# Play Together Learn Together:

## *Science, Technology, Engineering, and Math*

**David Moursund**

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"Mankind owes to the child the best it has to give."
(United Nations Declaration of the Rights of the Child, 1959.)

Origami. See Chapter 3.

**Second Edition (11/4/2011).** The first edition was titled *Expanding the Science and Technology Learning Experiences of Children* and is archived at http://i-a-e.org/downloads/doc_download/207-expanding-the-science-and-technology-learning-experiences-of-children.html.

**Robert Albrecht.** Editor and Content Consultant for the second edition.

**Available as a Free Download.** The most recent version of this book is maintained by Information Age Education as a free PDF download at http://i-a-e.org/downloads/doc_download/212-play-together-learn-together-stem.html and as a free Microsoft Word download at http://i-a-e.org/downloads/doc_download/213-play-together-learn-together-stem.html.

**The book is free, but contributions are welcome.** See http://iae-pedia.org/David_Moursund_Legacy_Fund.

# About the Author David Moursund

> "In a completely rational society, the best of us would be teachers and the rest of us would have to settle for something less, because passing civilization along from one generation to the next ought to be the highest honor and the highest responsibility anyone could have." (Lee Iacocca, American industrialist; 1924-.)

- Doctorate in mathematics, University of Wisconsin-Madison.
- Assistant Professor and then Associate Professor, Department of Mathematics and Computing Center (School of Engineering), Michigan State University.
- Associate Professor, Department of Mathematics and Computing Center, University of Oregon.
- Associate and then Full Professor, Department of Computer Science, University of Oregon. Served six years as the first Head of the Computer Science Department.
- Full Professor in the College of Education at the University of Oregon for more than 20 years.
- Started the publication that eventually became *Learning and Leading with Technology*, the flagship periodical of the International Society for Technology in Education.
- Founded the International Society for Technology in Education. Headed this organization for 19 years.
- Author or co-author of more than 40 commercially-published books and several hundred articles.
- Major professor or co-major professor for 82 Ph.D. students. See http://www.genealogy.ams.org/id.php?id=8415.
- For more information about David Moursund, see http://iae-pedia.org/David_Moursund.

# Table of Contents

"Children are the message we send to the future." (Abraham Lincoln; sixteenth US President; 1809–1865.)

"Children are the world's most valuable resource and its best hope for the future" (John Fitzgerald Kennedy; 35th US President; 1917-1963.)

# Chapter 1: Preface and Introduction

"It takes a whole village to raise a child" (African Proverb.)

"In short, learning is the process by which novices become experts." (John T. Bruer. *Schools for Thought,* 1999.)

This book is for parents, grandparents, teachers, and other adult caregivers. Its goal is to help you improve the education of children. Here are the key aspects of this book:

1. The book focuses on the idea of "Play together, learn together." Learning can be fun. Children and parents can have fun and can learn through playing together. Children can have fun and learn while playing together.
2. A parent, teacher, or other caregiver, when working with a child or very small group of children, is serving as a tutor. One-on-one or small group tutoring is a very effective aid to learning. David Moursund is co-author of a free book on math tutoring designed for parents, teachers, and others. See http://iae-pedia.org/Math_Tutoring.
3. The Web is a tremendous and steadily growing resource of learning materials and activities. More generally, there are many computer-based resources that are designed to help a learner learn. In this book we use the idea of a human tutor and a computer-as-tutor (a computer tutor) working together to help a student learn.
4. The book focuses on the areas of Science, Technology, Engineering, and Mathematics (STEM). It contains links to a large number of valuable resources.

The book contains a large number of activities designed for children and/or for adults and children playing and learning together. Quite a few of the activities require some adult supervision or adult help in getting started. Thus, this book is written for adults, rather than for children, but the focus is on children's activities. The goal of the book is to help you get better at helping children learn about science, technology, engineering, and mathematics though the use of educationally sound, fun activities.

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| | If you have not already done so, spend a couple of minutes browsing the Table of Contents. You will likely find a number of topics that might interest you and your children. There is no need to read this book from cover to cover. Find a topic that interests you, and go directly to it. | |

## Example: Tower of Hanoi

The Tower of Hanoi is a puzzle game. The setup (starting position) is a cone-shaped stack of disks as shown in Figure 1.1. Notice that from bottom to top, the disks are of uniformly decreasing radius but equal thickness.  The goal to move the stack of disks to the third post subject to the two rules:

1. A "move" consists of taking one disk from the top of the stack on one post and moving it to the top of the zero or more disks that are on a different post.
2. You may not place a larger disk on a smaller disk.

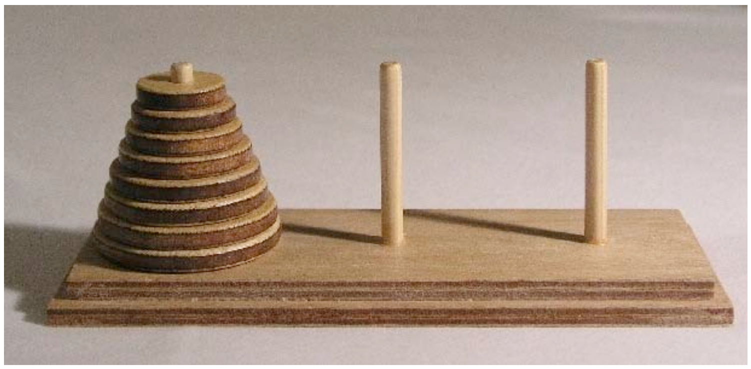

Figure 1.1. Eight-cylinder Tower of Hanoi.

Figures 1.2 and 1.3 show a way to solve the three-cylinder Tower of Hanoi puzzle.

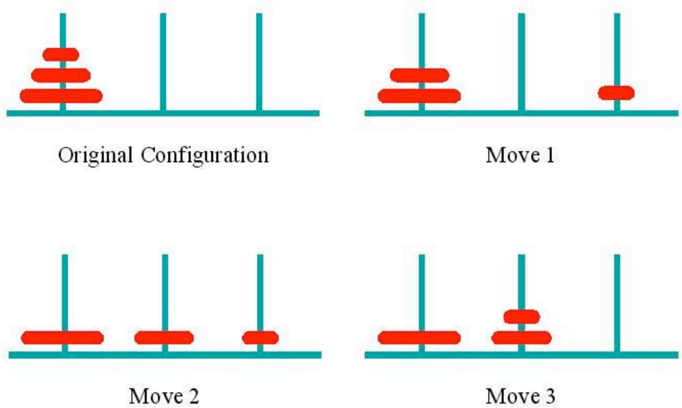


Figure 1.2: First three moves in solving the three-cylinder Tower of Hanoi puzzle.

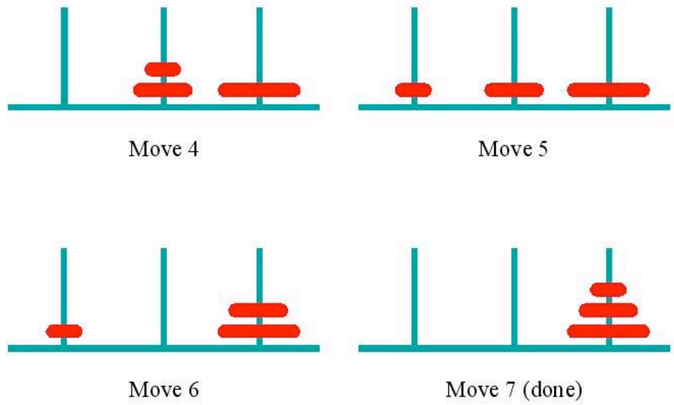


Figure 1.3: Next four moves in solving the three-cylinder Tower of Hanoi puzzle.

A Tower of Hanoi puzzle can be made of various materials, such as wood, plastic, or cardboard. It can also be made as a computer simulation—that is, as a version that can be played on a computer. See, for example, http://www.mathsisfun.com/games/towerofhanoi.html and http://www.mazeworks.com/hanoi/.

The Tower of Hanoi puzzle was developed by the French mathematician Edouard Lucas in 1883. (See http://www.cut-the-knot.org/recurrence/hanoi.shtml.) Thus, we have:

1. A puzzle with interesting and challenging underlying mathematics. (Math is one of the STEM disciplines.)
2. A puzzle of varying levels of difficulty (depending on the number of disks, so it fits children of varying levels of development.
3. A puzzle that can be played without a computer, but has also been computerized. The computer can be used to help a student learn about the puzzle and to practice solving the puzzle.

