation of the word "row" here!

10. If you arrange n^2 dots in the same way as you did in question 9, find an expression for the number of rows containing n dots.

11. How many squares are there in each of the following diagrams? (Think before you leap!)





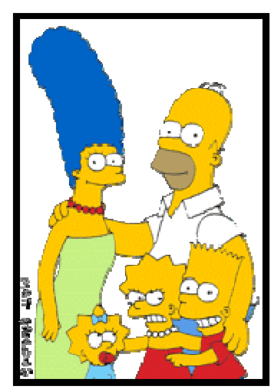
Make sure that you find ***all*** the squares!

12. Now sketch a few diagrams similar to those in question 11 (i.e. 3 rows of 3 squares, 5 rows of 5 squares, 6 rows of 6 squares, etc). Do you notice any patterns? Can you find a relationship between the number of squares in each row and the total number of squares?

13. Define the word "paradox." (Find as many definitions as you can. If you do not have a dictionary handy, use one or more of the many online dictionaries on the Internet.)

Yes, indeed, language ***is*** very important!

14. This question deals with ***Simpson's Paradox***. Despite what you may think, Simpson's Paradox has nothing to do with the Simpson's family on TV. Nonetheless, I included a picture of them because I thought you might enjoy it!



Drug "A" on its first test was effective on 100 of 1000 patients = 10%.

Drug "B" on its first test was effective on 2000 of 10000 patients = 20%.

Drug "A" on its second test was effective on 4000 of 10000 patients = 40%.

Drug "B" on its second test was effective on 600 of 1000 patients = 60%.

Therefore, drug "B" is more effective than drug "A."

Is the conclusion of the above argument true or false? Explain.
(Do you think that Homer could answer this question?)

Statistics can be very ***misleading***!

15. This question is based on the ***liar's paradox***.

If a ***liar*** (defined as someone who ***never tells the truth***) tells you that he/she is lying, is he/she lying or telling the truth?

Not all statements ***make sense***!

16. Five-sixths of all men in a certain town are married. One-half of all the women in the same town are married. What fraction of the people in this town are single men?

A picture says a thousand words!

17. What number should go in the place of the question mark? (This problem will seem very difficult ***unless*** you do not confine your thinking to the realm of numbers.)

2 – 3, 3 – 5, 4 – 4, 6 – 3, 7 – 5, 8 – 5, 9 – 4, 10 – ?

Don't allow yourself to get trapped in the world of numbers! Think about words too!

18. Find a general formula that predicts any number in the following sequence given its *position*.

0, 2, 6, 12, 20, 30 …

Hint: Let *p* represent the position of the number in the sequence and let *n* represent the number at position *p*. Then, create a table (as shown below) showing the correspondence between *p* and *n* for the first few values of *p*. Look for patterns and then try to write out a formula for *n* in terms of *p*.

p	*n*
1	0
2	2
3	6
4	12
5	20
6	30
7	

Math is like a dating service! It's all about finding ***relationships***! (However, math is ***not*** like a ***blind*** date.)

19. You are in a room that has three light switches, none of which controls a light fixture found in that room. However, ***one*** of the switches controls a light fixture in a different room. In addition, the first room is completely isolated from the room with the light fixture; the only way to determine whether the light is on in the second room is to visit it. Suppose that you are allowed to visit the second room only once and that once having done so, you are not allowed to return to the first room. Devise a foolproof strategy for determining ***exactly*** which switch controls the light fixture in the second room.

Sherlock Holmes would probably be able to solve this mystery! It's a matter of clever deduction! (**Hint**: Light bulbs emit both heat and light!)

20. What will carry more water, a single pipe with a diameter of 10 cm or two pipes, each of which has a diameter of 5 cm?

A picture says a thousand words!

21. Replace each of the letters with one of the digits from 0 to 9. Arrange the digits such that A×B×C equals B×G×E equals D×E×F. You may use each digit only once.

A		D
B	G	E
C		F

22. Edwin is a judge and a numerologist. He is married to a woman whose name

(a) has a "product" that is the same as that for "JUDGE" using the correspondence of letters and numbers below,

(b) has no letter in common with "JUDGE" and has no "C" because 3 is his unlucky number and

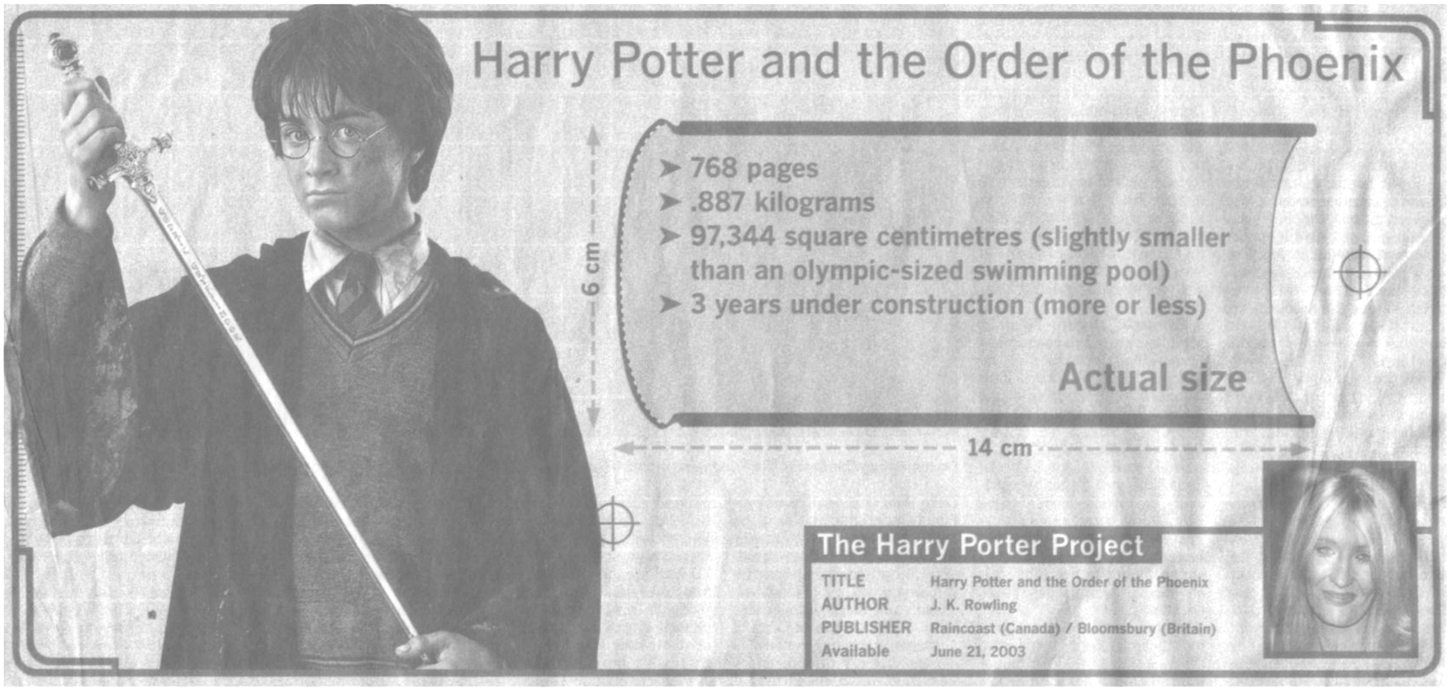
(c) has its letters in alphabetical order when the first letter and the second letter are interchanged.

What is the English name of the judge's wife?

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	23	25	26

"How often have I said to you that when you have eliminated the impossible, whatever remains, however improbable, must be the truth?"

23. Do you believe everything that you read?

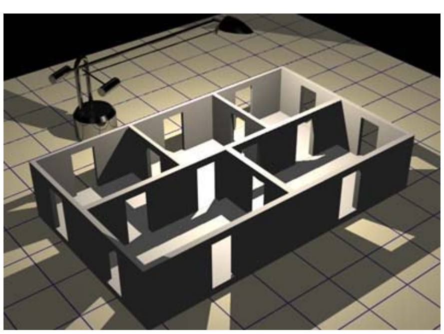


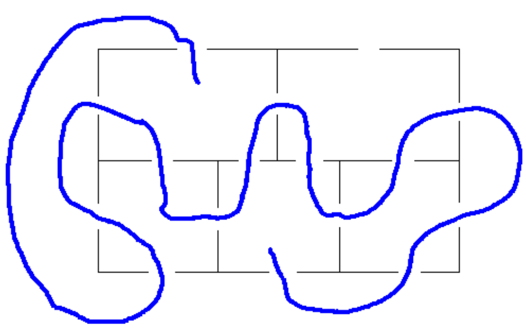
We tend to believe in the printed word, but it is ***not*** wise to do so unquestioningly. For instance, consider the above diagram taken from a local newspaper. Although visually impressive, there are ***two errors*** in the given text (at least I have noticed only two). One of the errors is glaring but not too serious. The other is far less noticeable but is a great deal more severe. Your task is to find both errors.

Find both errors in the diagram shown at the top of the page. One of the errors is a simple typographical error; all you need to do is point it out. The other error is far less obvious. In this case, it is not sufficient merely to point it out. You must support your answer with a logical argument.

Don't believe ***everything*** that you read!