Suppose that by playing this game with your child, you help your child to learn to focus his or her attention. You help your child to learn to plan ahead. You help your child gain in having persistence and in dealing with challenging problem situations

Wow! These are all lifetime skills! The game by itself helps, but it is you—a responsible and committed adult—who is a prime contributor to the important learning that occurs.

After playing with the game for a while, perhaps you are now ready to get back to tackling this book! In reading this book you will encounter a large number of educational games and other materials that will be interesting to you and that are designed for children.

## Purpose of the Book

The book is for all adults who are interested in working with children to help improve the STEM education of children.

A child's healthy brain has a tremendous capability to learn. It is naturally curious and is always learning—and it learns at an amazing rate. Just try to imagine the amount of learning involved in developing oral fluency in one or more languages. Children do this easily as they grow up in a monolingual or bilingual home and community environment. Imagine the amount of one's family and local culture that is learned during the first half dozen years of life.

An excellent video on brain science developed by Helen Neville's research group at the University of Oregon is available free at http://changingbrains.org/. Click on WATCH ONLINE in the menu on the left side of the web page. (Here, I am being sneaky. I want you, the reader, to learn more about science. The video is intended for adults.)

The adults in a child's life strongly influence breadth, depth, and quality of informal early childhood learning experiences. From the point of view of a young child every adult (along with siblings, peers, and so on) is a teacher. Every experience is a learning experience.

As you read this book and try out its ideas with children, keep in mind that all people are lifelong learners and lifelong teachers. Every time you interact with a child, you are helping that child to learn, and you are learning about helping children learn.

### More Structured Learning Experiences

As children progress through early childhood, many parents and other adult caregivers provide an extra depth of learning experiences in areas that they are especially competent in and/or feel are particularly important.

A child growing up in a musical home environment is likely to gain considerably more music knowledge, skill, and interest than a child growing up in an environment that places less stress on music. The same type of analysis holds for sports environments, academic environments, outdoor nature environments, and so on.

Think about the Science, Technology, Engineering, and Mathematics (STEM) environment available to the children you work with. Important parts of this environment are available in homes, schools, and the general community environment. Parents and teachers can significantly improve the science and technology education of the children they work with by creating home and school environments that emphasize informal STEM education. For example, if you are a parent who lets your children watch a lot of television, think about the very large number of excellent STEM-oriented materials that are now available on television. (See Chapter 7 in this book.) Or, think about what children learn as they build and test fly paper airplanes, do Origami, and engage in a wide range of arts and crafts activities. Computers add an important new dimension to the availability of such materials.

In addition, many parents find it is desirable to make some use of "outside experts" to add to a child's experiential learning environment. Thus many children take part in music camps, sports camps, art camps, outdoor nature camps, computer camps, and trips to a Science and Technology Center. Parents often encourage their children to participate in in-school and after-school clubs, and some hire tutors for their children.

### A Trip to a Science & Technology Center

A trip to a science and technology center falls between the parent-provided environment and the outside expert-provided environment. Regular trips to such a center can help both you and the children you work with to learn.

Advance planning is highly desirable. Develop some ideas of what you want the children to learn during the tour. The chances are quite good that you can find a Web Page that describes the various parts of the exhibit and briefly discusses some of the underlying science, technology, engineering, and mathematics.

If you are touring a science and technology center with your child, try to figure out at least one child-appropriate learning idea for each of the exhibit pieces you visit together. Explicitly bring this to the attention of your child. This is exceedingly important in terms of child learning. Approach an exhibit both from your adult perspective and your insight into your child's point of view.

Suppose, for example, one of the exhibits is an inclined plane that can be used in sliding (flat) blocks or rolling (cylindrical or spherical) blocks down the incline plane. The incline plane is inclined at a fixed angle. What do you know about this situation? I'll bet you know something about sliding friction and rolling friction. Have you ever used roller skates, ice skates, or a skateboard? What do you know about applying the brakes on a car going up hill (up an inclined plane) versus going down hill?

Figure 1.4: Rolling objects down an inclined plane. See http://demos.phy.duke.edu/phydemos/1/1Q/Ring_Disk_and_Sphere_on_Incline/index.php.

The invention of the wheel is certainly one of the most important inventions ever. Notice some of the relevant words and ideas: incline plane, angle of inclination, sliding friction, and rolling friction. Think about what these words mean to you and to young children. Can you think of some things you might do at home or school to help prepare a child for this learning experience? Can you think of possible roles of lubricants such as water or oil in these incline plane examples?

Next, how about some follow-up? This book contains a large number of activities that you can do with children. Quite a few require some adult supervision. Remember, this book is written for adults, rather than for children. However, the focus is on children's activities. The goal of the book is to help you get better at helping children learn about science, technology, engineering, and mathematics though the use of educationally sound, fun activities.

If you have not already done so, spend a couple of minutes browsing the Table of Contents. You will likely find a number of topics that might interest you and your children. There is no need to read this book from cover to cover. Find a topic that interests you, and go directly to it.

**Representing, Thinking About, and Solving Problems**

It takes careful thinking to solve challenging problems one has not encountered before. Science, technology, engineering, and mathematics focus on certain types of problems and how to attempt to solve these problems. Over thousands of years, there has been a steady accumulation of know what and

know how in the STEM disciplines. Moreover, products of this progress are a routine part of our lives.

This book contains many opportunities to learn more about problems and problem solving. A key idea is transfer of learning from one learning experience to a different application area. Suppose, for example, one learns about paper folding in developing Origami figures. The art of paper folding is applicable to wrapping packages, making decorations to go on packages, making paper airplanes, and in various areas of science. The process of learning to make Origami figures helps to develop patience, skill in following directions, creativity, manual dexterity, and so on.

Adults who work with children in using the Internet need to be especially aware of dangers that lurk there. These child and parent Internet encounters provide an excellent environment for parents to help their children learn about appropriate and inappropriate use of the Internet. An excellent source of information and advice to parents is available at http://www.onguardonline.gov/topics/net-cetera.aspx. Quoting from this Website:

> In *Net Cetera: Chatting With Kids About Being Online*, OnGuard Online gives adults practical tips to help kids navigate the online world.
>
> Kids and parents have many ways of socializing and communicating online, but they come with certain risks. This guide encourages parents to reduce the risks by talking to kids about how they communicate—online and off—and helping kids engage in conduct they can be proud of. Net Cetera covers what parents need to know, where to go for more information, and issues to raise with kids about living their lives online.
>
> OnGuard Online encourages you to use this guide with your kids, in your school, at your PTA meeting, or anywhere else parents might gather. Feel free to order as many free copies as you'd like, put your own sticker on it, reprint sections in a newsletter or on a website, download a button or link to it, or even reprint it with your own logo. These materials are in the public domain.

In summary, view every activity discussed in this book as a learning opportunity both for you and for the children you work with. As an adult working with children and these activities, figure out what general learning expectations are appropriate to the children you are working with. Then figure out what you can do to enhance the learning experience. Give careful thought to what the children are learning from the experience. Make this learning more concrete by openly discussing it with the children.

Please reread the previous paragraph. Many adults think that if they just place children in a good learning environment (for example, buy them educational toys) the desired learning will sort of magically and automatically happen. They seem to forget the need for explicit emphasis on what is to be learned, and the value of adult-children interaction.

# Chapter 2: Important Educational Background Information

"The saddest aspect of life right now is that science gathers knowledge faster than society gathers wisdom." (Isaac Asimov, Russian-born American author and biochemist, 1920–1992.)

This chapter provides a very brief introduction to some of the key ideas in education. Readers who are not professional educators will likely find some of the ideas are new to them. Experienced teachers can use this chapter as a quick review.

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| | Some readers may decide that they are not interested in the educational theory underlying the content of this book. They just want to get to the fun and interesting examples and resources. If you fall into this category, feel free to skip this chapter. | |

Science, Technology, Engineering, and Mathematics (STEM) play a huge role in our everyday lives. Just think about food, clothing, shelter, medicine, transportation, communication, entertainment, and other products and services that contribute to our daily lives. All of these are affected by improvements in technology.

We live at a time of a rapid pace of change in STEM. This pace of change is increasing and is a challenge to people of all ages throughout the world. All children deserve an education that helps them to learn about and to deal with current and likely future STEM changes. This education benefits from home, community, and school environments that include an emphasis on learning about and dealing with change.

**Informal and Formal Education**

We all know that schooling is important to our children. This schooling is done through public schools, private schools, home schooling, distance education, and so on.


However, formal schooling is only a modest part of a child's total education. Just think about how much a child learns before starting in a formal kindergarten or first grade. The child has already learned oral communication in one or more languages. The child has made great strides in learning about everyday life in his or her home and community environment. The child has learned to cope with a wide range of routine problem-solving situations.

In addition, the child has learned a great deal about the culture of his or her family and community. The child has learned how to get along with people of all ages, how to make use of a broad range of technological devices, and other aspects of day to day life in the child's society.

This informal learning environment may also include a substantial amount of semiformal instruction that helps prepare the child for formal schooling. A very important part of this comes from parents and other adult caregivers exposing children to varied learning experiences—especially reading and interactive communication. On average, children who grow up in an "enriched" environment of such informal education begin school about a year ahead of children who are much less fortunate in their early childhood. This enriched environment included parent spending a lot of time talking with and reading to their children.

A young child asks a great may "why" and "what" questions. Each question provides an opportunity for a two-way conversation. Such two-way communications are quite different than those in which parents and other adults order or tell a child what to do in an authoritative manner. In these two-way communications you can gain insight into the child's mind and understanding of the world.

Informal education does not stop when children begin school. Even without counting the time a child is asleep, in a year a typical student spends more than three hours outside of school for every hour in school. Thus, a child's informal education continues to be very important year after year. Parents and other adult caregivers continue to play a major role in the education of their children!

**Some Key Ideas in Education**

Here are some really important educational ideas. If you are a professional teacher, you have probably encountered all of these ideas, and you can easily add to this list. If you are a layperson, some of the ideas are apt to be new to you.

Each learning experience can be analyzed by how well it incorporates these ideas. As you work to help children learn, think about how these ideas fit in with what you are doing. Also think about what you want children to learn about these ideas.

1. **Motivation.** Motivation that comes from within a person is called intrinsic motivation. An intrinsically motivated learner is strongly, personally interested in and involved with what he or she is learning. Research and actual practice indicates this involvement leads to much faster and better learning than when the driving force is extrinsic motivation—motivation that comes from outside the learner. This is a very important idea. Often parents and teachers follow an extrinsic approach to education—rewarding or bribing students for learning and punishing them for not learning. The rewards and punishment issue is beyond the scope of this book. However, research is gradually providing us better approaches.

   Remember the quote: "You can lead a horse to water, but you cannot make it drink." Children are born with innate curiosity and thirst for knowledge. Our informal and formal education system seems to damage these characteristics in many children.

2. **Feedback.** High quality and immediate feedback, such as occurs in one-on-one or very small group teaching/learning environments, is much more effective than large group instruction. To put this simply, a parent or other adult caregiver working one-on-one with a child greatly speeds up learning and greatly improves retention as contrasted with large group teaching situations.

Self-assessment and formative assessment are two really important ideas in feedback. We want students to learn to judge the quality and correctness of their own work. We want to provide assessment that is not judgmental, but rather is designed to help improve the teaching and learning for individual students.

3. **Learning to Learn.** We are all lifelong learners. But, many of us do not gain an initial education and habits of learning that support a lifetime of independently continuing in our educational endeavors. We do not learn about metacognition and reflective thinking (thinking about our thinking). Many of us fall into patterns of "going with the flow" rather than continuing to actively pursue new knowledge and skills.
4. **Individualization.** Children vary considerably in their learning abilities and interest areas. Through appropriate informal and formal education, learning abilities can be increased and interests can be broadened and deepened. Individualization of content to be learned and instructional processes to meet individual differences of learners contributes substantially to the effectiveness of informal and formal education.
5. **Transfer of learning.** Learning is useful to the extent that one gains the knowledge and skills to make use of the learning in the variety of different situations one will encounter in the future. This is called transfer of learning. Parents can play a significant role in helping their school age children increase the transfer from what they are learning in school to settings outside of school. A simple question, "What did you do in school today?" can instead be changed into a discussion that begins with the request, "Please share with me some of the ways you are currently using or plan to use what you learned in school today." Be persistent in this inquiry. Even 5-10 minute sharing sessions of this sort add considerably to what a child retains from a day's formal schooling.

   Many teachers and educational researchers have found the high-road/low-road transfer of learning theory to be quite useful in teaching and learning. In low-road transfer, one learns something to a high level of automaticity. In high-road transfer, one learns a strategy, gives it a name, and practices in on a wide variety of problems. See http://learnweb.harvard.edu/alps/thinking/docs/traencyn.htm. (Note to people who are not school teachers. The chances are that you have not heard of high-road/low-road transfer of learning. Please spend some time learning about this topic. This learning will be of considerable value both to you and to your children.)
6. **Islands of expertise.** Through informal and formal education, a child develops islands or pockets of expertise. Through practice and more learning, these islands of expertise grow to meet the personal needs of the learner. Thus, for example, a child may develop a personally satisfying level of expertise in doing tricks with a yo-yo, in building and flying paper airplanes, in making origami figures, or in yodeling. The process of developing a

personally satisfying island of expertise is an opportunity to learn about one's personal abilities and interests in learning.

7. **Human and computer brains.** Human brains get better through informal and formal education, study, and practice. Computer brains get better through building better computers and through the research of thousands of researchers advancing the field of artificial intelligence. If this idea interests you, see *Two Brains are Better Than One* at http://iae-pedia.org/Two_Brains_Are_Better_Than_One and *Five Brains are Better than One* http://i-a-e.org/iae-blog/five-brains-are-better-than-one.html. For an introduction to Artificial Intelligence, see http://iae-pedia.org/Artificial_Intelligence.

8. **Education for the future.** Informal and formal education help prepare children for their future. See http://iae-pedia.org/What_the_Future_is_Bringing_Us. Continued rapid progress in science, technology, engineering, and math is changing our world. It is changing the world our children will face as adults. It is a major challenge to help students get an education that is well rooted in the cultures and values of the past but that also prepares them for a very rapid pace of change and the types of problems they will face in the future, such as globalization, sustainability, increasingly intelligent and capable computers and robots, nanotechnology, and genome technology.

   A key aspect of education for the future is learning to make effective use of the accumulated knowledge of the human race. One way of describing this is that we want each student to develop some of the knowledge and skills of a research librarian. A different way of saying this is we want people to learn to work in teams that include both people and machines—such as computers—to represent and solve problems. Outside of school, "open book, open computer, and open connectivity" are the way people do productive work. You might ask yourself why schools do not place more emphasis on preparing students to work in such environments.

One of the major challenges faced by both adults and children is what constitutes a good education for the future. We live in a time of fast-paced change, particular in things related to science and technology. Historically, the pace of change was relatively slow. An education that was good enough for our parents was good enough for their children.

That is no longer the case. We now have an educational system that tends to be backward looking, while we live in a world that is changing very rapidly. As a parent or teacher, you need to adjust your "educator" thinking into preparing children for the future. A key concept here is less emphasis on rote learning (memorize and regurgitate) and more emphasis on higher-order thinking and problem solving. Judy Willis, a cognitive neuroscientist,  has written extensively about this topic (Willis, 2011).

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| | For young brains to retain information, they need to apply it. Information learned by rote memorization will not enter the sturdy long-term neural networks in the pre-frontal cortex (PFC) unless students have the opportunity to actively recognize relationships to their prior knowledge and/or apply new learning to new situations. (Willis, 2011) | |

Here is a special note for parents. As you talk to your children about what they are learning in school, look for evidence related to the eight ideas listed above. For example, when your child tells you something specific that was covered in school that day, ask probing questions about how this ties in with what was learned in previous days or weeks. Ask question about how it pertains to other topics they are studying, and how it pertains to their lives outside of school. Help you child learn about transfer of learning and learning about learning.

## Science, Technology, Engineering, and Mathematics

Science, Technology, Engineering, and Mathematics are all deep, broad, and well-established areas of research and development. As you work with children, you will find it helpful to have some insight into each of these disciplines. The next four subsections give very brief introductions to these four disciplines.

### What is Science?

Science involves repeatable and accurate measurement, and predictability (see http://i-a-e.org/newsletters/IAE-Newsletter-2010-56.html and http://iae-pedia.org/What_is_Science%3F). Also see some really nice science-magic videos at http://www.youtube.com/watch?v=4EABdAEt_fM.