24. This is Mr. Nolfi's very famous ***$20 problem***. Imagine that the picture shown below is an overhead view of the layout of five rooms in a very strange house. The reason that this house is so strange is that every room has a doorway on every single wall. Your task is to find a continuous path that passes through every doorway ***exactly once***.





This is an example of an ***unsuccessful attempt*** to solve this problem. The path shown in the diagram passes through every doorway except for one. There is no way to reach the final doorway without passing through one of the doorways twice!

25. Three men walk into a motel and ask for a room. The cost of a room is \$30 so each man pays \$10 toward the cost to the desk clerk. Later, the clerk realizes that he had made a mistake; the room should have cost only \$25. He calls the bell boy over and asks him to refund the other \$5 to the three men. The bellboy, not wanting to mess with a lot of change dividing the \$5 three ways, decided to lie about the price, refunding each man \$1 and keeping the other \$2 for himself. Ultimately each man paid \$9 towards the room and the bellboy got \$2, totalling \$29. However, the original charge was \$30, where did the extra \$1 go?

> Persuasive arguments are not always correct arguments!

26. A box contains two coins. One coin is heads on ***both*** sides and the other is heads on one side and tails on the other. One coin is selected from the box at random and the face of one side is observed. If the face is heads what is the probability that the other side is heads?

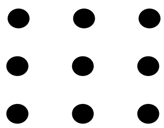
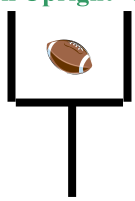
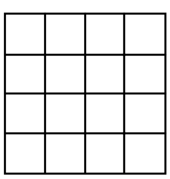
> Draw a diagram!

27. What is the minimum number of people required, chosen at random, so that there is at least a 50% chance that two or more people have the same birthday. Assume that people are born randomly throughout the year. You may ignore leap years.

28. Find a mathematical expression that satisfies ***all of the*** following conditions:
-it involves the numbers 3, 3, 7 and 7, once each
-any of the four basic operations of arithmetic (+, –, ×, ÷) may be used
-no other mathematical operations are allowed
-when the expression is evaluated, the result is 24

29. While three wise men are asleep under a tree, a mischievous boy paints their foreheads red. Later, they all wake up at the same time and all three start laughing. After several minutes, one of them suddenly stops laughing. Why did he stop?

What you can Learn by Solving Challenging Problems

Problem	***What you can Learn from the Problem***
"Nine Dots" Problem 	
"Football Upright" Problem 	
"Roman Numerals" Problems	
"Remove Six Letters" Problem	
"Select the Shape that is Different" Problem	
"How Many Squares" Problem 	
"Simpson's Paradox"	
"Liar's Paradox"	
Five-sixths of all men in a certain town are married. One-half of all the women in the same town are married. What fraction of the people in this town are single men?	
Sequence and Pattern Problems	

THERE IS MUCH MORE TO THE INTERNET THAN CELEBRITY GOSSIP: SEARCHING THE INTERNET FOR EDUCATIONAL INFORMATION

Problem: How can I find information quickly whenever I need it?

Solution: Learn how to search the Internet for valuable Information!

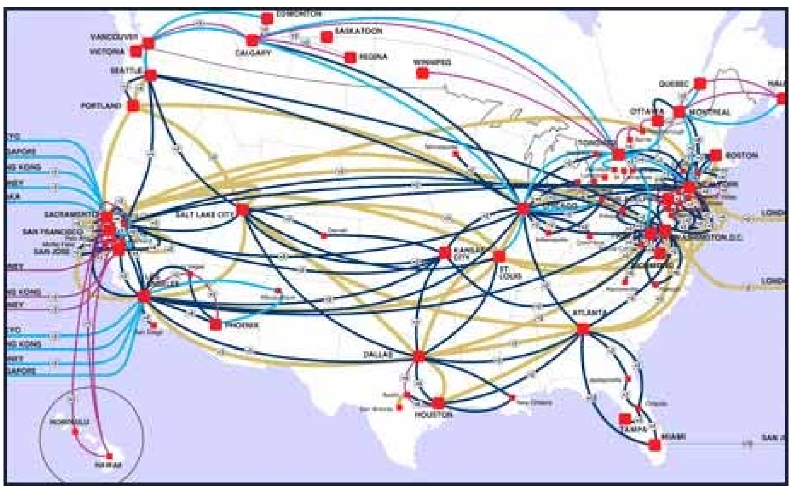
Somehow, it seems that my students are always able to find online video games, chatting sites, celebrity gossip, movies, music and dirty pictures. However, whenever I ask students to use the Internet to search for ***educational information***, many of them react as if I had just asked them to explain Einstein's General Theory of Relativity! Indeed, the Internet does give us virtually instantaneous access to a wide variety of entertainment. Unbeknown to many, however, is that the Internet is also a veritable goldmine of educational resources!

Internet Terminology

Terms and Definitions

The ***Internet*** (considered a proper noun, it is spelled with an uppercase "I") is the largest ***internet*** ("network of networks") in the world. (See ***internet*** below for an explanation of the difference between the two). It is a vast global communications network consisting of more than ***one hundred thousand*** interconnected networks that use the ***TCP/IP protocols*** (see page 21). Although many believe that the Internet is a recent development, it actually evolved from the ***ARPANET*** (Advanced Research Projects Agency Network) of the late 1960s and early 1970s.

Note that the Internet is ***not*** synonymous with World Wide Web. The World Wide Web is ***one*** of the many services (arguably the most popular service) that uses the infrastructure of the Internet to send and receive information. Other services that use the Internet include ***email*** (POP and SMTP protocols), ***file transfer protocol*** (FTP), ***instant messaging*** (**e.g.** Windows Live Messenger, Yahoo Messenger, ICQ, AIM, IRC) and ***voice over IP*** (VOIP, Internet-based telephone).



The diagram at the left shows the main Internet connections within the U.S.A. and southern Canada.

Notice the connections leading toward the Atlantic and Pacific oceans. These link North America to other continents, mostly through fibre optic cables lying on the ocean floor.

Undersea cables connect all the continents except for Antarctica. Researchers working in Antarctica use satellite links to communicate with the rest of the world.

The word ***internet*** (spelled with a lowercase "i") is a contraction of the phrase ***interconnected network***. That is, ***internet*** (also called ***ineternetwork***) refers to any group of networks that are connected to one another (i.e. any "network of networks"). When written with a capital "I," the Internet refers to the worldwide set of interconnected networks. Hence, the Internet is an internet but the reverse does not apply.

At present, the use of TCP/IP (see page 21) is now taken for granted in computer networks, and there are no other significant internetworks besides the Internet. Instead, the term ***intranet*** (see below) is generally used for private networks.

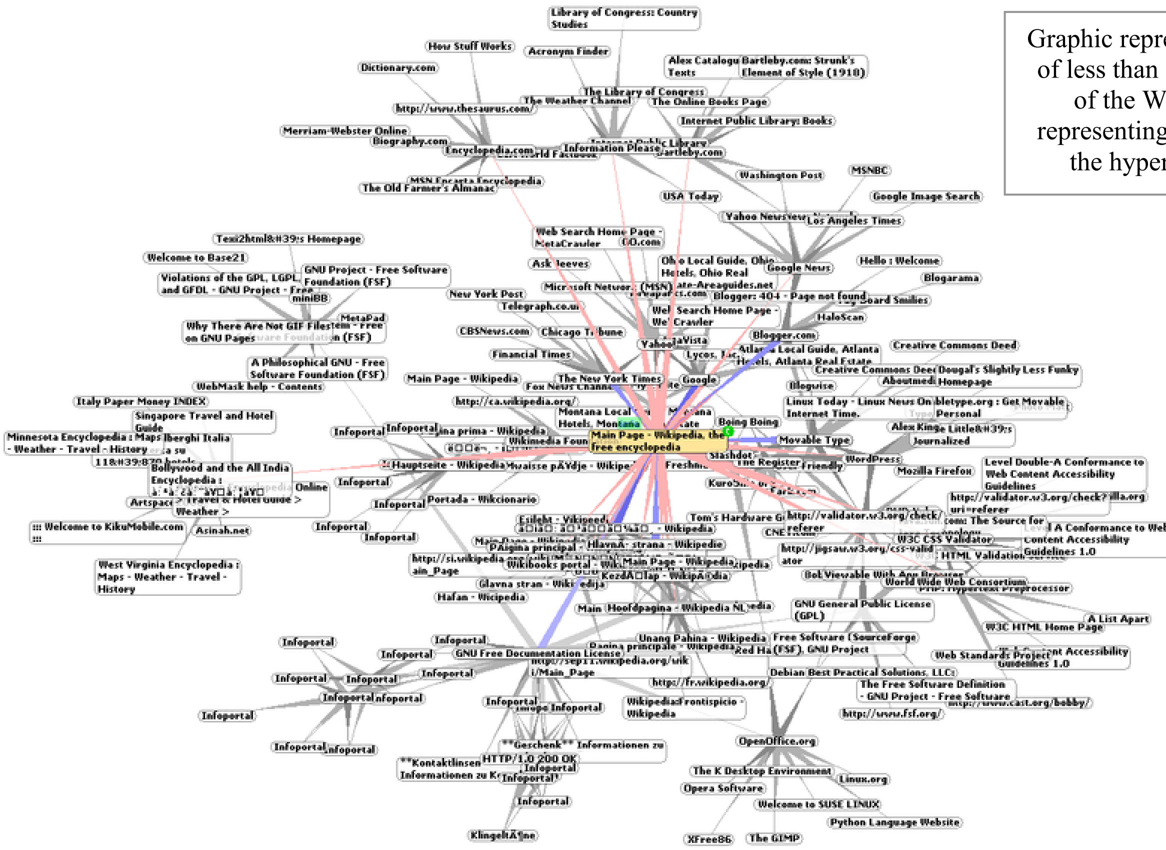
An ***intranet*** is a private network based on TCP/IP protocols that belongs to an organization (often a corporation) and is accessible only by the organization's members or others with authorization. The purpose of an intranet is to share information within an organization while fending off unauthorized access. Otherwise, an intranet's Web sites look and act just like any other Web sites. A program called a ***firewall*** is used to prevent unauthorized access to an intranet.

e.g. The home page of the Peel District School Board's intranet is http://home.peel.edu.on.ca/ . This site can be accessed without restriction using any computer that is directly connected to the Peel Board's intranet. However, a user name and password are required to access this site from a computer that is outside the boundaries of the Peel Board intranet.