You are familiar with a number of different areas of science, such as Astronomy, Biology, Chemistry, and Physics. All of the sciences share much in common. Quoting from the Macquarie Dictionary www.arc.gov.au/general/glossary.htm:

> Science is systematic study of humans and their environment based on the deductions and inferences which can be made, and the general laws which can be formulated, from reproducible observations and measurements of events and parameters within the universe.

Many answers to the "what is science" question include a discussion of scientific method. This is a method of thinking, exploration, and analysis common to all sciences. Quoting from the Wikipedia http://en.wikipedia.org/wiki/Scientific_method:

> Scientific method is a body of techniques for investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge. It is based on gathering observable, empirical and measurable evidence subject to specific principles of reasoning. The scientific method consists of the collection of data through observation and experimentation, and the formulation and testing of hypotheses.

Science literacy is a primary goal of science learning for children. Science literacy involves two dimensions. The first is the ability to understand the methods of science, how science influences our daily lives, and to apply science concepts to our understanding of the world around us. The second is the ability—and the inclination—to obtain science information through active investigation, be it indirectly through access to various media information sources, or through direct experience with science phenomena.

It is easy to interact with children in ways that increase their knowledge and **understanding** of science. Notice the emphasis on understanding. You look up into the sky and see clouds. What is a cloud, where does it come from, why are there more clouds some times than others, what makes clouds move? You see some dark clouds. Why are some clouds dark? You see some jet airplane contrails. Is that where some of the clouds come from? Do the airplane contrails affect our global environment? You continue to look up into the sky. You see some blue parts of the sky. Why is the sky blue? It is easy to make up challenging questions that relate to understanding various parts of science.

### What is Technology?

You make routine use of many different kinds of technology. Technology includes the vast collection of processes and knowledge that people use to extend their abilities and satisfy their needs and wants.

Quoting from http://en.wikipedia.org/wiki/Technology:

> The human race's use of technology began with the conversion of natural resources into simple tools. The prehistorical discovery of the ability to control fire increased the available sources of food and the invention of the wheel helped humans in travelling in and controlling their environment. Recent technological developments, including the printing press, the telephone, and the Internet, have lessened physical barriers to communication and allowed humans to interact on a global scale.

Writing is a technology developed more than 5,000 years ago. Through formal and informal education, people learn to read and write. They are empowered by the expertise they gain in this area, and their lives are enriched.

Each technological development can be examined from the point of view of its positive and negative features and effects. The development of spears, bows, and arrows certainly was advantageous to hunters. However, when used as weapons of war, they have led to the death and injury of a huge number of people.

You are undoubtedly familiar with the current discussions about global warming and air pollution, and the contributions our technological developments are making to these worldwide problems. It is nice to travel by car, train, and airplane. It is nice to have a home heated in winter and cooled in summer. All of this technology helps to fulfill our needs and wants—and all contribute to global warming and air pollution.

Since our children are immersed in a technological environment, it is easy to help children learn about capabilities, limitations, advantages, and disadvantages of the various technologies they routinely encounter. Even quite young children can learn about recycling and aid in the recycling process. In addition, you can help them to learn about needs versus wants. We are a society of conspicuous consumption!

### What is Engineering?

Engineers play a major role in the design and development of the technology we routinely use. Engineering is the application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.

There are many different kinds of engineers. The U.S. Department of Labor, at is Website http://www.bls.gov/oco/ocos027.htm, lists 17 different types of engineers. Quoting from this site:

> Engineers apply the principles of science and mathematics to develop economical solutions to technical problems. Their work is the link between scientific discoveries and the commercial applications that meet societal and consumer needs.
>
> Many engineers develop new products. During this process, they consider several factors. For example, in developing an industrial robot, engineers precisely specify the functional requirements; design and test the robot's components; integrate the components to produce the final design; and evaluate the design's overall effectiveness, cost, reliability, and safety. This process applies to the development of many different products, such as chemicals, computers, power plants, helicopters, and toys.

Notice the emphasis on use of mathematics, science, and computer technology. Engineering is a demanding and rewarding field of study.

Parents and other people who work with children have many opportunities to help children learn about the field of engineering. As an example, think about details of why one paper airplane flies better and stays aloft longer than another. Think about how the design of a rubber band-powered toy boat affects its performance. Why does water come out of a water facet? Where does the water go when it goes down the drain? How does a toilet work? What makes the light come on when one flips a light switch?

**What is Mathematics?**

Arithmetic is a part of mathematics, but it is a very small part. Math is a language and a discipline of study devoted to representing and solving certain kinds of problems. Math deals with arithmetic problems, geometry problems, algebra problems, calculus problems, probability problems, statistical problems, and so on. See http://iae-pedia.org/What_is_Mathematics%3F and http://iae-pedia.org/Math_Education_Quotations.

In each of these areas of math, there has been a huge accumulation of knowledge over time. Thus, for example, Isaac Newton and Gottfried Leibniz developed many of the ideas of calculus well over 300 years ago. At that time, these ideas were at the frontiers of math research and helped to advance the field. Now, some students study calculus in high school, and it is a required course for college majors in the various STEM fields.

The following is quoted from a talk that George Polya (1887–1985) gave to a group of elementary school teachers. Polya was one of the leading mathematicians and math educators of the 20th century.

> To understand mathematics means to be able to do mathematics. **And what does it mean doing mathematics? In the first place it means to be able to solve mathematical problems.** For the higher aims about which I am now talking are some general tactics of problems—to have the right attitude for problems and to

> be able to attack all kinds of problems, not only very simple problems, which can be solved with the skills of the primary school, but more complicated problems of engineering, physics and so on, which will be further developed in the high school. But the foundations should be started in the primary school. And so **I think an essential point in the primary school is to introduce the children to the tactics of problem solving. Not to solve this or that kind of problem, not to make just long divisions or some such thing, but to develop a general attitude for the solution of problems.** [Bold added for emphasis.]

Mathematics is a very important discipline because there is so much accumulated knowledge about how to solve math problems. If a problem from some other discipline (such as social science, science, or engineering) can be represented as a math problem, then there is a good chance that it can be solved using the accumulated math knowledge of the human race. Computers can be a big help in this problem solving process.

### Cognitive Development (Mental)

The brain of a grownup is different than the brain of a child. Educators often mention the research work of Jean Piaget (1896-1980) on stages of brain development (cognitive development). By the time a child starts school, the child may well be quite fluent in one or more natural languages. But, the child does not yet have the logical thinking and analytic skills of an adult. The 6-year-old brain does not understand cause-effect and thinking about consequences of possible actions in the same way as does an 18 or 25-year-old brain. It takes until age 25 or so for a brain to achieve its full maturity.

If child development and brain science are topics that interest you, you can find lots of good resources on the Web. See, for example *Brain science and cognitive neuroscience for children and teachers* available at http://i-a-e.org/iae-blog/brain-science-and-cognitive-neuroscience-for-children-and-teachers.html.

Here is a brief summary of some of the research results for children at the K-2 grade levels. It is quoted from a federally funded project at the University of California, Berkley http://undsci.berkeley.edu/teaching/k2_nature.php:

> The purpose of this segment is to help connect what is known about students' cognitive development with what you want them to understand about science concepts and the nature of science. Use this brief description, combined with your knowledge of your students, to guide you in making instructional decisions appropriate for your grade level.
>
> Students in grades K, 1, and 2 range in age from 5 to 8 years. During these years, students develop the ability to approach the world logically for the first time. They move from an inability to complete mental operations through even the simplest abstractions to an increasing ability to utilize abstract reasoning. Primary students are naturally curious about their world and learn best through direct discovery in hands-on experiences with manipulatives that engage the five senses.
>
> **The primary focus of a kindergartner is to please the teacher.** They may struggle to distinguish between fantasy and reality. Some may explain cause and effect through intuition rather than logic.

> **First grade students are beginning to approach the world logically.** They are in a transitional stage between pre-operational thinking and concrete operations. As this shift occurs, students' abilities to reason, understand cause and effect in the natural world, identify differences, compensate for differences, and reverse an idea through mental activity improve.
>
> **Second grade students are active thinkers who begin to organize their internal mental structures in new ways.** They can now categorize spontaneously for the first time. They have an increasing ability to utilize abstract reasoning, to interpret observations, and to generate expectations about what will occur in a particular situation. Second graders show increasing interest in the world around them —and thus, science takes on a new meaning for them.

The same Website contains similar sections for grades 3-5 students, 6-8 students, 9-12 students, and 13-16 students. See http://undsci.berkeley.edu/teaching/index.php. For additional general information about cognitive development see the Wikipedia article at http://en.wikipedia.org/wiki/Theory_of_cognitive_development.

**Final Remarks**

The goal of this book is to help foster fun learning interactions between adults and children. Both children and adults will learn through such learning interactions.

Keep in mind that your goal is to help get children ready for their future. This future will be a life in a rapidly changing and challenging world. Be guided by Abraham Lincoln’s statement, “Children are the message we send to the future.”

Also keep in mind the importance of role modeling. You have probably heard the statement, “Monkey see, monkey do.” Role model the curiosity, inquisitiveness, problem solving, and independence of thinking that you want to see in children.

# Chapter 3: Arts, Crafts, and Constructions

> "Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand." (Confucius, 551-479 B.C.)

Many people learn best in a hands-on, learn by doing mode: "Involve me, and I will understand." The idea is simple enough. How to do something is demonstrated and perhaps talked about by a person with knowledge, skill, and experience. Learners observe, listen, and imitate. The learners provide feedback to themselves, and they receive feedback from the teacher and from their fellow learners. As a result of this type of education, the learner can do things and understand things.

Humans have many tens of thousands of years learning in the "Involve me, and I will understand." mode of learning. It was just a little over 5,000 years ago when reading and writing were invented. It is only in the past two hundred years that countries throughout the world have begun to focus on all children learning to read and write, and children learning to read well enough so that they can use reading as an aid to learning in various discipline areas.

In a learning by doing environment, both the use of the learning and the feedback occur in a timely fashion—typically, immediately. The learners can see, feel, and sense they are gaining in expertise, and they can demonstrate their increase in expertise. A learner may well be gaining considerable personal satisfaction and an increase in self-esteem through developing or expanding an area of expertise.

Contrast this with much of our formal education system. There, students are often asked to learn things that they will use "sometime" in the future. The "sometime" may be hours, days, weeks, months, or even years in the future. Needless to say, many students have considerable trouble in this type of delayed feedback, delayed use type of learning environment.

This chapter contains information about a number of different "learn by doing" situations that many children (and adults) find fun and interesting. The types of projects described in this chapter are especially valuable when used in an environment involving groups of children with some adult supervision. Such environments help children learn to provide feedback to themselves and each other. In addition, children gain skills in figuring out things for themselves, receiving feedback from adults and from each other, and in asking for help when it is needed.

In each of these learn-by-doing situations, children (and adults) gain islands of expertise (small areas of expertise) that may well prove enjoyable and useful for many years to come. In this process, learners gain increased skill and confidence in learning, and they learn about some of their capabilities and limitations as learners.

### Origami

Origami is fun and a great vehicle for learning. Quoting from the Wikipedia page http://en.wikipedia.org/wiki/Origami:

> Origami (derived from "ori" meaning "to fold", and "kami", meaning paper) is the ancient Japanese art of paper folding. The goal of this art is to create a given

result using geometric folds and crease patterns. "Origami" refers to all types of paper folding, even those of non-Asian origin.

Figure 3.1. Two origami boxes.

An origami box is relatively easy to make, so it is a good beginner's project. The picture given above comes from http://www.origami-fun.com/origami-box.html. That website has both a video and printable step-by-step directions for making an origami box. It is common for beginners to learn paper folding from people who have already gained some skill in the activity. Such beginners imitate the step-by-step process being carried out by the "expert."

However, it is possible to learn origami by watching video and/or following a printed set of instructions. The Website http://video.google.com/videosearch?hl=en&q=paper+folding&um=1&ie=UTF-8&sa=X&oi=video_result_group&resnum=4&ct=title# contains a number of short videos of various paper folding projects. My recent Web search of the expression *paper folding* produced about a million hits.

The cootie catcher (also called a fortune teller) pictured in Figure 3.2 is one of my childhood favorites. See http://www.enchantedlearning.com/crafts/origami/fortuneteller/.

An elaborately decorated fortune teller.

Figure 3.2. Cootie catcher.

The crane shown in Figure 3.3 is a relatively complex figure that most Japanese school children learn to make. On the Web one can find videos and still photos that show step by step how to make a crane. For example, see http://www.youtube.com/watch?v=R9VF3gdf_Hk and http://monkey.org/~aidan/origami/crane/

Figure 3.3. Crane made from a square piece of paper.

In the past, people typically learned how to make an origami structure (figure) from a person who is skilled in making it.

Now there are many excellent origami Websites. For example:

- Origami club. http://www.origami-club.com/en/.
- Instructions for 405 different models. http://dev.origami.com/diagram.cfm.
- Origami resource center. http://www.origami-resource-center.com/educational-benefits.html.
- Using origami to teach math. http://math.serenevy.net/?page=Origami-TeachingLinks

See http://www.ted.com/talks/robert_lang_folds_way_new_origami.html for a 16-minute video on origami. Quoting from the site: "Robert Lang is a pioneer of the newest kind of origami—using math and engineering principles to fold mind-blowingly intricate designs that are beautiful and, sometimes, very useful."

**Paper Airplanes**

It is hard to imagine a child who has not learned to make and fly paper airplanes. Figure 3.4 is from http://www.paperairplanes.co.uk/peteplan.php. It is one of the easiest paper airplanes to make. The site includes a video on how to make this plane.

Figure 3.4. Classic Dart Paper Airplane

Figure 3.5 shows a paper airplane that I learned to make as a child, and that I still make from time to time. The picture is from http://www.exploratorium.edu/exploring/paper/airplanes.html, and the site contains step-by-step instructions.

Figure 3.5. Dave Moursund's favorite paper airplane.

Paper airplanes are fun to make and fly. The builder can receive immediate feedback on the flying abilities of a paper airplane by merely launching it into space. There are lots of commercially available books on building paper airplanes. Here are some excellent Websites:

- Short videos on how to make many different kinds of paper airplanes. http://www.paperairplanes.co.uk/.
- Ten original paper airplanes designs that fly well. http://www.bestpaperairplanes.com/.

- Information from NASA for teachers. http://futureflight.arc.nasa.gov/designs/index.html
- The science of paper airplanes. http://paperplane.org/Aerodynamics/paero.htm.

## Paper Snowflakes

Many children and adults enjoy creating paper snowflakes. All it takes is a piece of paper and a pair of scissors—plus some learning. Trial and error can be a fun part of this learning experience. See Figure 3.7 for some examples.

Figure 3.6. Paper snowflakes.

Many Websites that provide instructions for making a wide variety of paper snowflakes. The website http://www.highhopes.com/snowflakes.html is a good starting point.

The Website http://snowflakes.barkleyus.com/ makes it possible for a person to cut out a virtual snowflake, using a virtual pair of scissors and a virtual piece of paper. I found the interface somewhat awkward and it took me some trial and error to get started.

However, it is a fun and educational experience. One of the things a person can learn through use of this free software is some of the differences between "physically real" and "virtual or simulated." It is now common for architects to develop computerized models (virtual models) of the buildings, bridges, and other structures they are designing. With these models, it is possible to view what the final structure will look like from different angles and viewing elevations. Indeed, with appropriate software, one can do a walk through of a building, walking into each room and viewing the room with different arrangements of furniture and decorations.

### Bridge Building

There are many Websites that discuss bridge building projects and contests. These provide excellent examples of highly educational, fun, group and individual projects. Figure 3.7 shows a Popsicle stick (a craft stick) bridge built from sticks and blue. It supports a quite heavy weight. See http://www.instructables.com/id/Popsicle-Stick-Bridge/.

Figure 3.7 Bridge (with a heavy weight) built using craft sticks and glue.

Here are some links to bridge-building sites.

- Popsicle bridges. http://www.garrettsbridges.com/category/photos/popsicle-bridges.
- General Information: Building Bridges from Toothpicks. http://www.worsleyschool.net/science/files/bridge/building.html.
- General Information: Bridges Updated 7/17/07. See http://webtech.kennesaw.edu/jcheek3/bridges.htm.
- Fun and Learning About Bridges. Many good resources, but with a number of broken links at http://www.bridgesite.com/funand.htm.
- Bridge building competition for high school students. See http://bridgecontest.phys.iit.edu/
- Free book on building bridges out of file folders at http://bridgecontest.usma.edu/manual.htm. The Website also contains materials and links that can be used to learn a great deal about designing and building bridges.

**Building and Flying Kites**

Figure 3.8. Picture from http://www.my-best-kite.com/.