Terms and Definitions (continued)

The ***World Wide Web*** (WWW) is a system of Internet servers, known as ***HTTP servers*** (hypertext transfer protocol servers) that support specially formatted documents (see page 21 for a discussion of "HTTP"). The documents are formatted in a markup language called HTML (*HyperText Markup Language*) that supports links to other documents, as well as graphics, audio, and video files. This means you can jump from one document to another simply by clicking on "hot spots." Not all Internet servers are part of the World Wide Web.

Note that *World Wide Web* is ***not*** synonymous with *the Internet*.



Graphic representation of less than 0.0001% of the WWW, representing some of the hyperlinks.

A ***Web browser*** is software that interprets the markup of files in HTML, formats them into Web pages and displays them to the user. Web browsers use HTTP to make requests of Web servers throughout the Internet on behalf of the browser user. Examples of Web browsers include Microsoft Internet Explorer, Mozilla Firefox, Opera and Safari.

A ***server*** is a computer system that provides services to other computer systems—called ***clients***—over a computer network. The term ***server*** can refer to hardware or software. An ***Internet sever*** is any server that provides Internet services to clients. For example, Web servers provide the services that allow client machines to view Web pages.

A ***search engine*** is an information retrieval system designed to help find information stored on a computer system, such as on the World Wide Web, inside a corporate or proprietary network, or in a personal computer. The search engine allows one to ask for content meeting specific criteria (typically those containing a given word or phrase) and retrieves a list of items that match those criteria. This list is often sorted with respect to some measure of relevance of the results. Search engines use regularly updated indexes to operate quickly and efficiently.

Without further qualification, ***search engine*** usually refers to a ***Web*** search engine, which searches for information on the public Web. Other kinds of search engine are *enterprise search engines*, which search on intranets, personal search engines, and mobile search engines. Different selection and relevance criteria may apply in different environments, or for different uses.

Clearly, the most popular search engine is ***Google***. However, there are many others including ***Yahoo***, ***Windows Live Search*** and ***ask.com*** (formerly Ask Jeeves).

Terms and Definitions (continued)

A ***metasearch engine*** is a search engine that sends user requests to several other search engines and/or databases and returns the results from each one. Metasearch enables users to enter search criteria once and access several search engines simultaneously. Since it is hard to catalogue the entire web, the idea is that by searching multiple search engines you are able to search more of the web in less time and do it with only one click. The ease of use and high probability of finding the desired page(s) make metasearch engines popular with those who are willing to weed through the lists of irrelevant "matches." Another use is to get at least some results when no result had been obtained with traditional search engines.

Examples of metasearch engines include ***Clusty*** (formerly Vivisimo), ***Copernic Agent***, ***SurfWax*** and ***Dogpile***.

In computing, a ***protocol*** is a convention or standard that controls or enables the connection, communication, and data transfer between two computing endpoints. In its simplest form, a protocol can be viewed as ***the rules governing the communication between two computing devices***. Protocols may be implemented by hardware, software or a combination of the two.

TCP/IP Protocol Suite, which is named after the two most important protocols within it, ***Transmission Control Protocol (TCP)*** and ***Internet Protocol (IP)***, refers to the set of communications protocols used for the Internet and for many commercial networks. TCP/IP Protocol Suite, usually called TCP/IP for the sake of brevity, consists of five "layers" of protocols used for a variety of different types of data transfer across the Internet.

HTTP, short for ***hypertext transfer protocol***, is a request/response protocol between clients and servers. The originating client, such as a Web browser, is referred to as the ***user agent***. The destination server, which stores or creates resources such as HTML files and images, is called the ***origin server***.

The five layer TCP/IP model
5. Application layer
DHCP • DNS • FTP • HTTP • IMAP4 • IRC • NNTP • XMPP • MIME • POP3 • SIP • SMTP • SNMP • SSH • TELNET • BGP • RPC • RTP • RTCP • TLS/SSL • SDP • SOAP • L2TP • PPTP • ...
4. Transport layer
TCP • UDP • DCCP • SCTP • GTP • ...
3. Network layer
IP (IPv4 • IPv6) • ICMP • IGMP • RSVP • IPsec • ...
2. Data link layer
ATM • DTM • Ethernet • FDDI • Frame Relay • GPRS • PPP • ARP • RARP • ...
1. Physical layer
Ethernet physical layer • ISDN • Modems • PLC • SONET/SDH • G.709 • Wi-Fi • ...
This box: view • talk • edit

Google – A Great Search Engine for almost all Purposes

Summary of Google's Query Language

- Google supports **+, –, OR, site:, ~, .. ,"   "**
- **Automatic "AND" Search**
  AND queries are automatic at Google. This means that the documents that Google finds must contain ***all the words*** in the search phrase.
- **"OR" Search**
  To find pages that include either of two search terms, add an uppercase **OR** between the terms.
- **Exact Phrase Search ("   ")**
  To search for an exact phrase, enclose it in quotation marks.
- **"–" Search**
  To exclude a word from a search, precede the word with a **"–"**
- **"+" Search**
  Google ignores common words such as "I," "a," "an," "where" and "how." Use the **"+"** to force Google to include such common words.
- **Domain Search**
  Use "site:" to restrict searches to a particular Web site.
- **Synonym Search**
  Use "~" to include synonyms of the search word.
- **Numrange Search**
  Use ".." to search for numbers in a given range.

Examples of Google Searches

Note: Although some of the words listed below begin with a capital letter, Google ignores case. The same results are obtained whether the search terms are typed in lowercase, uppercase or some combination thereof.

Search Phrase	*Documents Google will find*
Star Wars Episode +I	The document must contain the words "star," "wars" and "episode." In addition, the "+I" forces Google to include the common word "I" in the search.
bass –fishing	The word "bass" must appear in the document but the word "fishing" ***must not***.
"great barrier reef"	The exact phrase "great barrier reef" must appear in the document.
PlayStation $600..$800	The document must contain the word "playstation" and prices that lie between $600 and $800.
~food ~facts	Search for documents that contain the words "food" and "facts" and their synonyms.
excel site:www.microsoft.com	Search for documents that contain the word "excel" but only those found on the Web site www.microsoft.com.
hockey Toronto OR Montreal	The document must contain the word "hockey" and either of the words "Toronto" or "Montreal"

Exercises

1. Write a brief description of the information that you are likely to find by using the following Google search phrases.

Search Phrase	*Documents Google will find*
Brampton school –catholic	
~female scientist OR engineer	
"Central Peel"	
astronomy "black holes"	
"global warming" OR "climate change"	
bugs site:www.microsoft.com	
"goalie pads" $500..$1500	

2. Complete the following table.

The Information You Would Like to Find	*Google Search Expression you would use to find the Information*
Find information on video games that cost between $20 and $50.	
Find information on video game systems made by Sega or Sony.	
Find information on Central Peel but only at the Web site www.peelschools.org	
Find information on why the Meech Lake Accord failed to achieve a national consensus on the Canadian Constitution.	
Find information on the effects of global warming on the Earth's polar ice caps.	
Find information on communicable diseases.	
Find information on endangered species in North America.	
Find information on comet impacts on the Earth, Moon and Jupiter.	
Find information on Einstein's Special Theory of Relativity, but not his General Theory of Relativity.	

EXPERIMENTS INVOLVING RANDOMNESS: "PAPER AND PENCIL" VERSUS SPREADSHEETS

Problem: How can I use a computer to help me solve many problems more efficiently?

Solution: Learn how to use spreadsheets!

***Experiment 1:** Roll One Die Fifty Times*

Possible Outcomes	Tally	Frequency	Relative Frequency (Experimental Probability)	%Relative Frequency (%Experimental Probability)	Theoretical Probability
1					
2					
3					
4					
5					
6					
	TOTALS				

***Experiment 2:** Roll Two Dice Two Hundred and Fifty Times*

Possible Outcomes	Tally	Frequency	Relative Frequency (Experimental Probability)	%Relative Frequency (%Experimental Probability)	Theoretical Probability
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
	TOTALS				

USING SPREADSHEET SOFTWARE TO SIMULATE THE ROLLING OF A DIE

Prerequisite Knowledge

Before you attempt this spreadsheet exercise, you must

- ***have completed*** the "pencil and paper" die rolling experiments
- ***understand*** the terms ***random, experiment, outcome, trial, frequency, relative frequency (experimental probability), expected probability (theoretical probability)***
- ***understand*** that if an experiment is repeated ***a large number of times*** (i.e. a large # of ***trials***), the experimental probabilities ***approach*** (get closer and closer to) the theoretical probabilities
- ***understand*** that the ***sum of all probabilities must be 1 (100%)***

I, the undersigned, have satisfied all the conditions listed above. I am now ready to proceed with the die rolling simulation.