The following is quoted from http://www.discoverthis.com/article-kites.html:

> Thomas J. Benson loves kites. "I like things that fly," says the senior research engineer at NASA Glenn Research Center in Cleveland, Ohio. "I started out many years ago on the playground flying kites and now I make my career as an aerospace engineer—and they are connected."
>
> "Engineers are just people who solve problems and try to build things to help make the world a nicer place," Benson continues, "and in doing that you have to develop a feel for things." That feel, he says, is usually developed at an early age. "It's funny how many guys in my building (at NASA) started out down the trail when we were in fifth or sixth grade, flying kites or building model airplanes."

Kite building and kite flying was a fun part of my childhood, and was later revisited when I was an adult. My recent Web search of *building and flying kites* produced over 400,000 hits. Here are some good starting places.

- Kite Making Plans. Detailed instructions for making a very large number of different kinds of kites. http://www.inquiry.net/OUTDOOR/spring/kites/.
- The Virtual Kite Zoo. This Web page is designed for teachers and others working with a large group of children. http://www.blueskylark.org/zoo/class.html.
- Virtual Kite. The National Aeronautics and Space Administration (NASA) has a Kite Modeler program. Quoting from the site http://www.grc.nasa.gov/WWW/K-12/airplane/kiteprog.html:

  With this software you can study the physics and math that describe the flight of a kite. You can choose from several types of kites and change the shape, size, and materials to produce your own design. You can change the values of different variables that affect the design and immediately see the new flight characteristics. With this version of the program, you can even test how your kite would fly on Mars, or off the top of a mountain. The program tells you if your design is stable or not and also computes a prediction of how high your kite will fly.

**Construction Projects**

My recent Web search of c*raft stick projects* produced over 400,000 hits. Craft sticks—frequently called Popsicle sticks—are available free if you eat a lot of such frozen treats, or can be purchased inexpensively. At the time this book was being written, the Website http://www.enasco.com/product/0500462(A) sells a box of 1,000 craft sticks for $2.95.

Figure 3.9. Picture from http://www.biglearning.org/craft-sticks/.

Here are a few of the Websites I found particularly interesting:

- 11 articles containing great ideas for craft-stick projects. http://www.helium.com/knowledge/91000-great-project-ideas-for-popsicle-sticks.
- Artists helping children. http://www.artistshelpingchildren.org/popsiclesticksartscraftsideascraftstickskids.html.
- Kids go crazy with craft sticks. http://www.biglearning.org/craft-sticks/.

**Lego**

Lego blocks have long been a staple in many homes. Children can use their imaginations as they create projects they find personally interesting. Nowadays there are physical Lego blocks, virtual Lego blocks, an online Lego games (see http://universe.lego.com/en-us/default.aspx).

Indeed, one can build a virtual Lego construction and then purchase the bricks to build a physical model of the virtual construct. This is suggestive of how architects and construction engineers now do their work. They do their design work on a computer. After they and a customer are satisfied, then the actual physical construction begins.

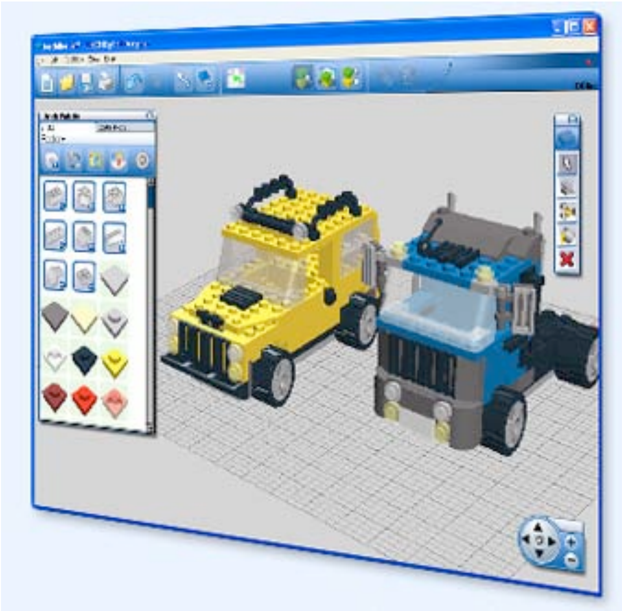


Figure 3.10. Computerized (virtual) Lego construction software

Computerized Lego building block systems available free on the Web. You can use these systems to construct quite intricate projects.

- http://ldd.lego.com/download/default.aspx takes you to a page where you can download Mac or Windows software. This site allows you to download software that you can use to do virtual constructions. You an also buy the Lego blocks that it would take to build a physical copy of your virtual model.
- http://bricksmith.sourceforge.net/ (Mac only).
- http://lifehacker.com/software/top/download-of-the-day-design-a-virtual-lego-masterpiece-with-blockcad-windows-217103.php (Windows only).

These three dimensional, virtual, building block systems help users to learn about Computer-Assisted Design (CAD) and gives them practice in 3-D visualization and modeling.

**Final Remarks**

Many children learn best in a hands-on, "learn by doing" environment. Working along side their peers, older and younger children, and adults, they learn to make things and do things. They can see the immediate results of their efforts.

Many adults experience great joy in learning alongside children. In the process, they role model the fun and value of being a lifelong learner.

# Chapter 4: Educational Puzzles

> "There are no extra pieces in the universe. Everyone is here because he or she has a place to fill, and every piece must fit itself into the big jigsaw puzzle." (Lewis Carroll, English mathematician and writer, 1832–1898.)
>
> "Egotism, n: Doing the New York Times crossword puzzle with a pen." (Author unknown.)

A puzzle is a type of game. A puzzle is a problem or enigma usually designed for entertainment. Often one can solve a puzzle without having to draw upon deep knowledge of any discipline. A jigsaw puzzle and a Rubrics cube provide good examples of this.

A child doing a jigsaw puzzle is engaged in tasks that involve looking for patterns and using spatial visualization skills. This puzzle playing may be done individually or in a small group. In a group setting, there is a strong social education aspect of putting together a jigsaw puzzle.

Contrast a jigsaw puzzle or a Rubik cube with a crossword puzzle from the New York Times newspaper. The crossword puzzle draws upon reading, spelling, word definitions, and word-suggestion clues. It is a substantially different challenge than doing a jigsaw puzzle. Putting together jigsaw puzzles draws on spatial sense and pictorial pattern recognition. Both types of puzzles require you to use your mind to fill in the blanks. For example, given a few letters in a word and a clue that doesn't seem very helpful to you, what are some possible words that are of the proper length? Using clues from shape, color, and the overall picture, what jigsaw pieces might fit?

There are lots of different interlocking jigsaw puzzles, and there are lots of different crossword puzzles. With practice, your level of expertise in doing either of these types of puzzles will increase substantially. This chapter explores puzzles and their underlying educational values, and provides access to free puzzles on the Web.

Much of the content of this chapter and the next chapter are drawn from the book Moursund (2008): *Introduction to using games in education: A guide for teachers and parents.* The book is available free on the Web at http://pages.uoregon.edu/moursund/Books/Games/Games1.pdf. It explores various educational uses of games and puzzles, and includes an extensive Appendix of problem-solving strategies that can be taught in a game-playing or puzzle-solving environment.

### Free Puzzles Usually Come with a Price

There are a huge number and variety of puzzles available on the Web, and many of them are free. However, most often, "free" actually comes with a price. Part of the price is your time that is wasted as you work your way through a variety of ads. You may well be offered the opportunity to sign up for a newsletter, or to buy various materials. The good news: there are sites that are free, with no gimmicks.

Many people generate and/or accumulate puzzles that they make available free on the Web. Some of the Web-based puzzles can be played on a computer, while others can be printed out and used in a paper and pencil mode. My recent Web search of the quoted term "*free puzzle*" produced over a million hits.

**Brainteaser—Think Outside the Box—Puzzles**

One of the important ideas in trying to solve new and challenging problems is thinking outside the box. For a collection of brainteasers that encourage thinking outside the box see http://www.begent.org/brainteasers.htm.

It is very important to keep in mind that the main goal in having a student try to solve brainteaser puzzle is to help the student get better at thinking outside the box. I don't really care if a student can solve a particular puzzle problem. (What is gained by memorizing how to solve a variety of such problems?) What I care about is that a student gains increased insight into the idea of thinking outside the box.

The following nine dots puzzle problem is used to illustrate thinking outside the box.