Signature: ____ ***Initials:*** _____________________

Instructions

You will create a spreadsheet that has exactly the same ***labels (titles)*** as the one shown below. (At 10000 rolls, your spreadsheet will have a ***similar appearance***, but due to the random nature of this experiment, it ***will not be identical*** to the given spreadsheet.)

	A	B	C	D	E	F	G	H
1	***Roll***	***Possible Outcomes***	***Frequency***		***Experimental Probability (Relative Frequency)***	***%Experimental Probability (%Relative Frequency)***	***Theoretical Probability***	***%Theoretical Probability***
2	6	1	1631		0.1631	16.31%	1/6	16.67%
3		2	1723		0.1723	17.23%	1/6	16.67%
4		3	1675		0.1675	16.75%	1/6	16.67%
5		4	1654		0.1654	16.54%	1/6	16.67%
6		5	1696		0.1696	16.96%	1/6	16.67%
7		6	1621		0.1621	16.21%	1/6	16.67%
8								
9		***Total # of Rolls***	10000	***Totals***	1.0000	100.00%	1	100.00%

1. First, type all labels (titles) as shown above. Notice that the label text is displayed in ***italicized boldface*** and is centred both vertically and horizontally.
2. In cell A2, type the formula that is used to generate the random integers from 1 to 6: **=@rounddown(@rand*6+1)**.
3. In cells B2 to B7, list the outcomes 1 to 6 respectively. These numbers represent all the possible outcomes that can be obtained by rolling a single die. A "fill series" operation can save you some typing.
4. Next, in cell C2, type the formula for the frequency of rolling a 1:
   =@if(A2=$B2, $C2+1, $C2). This formula "counts" the number of times that a "one" is rolled.

   ↑ If the value (roll) in A2 is equal to the value in B2, ↑ add 1 to C2. ↑ Otherwise, leave C2 unchanged

5. ***Do not type the rest of the formulae in the frequency column!*** Simply ***fill down*** from cell C2 to cell C7.
6. In cell C9, type the formula **=@sum($C2..$C7)**. This adds cells C2 to C7 inclusive. (Why?)
7. In cell E2, type the formula **=$C2/$C$9**. Then fill down to cell E7. As shown in the above table, format the values so that they are rounded to four decimal places.
8. Now highlight cells E2 to E7 and copy (ctrl-c) the formulas in those cells (ctrl-c). Click on cell F2 and paste (ctrl-v) the information copied from E2 to E7.

9. Highlight cells G2 to G7, click on the format menu and then click on "Selection…" Click on the "Numeric Format" tab, click "Fraction" and then click "OK." Type **1/6** in cell G2; then fill down to cell G7 (if filling down does not work properly, simply copy and paste). Column H can be generated in the same way, but as with columns E and F, format as shown in the above table.

10. Finally, type a formula in cell E9 for the sum of column E. Then fill right from E9 to H9.

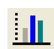
Note: Adjust the width of each column to produce the most pleasant appearance possible.

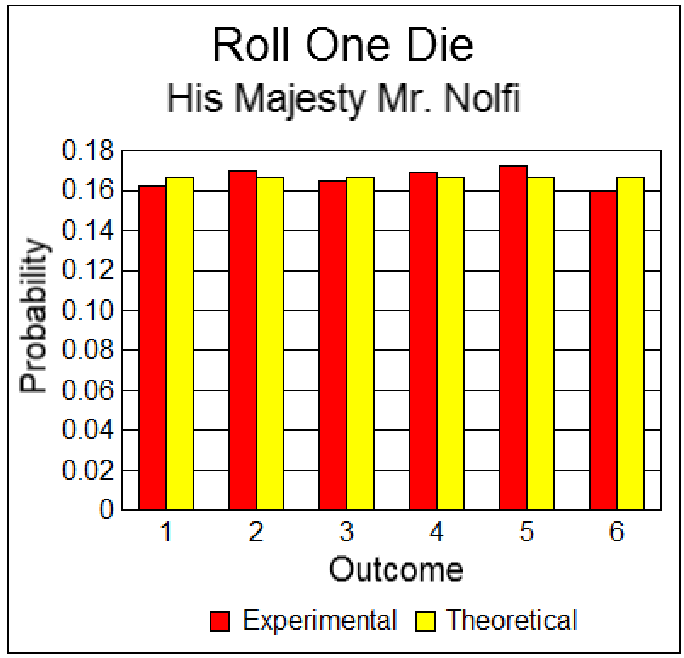
Running the Simulation

Now that you have properly set up your spreadsheet, run your experiment by pressing and holding the F9 key. Carefully observe how the values in your spreadsheet change as the number of rolls increases. Stop and examine your spreadsheet after 50, 100, 500 and 1000 rolls. After 1000 rolls have been completed, proceed to the next step.

Generating a Bar Graph

You will plot a bar graph of ***probability*** versus ***outcome***. To do so,

- Highlight cells C2 to C7 (to set the "Y-Range") and then click the graph button. 
- Right click on the graph to display a menu of graph-related options. Choose the "Source Data…" option and then set the "X-Range" to B2 .. B7.
- Select "Source Data…" again and click the "Add" button to add a second series. Set the "Y-Range" to G2 .. G7 (i.e. the theoretical probability column).
- Format your graph in such a way that it has an appearance similar to the graph shown at the right.



Questions

Use a word processor to create answers to the following questions.

1. Why is the theoretical probability the same for each possible roll? Would you expect the same to be true for the rolling of two or more dice?

2. As the number of rolls increases, what do you notice about the experimental probabilities?

3. What is the purpose of the "$" symbol when used in a cell reference?

4. What is the purpose of the "=" symbol when used in formulas?

5. What is the purpose of the "@" symbol when used in formulas?

6. Why are the experimental probabilities (relative frequencies) close to but ***very rarely*** equal to the theoretical probabilities?

7. Describe two possible ways of generating column F.

8. Define *random, frequency, outcome, theoretical probability, experimental probability, label, formula, cell, value, sum, trial, formulae.*

What to do when you are finished

Print the following:

- A copy of your spreadsheet showing the numerical values after 1000 rolls
- A copy of your spreadsheet showing all formulae instead of the numerical values
- A copy of your bar graph
- A copy of the answers to the above questions. Use a word processor to type up your answers.

Then place ***all*** printouts and the answers to the above questions in your notebook!

PROBLEMS THAT CAN BE SOLVED BY USING SPREADSHEETS

1. Create a spreadsheet that simulates the ***simultaneous*** rolling of a pair of dice. This spreadsheet should be similar to the one that you created for the rolling of a single die; however, you should note some key differences. Firstly, the number of possible outcomes will be greater than for the one die situation. Secondly, do not expect a ***uniform probability distribution*** like the one that you obtained for a single die. When two dice are rolled, certain outcomes will be more likely to occur than others will. For instance, rolling a seven is much more likely than rolling a two. Arrange your headings as shown in the following table.

Die 1	Die2	Roll	Possible Outcomes	Frequency	Experimental Probability	%Experimental Probability	Theoretical Probability	%Theoretical Probability

As with the single die situation, plot a graph with "frequency" on the ***left vertical axis***, "%relative frequency" on the ***right vertical axis*** and "outcome" on the horizontal axis. Make sure that all axes are labelled and that you have a title for your graph. Include your name somewhere on your spreadsheet.

2. Repeat question 1 for the simultaneous rolling of three dice.

3. Do you know how to calculate the amount of sales tax that you would need to pay for a given purchase? Sadly, if you are like the vast majority of my students, it is unlikely that you would be able to perform the ***requisite*** computations. This question is designed to help you acquire and refine the ***indispensable*** skill of computing sales tax.

Create a spreadsheet that has an appearance similar to that of the following.

	A	B	C	D	E	F	G
1	*Random Price*	*GST?*	*PST?*	*GST Amount*	*PST Amount*	*Total Tax*	*Total Cost*
2	$924.03	0	1	$0.00	$73.92	$73.92	$147.84
3	$330.85	0	0	$0.00	$0.00	$0.00	$0.00
4	$264.56	0	1	$0.00	$21.16	$21.16	$42.33
5	$746.78	1	1	$37.34	$59.74	$97.08	$156.82
6	$252.27	0	0	$0.00	$0.00	$0.00	$0.00
7							
8	$2,518.49			$37.34	$154.83	$192.17	$347.00

The price should be a ***random dollar amount*** between $0.01 and $1000. Use the formula ***@rounddown(@rand*100000+1)/100*** to generate the price. The "**GST?**" and the "**PST?**" cells should each contain a ***random whole number*** of either "0" or "1." A "0" indicates that the tax does not apply and a "1" indicates that the tax does apply. The remaining fields should be calculated by using appropriate formulas.