> **Problem:** Using pencil and paper, arrange nine distinct dots into a three by three pattern as illustrated in Figure 4.1. The task is to draw four straight line segments with the beginning of the second starting at the end of the first, the beginning of the third starting at the end of the second, and the beginning of the fourth starting at the end of the third, and so that the total sequence of line segments passes through each dot.

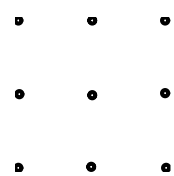


Figure 4.1. Nine dots in a 3x3 square pattern.

See if you can solve this puzzle before reading further down the page.

To begin, you may think about how easy it is to complete the task using five line segments. A solution is given in Figure 4.2.

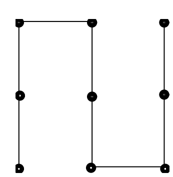


Figure 4.2. A 5-line segment solution for the 9-dots puzzle.

After studying this solution, you can easily find other 5-line line segment solutions. Here is a challenging question. How many 5-line solutions are there? (Part of the reason this is a hard question is because of symmetries. Are two solutions different if one is a reflection of the other? Mathematicians link to think about such questions.)

How can one possible complete the task with only four line segments? It is necessary to think outside of the box. In this case, the layout of the puzzle tends to create a visual box. Many people do not think about drawing line segments that go outside of the visual box. A solution using four line segments is shown in Figure 4.3. The solution requires using some line segments that extend outside of the box.

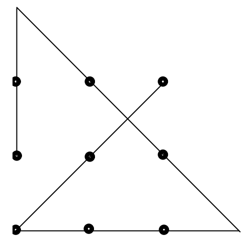


Figure 4.3. A 4-line segment solution for the 9-dots puzzle.

I suspect that most parents, teachers, and other adults really don't care whether students learn how to solve this 9-dots, 4-line segment puzzle problem. However, many people care about helping students learn to think outside the box. Thus, they want students to have an informal and formal educational system that will help students learn to think outside the box. For most children, it takes many examples and careful teaching over a period of years to develop this type of expertise.

Here is another 9-dot challenge. See if you can use just three connected line segments to draw through all of the dots. As before, think about this before reading further on. Think outside the box!

The chances are that you are like many other people, in that you have studied math for many years, starting in preschool or elementary school. Thus, you can probably explain the difference between a dot and a mathematical point. A dot has size, while a point does not. The puzzle was stated in terms of using nine distinct dots (not nine points). A 3-line segment solution is illustrated in Figure 4.4. To make the illustration easier to understand, I have used larger dots in the puzzle.

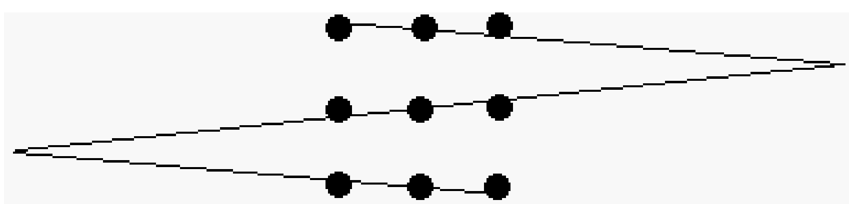


Figure 4.4. A 3-line segment solution for the 9-dots puzzle.

This solution not only illustrates thinking outside the box, it also illustrates the importance of precise vocabulary and the problem solver understanding the meaning of the precise vocabulary.

Here is another puzzle that requires thinking outside the box. This is a "classical" brainteaser puzzle, familiar to many adults.

> **Problem:** You are at a river that you want to cross with all of your goods. Your goods consist of a chicken, a bag of grain, and your large dog named Wolf. You have to cross the river in your canoe but can only take one passenger (chicken, dog, bag of grain) with you at a time. You can't leave the chicken alone with the grain, as the chicken will eat the grain. You can't leave your dog Wolf alone with the chicken, as Wolf will eat the chicken. However, you know that Wolf does not eat grain. How do you get everything across the river intact?

This chapter does not contain a solution to the river-crossing puzzle. Remember, the learning value of such a puzzle comes from figuring it out by yourself, by doing metacognition (thinking about your thinking) while you are solving the puzzle, and then by thinking about how what you have learned might transfer to other problems.

If you are unable to solve the river-crossing puzzle problem, you might want to try looking for a solution on the Web. In this task, you face the "how do I look it up" problem. As you work on this problem, do metacognition. When you succeed in solving the information retrieval problem, spend some time reflecting on what you have learned by the process.

Then, spend some time thinking about what you want your children to be learning in terms of thinking outside the box and in learning how to make effective use of the Web as an aid to problem solving. One approach is to share with your children as you carry on such activities. Involve your children in your "shopping trips" on the Web. Involve your children in posing questions and then trying to find answers on the web. Involve your children in facing the challenge of dealing with multiple "hits" when you do a Web search.

**Möbius Strip**

If you take a strip of paper, glue or tape it into a loop, and then uses scissors to cut along the center of the looped piece of paper, you will get two separate loops. However, if you put a half twist into the strip of paper before gluing or taping, and repeat the cutting process of this loop, you will get only one, longer loop.

Figure 4.5. Möbius Strip.

This is a fun activity for relatively young children as well as for older children and adults. See a (1:18) video at http://www.metacafe.com/watch/331665/no_magic_at_all_mobius_strip/. It is a great activity for use in a math class, as it demonstrates a geometric object that has only one side and only one edge. Contrast this with a sheet of paper that has two sides but only one edge, or with a paper chain link that has two sides and two edges.

The Möbius strip is a rather curious mathematical object. When you introduce children to this object, do you help them to explore and experiment with the object, some of the underlying or related math, and the person Möbius? For example, what happens if you put two or three twists into the loop? How about art based on the Möbius strip?

See a piece of M. C. Escher's artwork based on the Möbius strip at http://www.physlink.com/education/askexperts/ae401.cfm.

**Toothpick (Matchstick) Puzzles**

My 10/13/2011 Web search of *toothpick OR matchstick puzzle* returned well over a million hits. As an example, see Matchstick Puzzles at http://www.learning-tree.org.uk/stickpuzzles/stick_puzzles.htm.

Here is an example of a toothpick puzzle (also called a match stick puzzle). In Figure 4.6, you can see two squares outlined by matchsticks. The goal is to move 4 matchsticks to make exactly three squares. You can find two different solutions at the Website mentioned above.

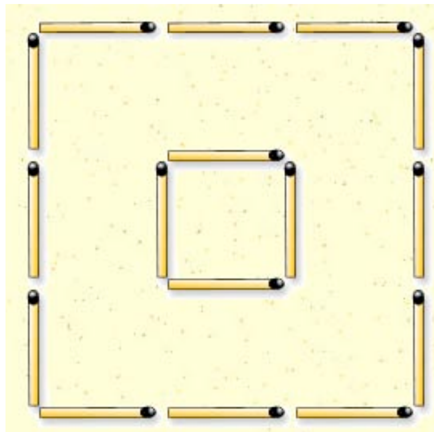


Figure 4.6. Matchstick puzzle.

There are a number of toothpick puzzles at AIMS Puzzle Corner: http://www.aimsedu.org/Puzzle/. In Figure 4.7, the goal is to move exactly three of the toothpicks so that there are now five triangles. Hint: Think outside the box! If the puzzle defeats you, see a solution at http://www.aimsedu.org/solutions/index.html. (Scroll down and click on The Three to Five Triangle Puzzle.)

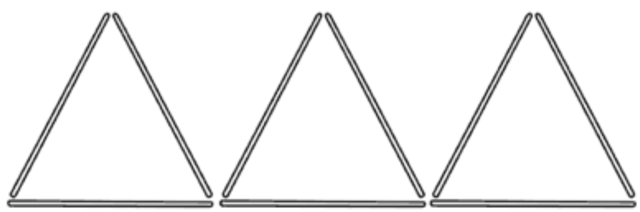


Figure 4.7. Toothpick "think outside the box" logic puzzle.

**More Logic Puzzles**

The river-crossing example given earlier is a logic puzzle. It requires careful logical thinking to solve the problem. There are many sources of logic puzzles on the Web. My 10/13/2011 Web search on the expression *logic puzzle* returned over 3 million hits.