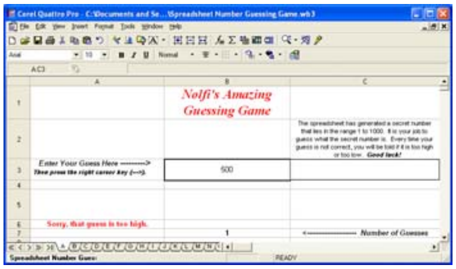
Note: In the above example, the numbers "0" and "1" have a special purpose. The "0" indicates that tax does not apply and the "1" indicates that tax does apply. More generally, "0" can be used to indicate that a certain statement is ***false*** and "1" can be used to indicate that a statement is ***true***. This use of the numbers zero and one is extremely common in computer science and computer circuit design. For example, in computer circuitry, a value of ***zero*** indicates that a given input or output is ***off*** and a value of ***one*** indicates that a given input or output is ***on***.

4. Define the terms ***simultaneous, requisite, probability distribution, indispensable*** and ***random***.

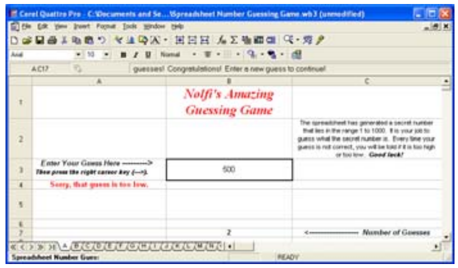
***************************** *IMPORTANT* *****************************

Place all printouts (and your answers to question 4) in your notebook!

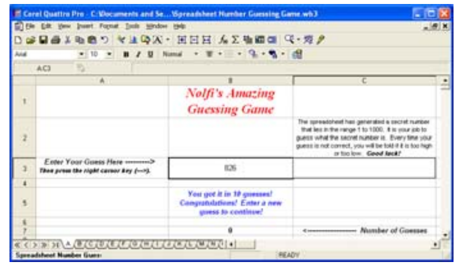
Using a Spreadsheet to Create a Game



If the user's guess is too high, display a message to that effect.



If the user's guess is too low, display a message to that effect.



If the user's guess is correct, display a friendly message.

Assignment

Create a spreadsheet that allows a user to play a number guessing game like the one illustrated above. The secret number should be an integer between 1 and 1000. Each time the user makes a guess, a message should be displayed indicating whether the guess is too low, too high or correct. In addition, there should be a cell that displays the total number of guesses entered. Once the user guesses the secret number, a friendly, congratulatory message should be displayed to tell the user how many guesses were needed to find the correct answer.

Hints

- The order in which the formulas are evaluated can make a ***huge*** difference. To change the order of evaluation of formulas in Quattro Pro, use the "Recalc Settings" tab in the "Format → Notebook" menu. Instead of using the "Natural" ***order*** and the "Background" ***mode***, consider using the "Column-Wise" or "Row-Wise" order, and the "Automatic" recalculation mode.
- Arrange your formulas so that the spreadsheet evaluates the formulas that check whether the answer is correct ***before*** it generates a new secret number. If you fail to do this, the game will become almost impossible to win. The spreadsheet would only detect a correct guess if the next secret number is equal to the previous one. The probability of this happening is only 1 in 1000!

Enhancement

Improve your game so that the user only has a limited number of guesses. If the user fails to guess the secret number in the allowed number of guesses, a message to this effect is displayed and the secret number is displayed.

Important Spreadsheet Assignment to be Handed in!

Instructions

Use a word processor for questions 1, 2 and 3. Use a spreadsheet for question 4. When you are finished, save your work in **I:\In\Nolfi\Tik2o0\SpreadAsst*YourName***, where *YourName* stands for your name. (In addition, your answers to questions 1, 2 and 3 must be submitted to www.turnitin.com.)

Questions

1. Whenever you use a program's "Help" menu, you will find three different ways of searching for information. You are able to search using the "contents," the "index" and the "find" ("find" is also called "search" in many programs). Explain the differences among them.

2. Use "Quattro Pro's" help menu to learn as much as you can about the following intrinsic (built-in) functions:

   @rand, @if, @int, @round, @rounddown, @roundup, @randbetween, @sum, @avg, @date, @max, @sqrt

   Then summarize what you have learned by creating a table just like the following:

Function Name	***Explanation***	***Example*** (including a brief explanation)
State the name of the function.	Give a brief explanation of the **purpose** of the function and how it is **used**. Do not blindly copy from the help files and paste into your documents! Paraphrase (explain in your own words) the explanations in the help files. Keep the explanations brief, simple and grammatically correct. Any computer user should be able to understand your explanation. One should not need to be a computer expert, nuclear physicist or rocket scientist to understand what you have written!	Give a simple, practical example. Include a brief explanation to ensure that the reader understands your example.
e.g. @if	**e.g.** The "@if" function is used whenever there are two possibilities for the value of a cell. If a certain condition is true, the cell will take on a particular value. If the condition is false, the cell takes on a different value. This is similar to travelling along a road and reaching a "fork" in the road. You would need to choose which path to take by considering certain factors. To use the "@if" function, use the following format: @if(*condition, value of cell if condition is true, value of cell if condition is false)*	**e.g.** @if(a2=$b2, $c2+1, $c2) If the value of cell a2 is equal to the value of cell b2, then the value of the cell in which this formula is stored is equal to c2+1. Otherwise, the value of the cell is c2.

3. Explain how to write a formula (without using @randbetween) that would generate a random integer between *a* and *b*, where *a* and *b* are any positive integers. **Hint:** Use @rounddown(@rand * $\boxed{}$ + $\boxed{}$)

   You need to figure out what values should go in place of these boxes.

4. Create your own spreadsheet! You may choose any topic, as long as it's suitable for a school project. Your spreadsheet must use all the intrinsic functions listed in question 2 and it must include at least one graph (the graph can be of any type).

Review of Problem Solving, Logic and Design

Problem: How can I obtain great marks on tests?

Solution: Review, review, review! Prepare, prepare, prepare!

1. Below you will find several terms/concepts that you have encountered during the course of this unit. ***Highlight*** the terms that you do not remember or that you do not fully understand. Then do whatever is necessary to resolve your difficulties. Finally, use a word processor to create a document in which each of the following terms/concepts is briefly explained.

   spreadsheet, row, column, label, cell, formula, fill up/down, fill right/left, $, @, intrinsic function, @int, @rounddown, @rand( ), @if, @sum, +, –, *, /, outcome, frequency, relative frequency (experimental probability), expected probability (theoretical probability), random, probability distribution, independent variable, dependent variable, cut, copy, paste, datum, data, horizontal axis (*x*-axis), vertical axis (*y*-axis), primary *y*-axis, secondary *y*-axis, die, dice, “recalc” settings (***order***: natural, column-wise, row-wise, ***mode***: automatic, manual, background), cell protection (locking cells)

2. Write Corel Quattro Pro spreadsheet formulas (formulae) to

   (a) generate a random **integer** from –50 to 50 inclusive (use diagrams and words to give a detailed explanation for this one)

   (b) generate a random **integer** from 0 to 50 inclusive

   (c) generate a random **integer** from 32 to 599 inclusive

   (d) generate a random **real number** from 0 to 0.999999… inclusive

   (e) generate a random **real number** from -50 to 49.9999999… inclusive

3. Write Corel Quattro Pro spreadsheet formulas (formulae) to be stored in cell b10 to do the following:

   (a) if a1 is equal to b1, add all cells from a3 to a20 inclusive and store the result in cell b10; otherwise, leave b10 unaltered

   (b) if a1 is equal to b1, add all cells from a3 to f3 inclusive and store the result in cell b10; otherwise, leave b10 unaltered

4. List and explain George Polya’s four steps of problem solving. Why is it so important to develop excellent problem solving skills?

5. What is the expected (theoretical) probability of

   (a) dealing an Ace from a deck of 52 cards?

   (b) dealing a heart from a deck of 52 cards?

   (c) rolling a 6 if ***six*** dice are rolled simultaneously?

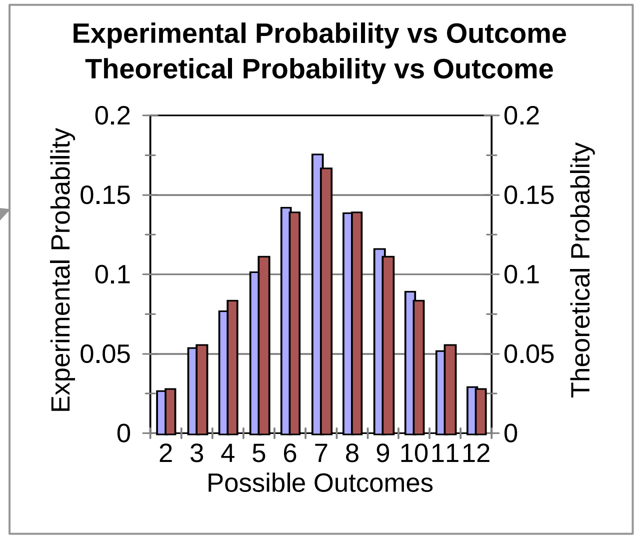
   (d) finding a student at this school who has the same birthday as you (assume student population is 1500)?

6. Explain why the bar graph of frequency versus outcome for rolling one die is fairly "flat," while the bar graph for rolling two dice has tall bars in the "middle" and short bars at the "ends."

7. While developing the spreadsheet number guessing game, we encountered a tricky problem. The secret number generated by the spreadsheet would change as soon as the user entered a correct guess. This caused the spreadsheet to fail to detect the user's correct answer. Explain the cause of this problem and explain how we solved it.

8. Explain the statement "there is order in randomness." (**Hint:** See the bar graphs given below.)

This graph shows both the experimental and theoretical probabilities for rolling two dice. The experimental probabilities shown are for 5000 rolls of the dice. Remember that the experimental probabilities are variable while the theoretical probabilities are fixed.



More Review Questions for Unit on Problem Solving and Spreadsheets

1. What important lessons about problem solving did we learn by solving each of the following problems?

Problem	What we Learned
Nine Dots Problem	
Football Upright Problem	
Roman Numeral Problems	
"Which Shape is Different?" Problem	
Simpson's Paradox	
Counting the Squares	

2. Think carefully before you answer the following questions!

(a) The formula =**@rounddown(@rand*20 + 3)** generates a random integer from ____________ to ____________.

(b) Explain your answer to 3(a). Why does the given formula generate a random integer from _____________ to ____________? Include number line set diagrams in your answer.

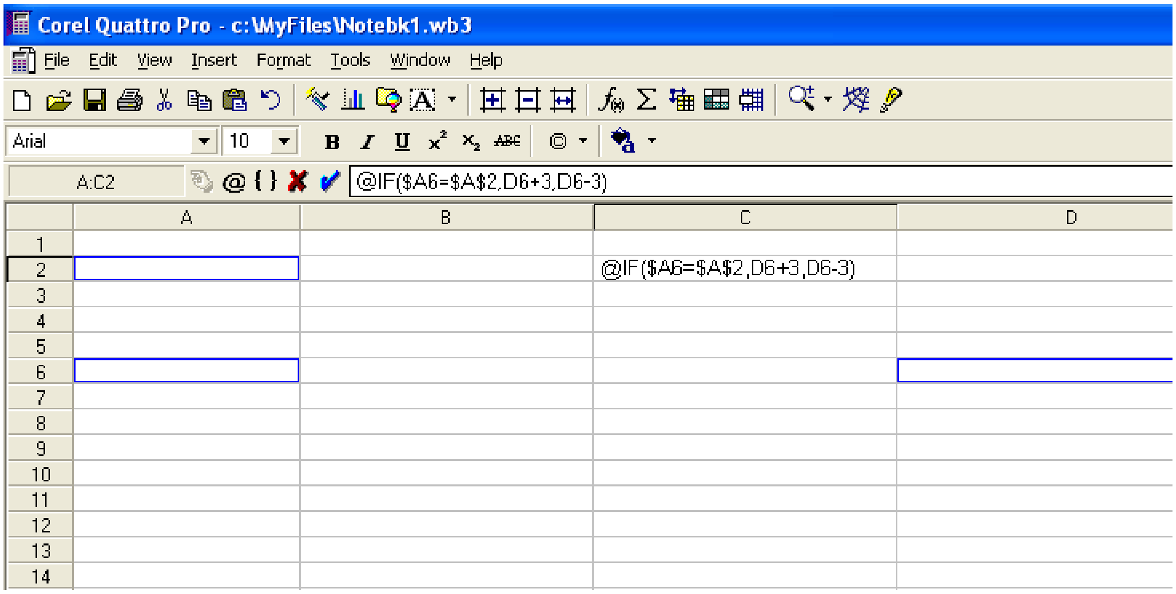
3. The formula "@if($a6=$a$2, d6+3, d6–3)" is stored in cell c2 as shown below. Write the ***adjusted formula*** after each of the following operations:

(a) The formula is copied to cell c6.

(b) The formula is copied to cell a2.

(c) The formula is copied to cell d2.

(d) The formula is copied to cell b14.

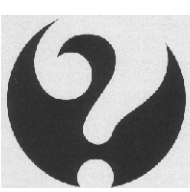


4. Solve the following problems:

(a) An eccentric old king wants to give his throne to one of his two sons. He decides that a horse race will be run and the son who owns the slower horse will become king. The sons, each fearing that the other will cheat by having his horse run less fast than it is capable, ask the court fool for his advice. With only two words, the fool tells them how to make sure that the race will be fair. What are the two words?

(b) Can you think of a way in which to put a sheet of newspaper on the floor so that when two people stand face to face on it, they will not be able to touch each other? You are not allowed to cut the paper or restrain the people in any way.

(c) What is this figure?



Problem Solving, Logic and Design: Review Checklist

By now, you should have **MASTERED** the following concepts! If you have not, it probably means that you have been negligent (you have been fooling around and not doing your work), so you **MUST** work harder!

Instructions

With a ***highlighting marker*** in hand, carefully read the above checklist. Highlight **ANY** concept that causes you even the slightest amount of uncertainty. Then review the highlighted concepts until you achieve a ***high degree of competence and confidence. Do not place a check mark in any of the check boxes until you have mastered each concept listed beside the check box!***

- ❑ ***George Polya's*** four steps of problem solving, ***logic***, ***creativity***
- ❑ ***Do not give up*** after a single attempt! ***Be patient***!
- ❑ ***Expand your view!*** Do not observe the universe with tunnel vision!
- ❑ If you do not know how to solve a certain problem, ***try solving a simpler but related problem.***
- ❑ Use the **Internet** to ***conduct research***, use ***Google*** effectively, " ", +, –, OR, ~, .., site:, etc.
- ❑ Before you ***choose a strategy,*** try to predict ***a reasonable answer*** or ***a reasonable range of answers*** for the problem that you are trying to solve. When you ***check your solution***, ask yourself if ***your answer is reasonable.*** Does your answer make sense? Does it agree with your prediction?
- ❑ When you are trying to understand a problem, identify ***information that you need, information that you don't need (extraneous information), missing information*** and ***what you are being asked to solve.***
- ❑ ***Windows keyboard shortcuts*** like ctrl-c, ctrl-x, ctrl-v, ctrl-s, shift + , ctrl-z, ctrl-s, ctrl-o, ctrl-a, ctrl-n, ctrl-p, ctrl-ESC, alt-TAB, alt-F4, PRINT SCREEN, alt-PRINT SCREEN, shift-DEL
- ❑ outcome, frequency, relative frequency (experimental probability), expected probability (theoretical probability), random, probability distribution
- ❑ ***"recalc"*** settings (**order**: natural, column-wise, row-wise, **mode**: automatic, manual, background, cell protection (locking cells))
- ❑ ***understand*** and ***explain*** the relationship between ***learning method*** and ***average retention rate*** (as displayed in the "Learning Bar Chart" at the beginning of this unit)
- ❑ Do not get caught in "the box!" ***Think outside the box!*** Do not limit your thinking by imposing boundaries on yourself!
- ❑ Do not be afraid to make mistakes! ***Take risks***!
- ❑ Often, there are ***several correct answers***. Learn how to find ***an answer*** instead of ***the answer***.
- ❑ If you do not know how to solve a ***general*** problem, ***try solving a specific example of the problem.***
- ❑ Do not blindly copy or memorize! ***You must strive to understand, analyze, apply, inquire, solve, interpret, communicate, design, implement, etc!***
- ❑ Understand Internet terminology such as internet, intranet, World Wide Web, browser, server, search engine, metasearch engine, protocol, etc.
- ❑ row, column, cell, formula, label, fill up/down, fill right/left, $, relative cell reference, absolute cell reference, intrinsic function, @int, @rounddown, @rand, @if, @sum, @avg, @roundup, @round, @randbetween, +, –, *, /
- ❑ datum, data, die, dice, horizontal axis (x-axis), vertical axis (y-axis), primary y-axis, secondary y-axis, independent variable, dependent variable
- ❑ ***generate random integers*** between two integers a and b, where $a < b$: @rounddown(@rand*($b - a + 1$) + a)
- ❑ ***explain*** using ***words and set diagrams*** why the formulas we used in this unit produce the correct range of ***random integers***

Appendix – What Is Problem Solving?

Michael E. Martinez

Errors are part of the process of problem solving, which implies that both teachers and learners need to be more tolerant of them, Mr. Martinez points out. If no mistakes are made, then almost certainly no problem solving is taking place.

To think is constantly to choose in view of the end to be pursued.[1]

Every educator is familiar with the term "problem solving," and most would agree that the ability to solve problems is a worthy goal of education. But what is problem solving? Its meaning is actually quite straightforward: ***problem solving is the process of moving toward a goal when the path to that goal is uncertain***. We solve problems every time we achieve something without having known beforehand how to do so. We encounter simple problems every day: finding lost keys, deciding what to do when our car won't start, even improvising a meal from leftovers. But there are also larger and more significant "ill-defined" problems, such as getting an education, becoming a successful person and finding happiness. Indeed, the most important kinds of human activities involve accomplishing goals without a script.

Problem solving is a ubiquitous feature of human functioning. Human beings are problem solvers who think and act within a grand complex of fuzzy and shifting goals and changing means to attain them. This has always been true, but it is doubly so today because we live in a time of unprecedented societal transformation. When circumstances change, old procedures no longer work. To adapt is to pursue valued goals even when circumstances – and perhaps the goals themselves – are in flux. Because the pace of societal change shows no signs of slackening, citizens of the 21st century must become adept problem solvers, able to wrestle with ill-defined problems and win. Problem solving ability is the cognitive passport to the future.

There is no formula for true problem solving. If we know exactly how to get from point A to point B, then reaching point B does not involve problem solving. Think of problem solving as working your way through a maze.[2] In negotiating a maze, you make your way toward your goal step-by-step, making some false moves but gradually moving closer toward the intended end point. What guides your choices? Perhaps a rule like this: choose the path that seems to result in *some* progress toward the goal. Such a rule is one example of a ***heuristic***. A heuristic is a rule of thumb. It is a strategy that is powerful and general, but not absolutely guaranteed to work. Heuristics are crucial because they are *the* tools by which problems are solved.

By contrast, algorithms are straightforward procedures that are guaranteed to work every time. For example, you have in your long-term memory algorithms that enable you to tie your shoelaces, to start up your car, and perhaps even to cook an omelette. Barring broken shoelaces, a dead battery and rotten eggs, these algorithms serve you very well. An algorithm may even be so automatic that it requires very little conscious processing as you carry out the procedure.

Now here is an important consideration: what constitutes problem solving varies from person to person. For a small child, tying shoelaces will indeed require problem solving, just as cooking an omelette entails problem solving for many adults. Thus problem solving involves an interaction of a person's experience and the demands of the task. Once we have mastered a skill, we are no longer engaged in problem solving when we apply it. For a task to require problem solving again, novel elements or new circumstances must be introduced or the level of challenge must be raised. Some problem solutions, however, can never be reduced to algorithms, and it is often those problems that constitute the most profound and rewarding of human activities. The necessity of problem solving to all that is important about being a person cannot be overstated.

In addition, problem solving is not an advanced process that is reserved solely for mature learners. Indeed, people of all ages can and must be solvers of problems. Perhaps young children are the most natural problem solvers. Because they continually face circumstances that are novel, they must adapt. It's their "job.' And they are amazingly good at it. Moreover, young children don't fret about failure the way that school-age children and adults tend to do. They take detours and setbacks in stride because they know intuitively that such obstacles are a part of the problem solving process. Still, we need to encourage problem solving in children. Whenever possible, this involves letting children find their own ways of reaching their goals. Good parents and other caregivers know when to stand back and let a child figure things out and when to step in and offer the right amount of help.

Armed only with our heuristics, then, we engage in a process of ***heuristic search***. Like finding one's way through a maze, we move closer, haltingly, to where we want to be. We can't be sure of what lies around the next corner or that the direction that once seemed so promising will pay off. Progress toward important goals is incremental, and each move is informed by our repertoire of heuristics. Because of the possibility of false moves, we need to monitor our progress continually and switch strategies if necessary.

The Power of Heuristics

If heuristics are the problem solver's best guide, it makes sense to elucidate them as much as possible. First, each learner must know what heuristics are and must be aware of their power. Second, each learner must have both general and specific heuristics at his or her disposal. General heuristics are cognitive "rules of thumb" that are useful in solving a great variety of problems. They are usually content-free and apply across many different situations. Specific heuristics are used in specialized areas, often specific subject domains or professions.

Probably the most powerful general heuristic, alluded to in the maze example, is "means-ends analysis." Essentially, the heuristic is this: form a subgoal to reduce the discrepancy between your present state and your ultimate goal state. Phrased more colloquially: do something to get a little closer to your goal.

Problems defy one-shot solutions; they must be broken down. Means-ends analysis accepts incremental advancement toward a goal. The method is not fail-safe, of course, because positive results are not guaranteed with any heuristic. However, if all goes well, this heuristic will help move you incrementally toward your ultimate goal. You apply it again and again, trying to reduce the discrepancy further. By means of this less-than-direct path, you find your way to the ends you seek. Such a search is not simply a process of trial and error, because the steps taken are not blind or random. Rather, the application of a series of tactical steps leads you ever closer toward the goal. Mistakes made along the way must be accepted as inextricable from the problem solving process.

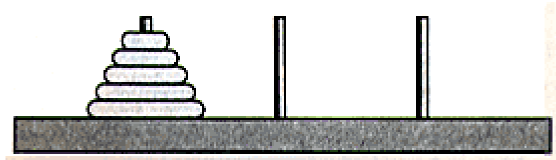
The benefits conferred by means-ends analysis may be as much emotional as intellectual. If a large and complex problem seems daunting as a whole, perhaps one can summon the will to accomplish a small piece of it. And that success can motivate one to persist. Thus, starting a task can make the effort self-sustaining. Sometimes, when we tackle a difficult project, it's as if we are trying to start a car on a cold winter morning. We encounter resistance. Once begun, however, the task becomes marginally easier and doesn't require a constant exertion of will to sustain it. At some point, we "cross the Rubicon" – we reach the point where it seems more difficult to stop than to carry on to completion. That is when a problem solving activity becomes self-sustaining and bears us along by its momentum. "Just do it!" is not solely a great marketing slogan; it can also be seen as a directive to disregard the ominous hulking problem that looms ahead and simply take the first step.

Heuristics are usually picked up incidentally rather than identified and taught explicitly in school. This situation is not ideal. A curriculum that encourages problem solving needs to provide more than just practice in solving problems; it needs to offer explicit instruction in the nature and use of heuristics. Herbert Simon has written:

> In teaching problem solving, major emphasis needs to be directed toward extracting, making explicit, and practicing problem solving heuristics – both general heuristics, like means-ends analysis, and more specific heuristics, like applying the energy conservation principle in physics.[3]

What are some other heuristics? One that is probably familiar to most readers goes by the name of "working backward." First, consider your ultimate goal. From there, decide what would constitute a reasonable step just prior to reaching that goal. Then ask yourself, "What would be the step just prior to that?" Beginning with the end, you build a strategic bridge backward and eventually reach the initial conditions of the problem.

An illustration of the use of this approach can be taken from the Tower of Hanoi problem. A number of disks are placed on a peg in an arrangement like this:



The rules are simple. Only one disk can be moved at a time, and a larger disk may never be placed on top of a smaller disk. The goal is to move the entire stack of disks from the first peg to the third. Working backward helps us understand that at some point, we must find a way to place the largest disk at the bottom of the third peg. Working backward from there, we would infer that all the smaller disks would eventually need to be placed on the middle peg, according to the rules, so that the largest disk is free to move. That step also has logical precursors, and so on. Working backward makes the problem more manageable and its solutions much more efficient than following a less reasoned approach.

Or take another example. My daughter came home from school with a story about a provocative exchange between a teacher and a student:

> *Teacher*: What do you want to be when you are an adult?
> *Student*: I want to be rich.
> *Teacher*: No, but what do you want to be?
> *Student*: I don't care. I just want to be rich.

This student certainly had a clear goal in mind, though some might question its value independent of the means for achieving it. In any case, the student has some serious "working backward" to do. If his goal is to be rich, what kind of career might allow him to achieve it? Becoming a movie star? A Wall Street investor? An entrepreneur? A criminal? Some combination of these? If an entrepreneur, that might imply that majoring in business in college would be in order. In turn, that goal might suggest that tonight the student should study his mathematics a little harder than is his custom. Working backward makes "next steps" plainer than simply wishing and hoping that dreams will materialize.

A third heuristic seeks to solve problems through "successive approximation." Initial tries at solving a problem may result in a product that is less than satisfying. Writing is a good example. Few accomplished writers attempt to write perfect prose the first time they set pen to paper (or fingertips to keyboard). Rather, the initial goal is a rough draft or an outline or a list of ideas. Over time, a manuscript is gradually moulded into form. New ideas are added. Old ones are removed. The organization of the piece is reshaped to make it flow better. Eventually, a polished form emerges that finally approximates the effect that the author intended.

Given time and effort, what started out as rough and approximate can become art. In fact, successive approximation seems to be an important heuristic in producing outstanding creative works of all kinds. This model is relevant to many pursuits other than writing. Inventions, theories, stories, recipes and even personal and group identities start out rough but are restructured and refined over time. Think of the bicycle, whose various designs over the decades have metamorphosed toward greater efficiency and lighter weight. Successive approximation accepts the design process as problem solving, a series of zigs and zags toward something better.[4] Not only is such a process compatible with human information processing, but awareness of the principle can sustain a half-baked idea that initially seems raw, wild and foolish but is just possibly the germ of an eventual marvel.

George Polya's advice was, "Draw a figure."[5] In that spirit, I offer a fourth and final example of a heuristic: portray the problem at hand in an explicit "external representation." List, describe, diagram or otherwise render the main features of a problem. This heuristic has several important features. First, it allows us to represent more complexity than we can hold in mind at once. Depicting a problem on paper, whiteboard or computer screen relieves short-term memory of the burden of representing the problem and allows the processing capacity of our brains to be directed toward solving it. An incidental benefit is that often the very attempt to represent the problem explicitly forces a problem solver to be clear about what it is he or she is trying to do and about what stands in the way. A clearer representation of goals and obstacles may by itself greatly simplify solution of the problem.

Another benefit of external representation is that the medium chosen to portray a problem may help the solver see the problem in a new way. In our heads we may understand a problem in words. On paper, we may discover that a picture makes more sense. Sometimes words can distort the more direct pictorial representations and so hinder problem solving.[6] Pictorial representations are used by experts in many fields and can be of considerable help.[7]

Finally, an external representation, unlike a mental representation, is potentially a "public document." The fact that other people can see it might help a group reach consensus about the nature of a problem. An obstacle that is prohibitive to one person might seem trivial or irrelevant to another. Likewise, a common representation might allow one participant to point out a significant opportunity that is unseen by other members of the group.

Metacognition

All heuristics help break down a problem into pieces. The problem as a whole is thus transformed. It is no longer a chaotic mass, like a ton of cooked spaghetti. Rather, through the creation of various subgoals, each of the pieces becomes manageable. The problem does become more complex in one sense because the pieces themselves must somehow be borne in mind. If a large goal is broken down into subgoals, then one cognitive challenge becomes goal management – keeping track of what to do and when. Goal management is probably a major aspect of intelligent thought. Patricia Carpenter, Marcel Just and Peter Shell regard goal management as a central feature of problem solving.

> A key component of analytic intelligence is goal management, the process of spawning subgoals from goals, and then tracking the ensuing successful and unsuccessful pursuits of the subgoal on the path to satisfying higher-level goals… The decomposition of complexity … consists of the recursive creation of solvable subproblems… But the cost of creating embedded subproblems, each with [its] own subgoals, is that they require management of a hierarchy of goals.[8]

The importance of monitoring subgoals is an example of a more general phenomenon: one common feature of problem solving is the capacity to examine and control one's own thoughts. This self-monitoring is known as metacognition. Metacognition is essential for any extended activity, especially problem solving, because the problem solver needs to be aware of the current activity and of the overall goal, the strategies used to attain that goal and the effectiveness of those strategies. The mind exercising metacognition asks itself, "*What* am I doing?" and "*How* am I doing?" These self-directed questions are assumed in the application of all heuristics. However, in practice, teachers cannot simply assume that students will engage in metacognition it must be taught explicitly as an integral component of problem solving.

Problem solving requires both the vigilant monitoring and the flexibility permitted by metacognition. When solving problems, means shift continually depending on one's position relative to desired goals. Even goals change as old goals are superseded by new and better ones. Maintaining flexibility is essential. Too often we feel wedded to a chosen strategy and continue to apply that strategy even if it leads us wildly astray. When this happens, it is usually wrong to conclude that we must start over. The important question is always "What do I do *now*, given my goal, my current position and the resources available to me?" Getting off course along the way is fully expected. Cool-headed reappraisal is the best response – not mindless consistency, panic or surrender.

A New Mindset

In pursuit of the goal of improving problem solving ability, I have advocated the use of heuristics and have suggested a few. There are countless others. Some are general and apply to many problem situations, but most are specific and apply in specialized fields. Heuristics are vital, but they are not necessarily the most important aspect of problem solving.

Perhaps more powerful than any heuristic is an understanding that, *by its very nature, problem solving involves error and uncertainty*. Even if success is achieved, it will not be found by following an unerring path. The possibilities of failure and of making less-than-optimal moves are inseparable from problem solving. And the loftier the goals, the more obvious will be the imperfection of the path toward a solution. The necessity of uncertainty is recognized implicitly whenever we commend someone for being a risk taker. It is not the taking of risks itself that is commendable; rather, taking risks is a means to an end. What we actually applaud is the courage to adopt a difficult and commendable goal and then to enter the thorny thicket of problem solving where the only way out is through heuristic search and nerve. The willingness to suspend judgment – to accept temporary uncertainty–is an important aspect of thinking in general. John Dewey linked tolerance of uncertainty to reflective thinking:

> Reflective thought involves an initial state of doubt or perplexity… To many persons both suspense of judgment and intellectual search are disagreeable; they want to get them ended as soon as possible… To be genuinely thoughtful, we must be willing to sustain and protract the state of doubt, which is the stimulus to thorough inquiry.[9]

How then is it possible to improve problem solving ability? First, we need to recognize when we are engaged in problem solving and accept as natural, normal, and expected the stepwise and discursive path toward a goal through the application of general and specific heuristics. Second, we must not let anxiety take hold. Anxiety is a spoiler in the problem solving process. It stalks right behind uncertainty, ready to pounce. Demanding and uncertain environments, the seedbeds of all problem solving, are fertile ground for anxiety. Uncertainty is an integral part of the business of solving problems. Those who cannot bear situations in which it is impossible to see the way clearly to the end are emotionally ill-prepared to solve problems.

Errors are part of the process of problem solving, which implies that both teachers and learners need to be more tolerant of them. If no mistakes are made, then almost certainly no problem solving is taking place. Unfortunately, one tradition of schooling is that perfect performance is often exalted as an ideal. Errors are seen as failures, as signs that the highest marks are not quite merited. Worse still, errors are sometimes ridiculed or taken as ridiculous. Mistakes and embarrassment often go hand in hand. Perfect performance may be a reasonable criterion for evaluating algorithmic performance (though I doubt it), but it is incompatible with problem solving.[10]

What so often counts most in schools is the important but incomplete cognitive resource of *knowledge*. Fixed knowledge and algorithms are easier to teach, learn and test than is the tangled web of processes that make up problem solving. Typically, it is not before graduate school that problem solving really becomes the focus of an educational program. Even in graduate school a student may not get to wrestle with the true problems of a field of study until the dissertation.

What can reverse this sorry state of affairs? A better understanding of the nature of problem solving is a place to start. Ultimately, we will have to change the culture of schooling. In the workplace as well, we need to revise our attitude toward errors – at least toward those that are a reasonable consequence of significant problem solving. (Errors in balancing the books don't count.) But if a job requires fluid intelligence – the ability to operate within the flux of continually changing demands and challenges – even the corporate culture must accept and deal with the multitude of paths toward solutions and the necessary existence of error.

For educators to accept errors, uncertainty, and indirect paths toward solutions is itself a difficult problem because doing so contradicts our engrained beliefs and expectations about teaching and learning. But problem solving must be understood and promoted if the next generation is to be prepared for the unprecedented challenges (i.e., problems) that it will face. Yet great things are accomplished when great things are attempted, and in our efforts we do not face total uncertainty. We have, in fact, our experience and its dividend, our knowledge, to support us. Heuristics and knowledge are what Herbert Simon has called the "two blades" of effective professional education, and he reminds us that "two-bladed scissors are still the most effective kind."[11] I would add that what is good for professional education is good for education of all kinds at all levels. By combining what we *do* know with our understanding of the problem solving process, we can move toward our goals – perhaps not unerringly, but by the sort of wending progress that is the signature of problem solving.

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1. Alfred Binet and Theodore Simon, *The Development of Intelligence in Children*, trans. E. S. Kite (Baltimore: Williams & Wilkins, 1916), p. 140.
2. Herbert A. Simon, *The Sciences of the Artificial* (Cambridge, Mass.: MIT Press, 1981).
3. Herbert A. Simon, "Problem Solving and Education:' in David T. Tuma and Frederick Reif, eds., *Problem Solving and Education: Issues in Teaching and Research* (Hillsdale, N.J.: Erlbaum, 1980), pp. 81-96.
4. Charles E. Lindblom, "The Science of Muddling Through" *Public Administration Review*, vol. 19, 1959, pp. 79-88.
5. George Polya, *How to Solve It*, 2nd ed. (Garden City, N.Y.: Doubleday, 1957).
6. Jill H. Larkin and Herbert A. Simon, "Why a Diagram Is (Sometimes) Worth Ten Thousand Words," *Cognitive Science*, vol. 11, 1987, pp. 65-99.
7. Fred Reif and Joan I. Heller, "Knowledge Structure and Problem Solving in Physics," *Educational Psychologist*, vol. 17, 1982, pp. 102-27.
8. Patricia A. Carpenter, Marcel Adam Just, and Peter Shell, "What One Intelligence Test Measures: A Theoretical Account of the Processing in the Raven Progressive Matrices Test," *Psychological Review*, vol. 97, 1990, pp. 404-31.
9. John Dewey, *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process* (Boston: Heath, 1933), p. 16.
10. It is not impossible to solve a problem without error, but it is misleading to think that this experience is the normal character of problem solving.
11. Simon, "Problem Solving and Education"

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This article is taken from http://www.gse.uci.edu/faculty/michael_problemSolving.php .

Questions

1. Define the following terms:
   ubiquitous, discursive, adept, entrepreneur, render, protract, criterion, loftier, exalted, astray, vigilant
2. Now list the sentences in the article that contain the words listed in question 1. Do you have a better understanding of the sentences now that you have looked up the definitions?
3. List any other words and sentences that you do not understand.
4. What is problem solving? How does it differ from applying a skill? Is there a formula for solving problems?
5. What is an ***algorithm***? What is a ***heuristic***? Which of these two is more closely associated with ***genuine*** problem solving tasks?
6. Why has it always been important to develop strong problem solving skills? Why is it especially important nowadays?
7. List four examples of heuristics.
8. Recall the following exchange between a student and a teacher:

   Teacher: What do you want to be when you are an adult?
   Student: I want to be rich.
   Teacher: No, but what do you want to be?
   Student: I don't care. I just want to be rich.

   What is the problem with the student's approach to setting goals?
9. What are the roles of error and uncertainty in the problem solving process?
10. How can problem solving ability be improved?