One of the hits was *Logic Puzzles* at http://brainden.com/logic-puzzles.htm. It contains a number of puzzles and their solutions. Here is an example of a puzzle from this site:

> A square medieval castle on a square island is under siege. All around the castle there is a square moat 10 meters wide. Due to a regrettable miscalculation the raiders have brought footbridges, which are only 9.5 meters long. The invaders cannot abandon their campaign and return empty-handed. How can the assailants resolve their predicament?

Here are some Websites where you can find more logic puzzles.

- BrainDen.com Logic Puzzles. http://brainden.com/logic-puzzles.htm. Word puzzles and many other types of puzzles.
- Math Playground. See http://www.mathplayground.com/games.html ] This site contains a number of challenging, educational games. Here are just a few of them, covering a variety of math topics, to help you get started using this excellent Website:
    - Alien Angles: http://www.mathplayground.com/alienangles.html. It's about estimating angles.
    - Bridge Builders: http://www.mathplayground.com/FractionGame/FractionGame.html. It's about fractions.
    - Save the Zogs: http://www.mathplayground.com/SaveTheZogs/SaveTheZogs.html. It's about linear equations.
    - Space Boy to the Rescue: http://www.mathplayground.com/spaceboyrescue.html. It's about identifying coordinates.
    - Locate the Aliens: http://www.mathplayground.com/locate_aliens.html. It's about identifying coordinates.
    - Decention: http://www.mathplayground.com/Decention/Decention.html. It's about fractions, decimals, and percents.
- Math Puzzles: http://www.puzzle.dse.nl/math/index_us.html.
- Puzzle Choice: http://www.puzzlechoice.com/pc/Puzzle_Choicex.html.
- Puzzles and Problems: http://perplexus.info/tree.php. This Website uses the following categorization terms for puzzles: logic, probability, shapes, general (includes tricks, word problems, cryptography), numbers, games, paradoxes, riddles, just math, science, and algorithms.
- Water bucket puzzles. See http://www.dr-mikes-math-games-for-kids.com/measure-that-volume-puzzle.html .

**Jigsaw Puzzles**

Jigsaw puzzles come in many levels of difficulty. A typical jigsaw puzzle has only one solution, but a person can arrive at the solution in many different ways.

There are quite a variety of types and difficulties of jigsaw puzzles available free on the Web. Doing such a puzzle on a computer is often quite different than doing a physical (cardboard or wood) jigsaw puzzle. To get a feel for doing jigsaw puzzles on a computer, try the Smithsonian site *Just for Kids*: http://nationalzoo.si.edu/Audiences/Kids/jigsaw.cfm. It has easy animal puzzles with fewer than 20 pieces. Figure 4.8 shows pictures of some of the available puzzles. These are interlocking puzzles, where the pieces have bumps and holes that lock together.


Figure 4.8. Jigsaw puzzles from the Smithsonian site.

A 10/13/2011 Web search of the expression *free jigsaw puzzle* produced over 10 million hits. See, for example:

- At the Jig Zone http://www.jigzone.com/puzzles/daily-jigsaw you can make a puzzle quite easy to reasonably difficult by specifying the number of pieces in the puzzle (from 6 to 247). (To select the number of pieces in the puzzle, click on **Change Cut** in the menu on the left side of the page.)
- http://www.crea-soft.com/online-jigsaw-puzzle/ provides a variety of puzzles, with each available in an easy, average, and hard version. The easy versions are quite suitable for preschool-age children.
- http://www.jspuzzles.com/ provides puzzles that do not interlock. Since interlocking is a helpful spatial-visual clue, this increasing the difficulty of the puzzles.

Jigsaw puzzles have a number of educational values. For example, they provide an environment is which one makes use of spatial visualization as well as identifying and making use of color or shape patterns. Jigsaw puzzles illustrate incremental improvement or incremental progress, which is a powerful strategy in solving certain kinds of problems. Jigsaw puzzles also illustrate a problem-solving strategy called divide and conquer. See the next section for a discussion of this strategy.

**Problem Solving Using Incremental Improvement Strategy**

Many types of problems can be solved by incremental improvement. Think about this in terms of walking or running a given distance on a level track. Each step brings you closer to completing the walk or run.

Think about this in terms of completing a jigsaw puzzle. Every piece that is correctly connected to another piece or a group of pieces is a step toward completing the puzzle. It is an incremental improvement.

Lots of "real world" problems can be solved by incremental improvement. On the other hand, many cannot.

Think of this in terms of climbing a mountain. Figure 4.9 shows a cross section of a mountain. Starting at point A, one can make incremental improvement, moving upward at each step (for awhile). Then, however, one reaches the top of a local peak and must go downhill for a while before one can again go uphill.

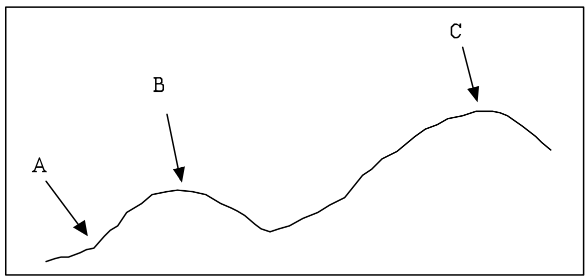



Figure 4.9. Incremental improvement (hill climbing) starting from point A.

**Problem Solving by Divide and Conquer Strategy**

Solving crossword puzzles also illustrates another very important strategic approach to problem solving. It is called divide and conquer. Many types of jigsaw puzzles have quite distinct edge pieces—and corner pieces, that are even easier to put into their correct places. For such a puzzle, it is easy to sort the edge pieces from the non-edge pieces. This divides the original problem into two distinct sub problems.

Often a jigsaw puzzle has some distinctive color or figure patterns, and the pieces for these sub components of the puzzle can be sorted out from the total collection of pieces. This is another use of the divide and conquer strategy.

**Sudoku Puzzles**

The left panel of Figure 4.10 shows a 4 x 4 Sudoku board. The 16 cells are divided into 4 boxes. The right panel illustrates notation to talk about and write about a Sudoku puzzle. Using this notation, the four cells in box 1 are a1, a2, b1, and b2.

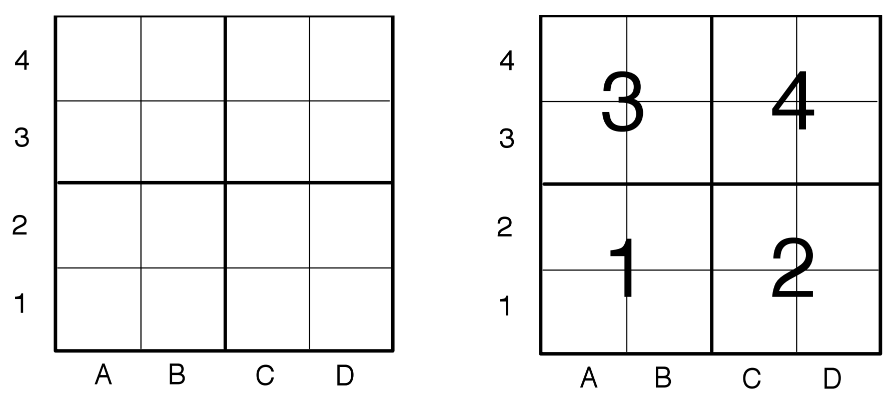


Figure 4.10. Sudoku board and Sudoku board notation.

A 4 x 4 Sudoku puzzle makes use of the digits 1, 2, 3, and 4. A puzzle consists of a board with some of the cells filled in and a goal of filling in the empty cells so that:

1. Each box contains all four digits 1, 2, 3, and 4.
2. Each row and each column contains all four digits 1, 2, 3, and 4.

The left panel of Figure 4.11 shows a "very easy" 4 x 4 Sudoku puzzle and the right panel shows the completed puzzle.

| | | | | |
|---|---|---|---|---|
| 4 | 2 | 1 | | |
| 3 | | 3 | 2 | |
| 2 | | | | 4 |
| 1 | 1 | | | |
| | A | B | C | D |

| | | | | |
|---|---|---|---|---|
| 4 | 2 | 1 | 4 | 3 |
| 3 | 4 | 3 | 2 | 1 |
| 2 | 3 | 2 | 1 | 4 |
| 1 | 1 | 4 | 3 | 2 |
| | A | B | C | D |

Figure 4.11. A 4 x 4 Sudoku puzzle and its solution.

In solving this easy Sudoku puzzle, I notice that box 3 had only one missing digit. So, I filled in cell A3 with the digit 4. Then I noticed that column A had only one missing digit, so I put a 3 into cell A2. Next I notice that row 3 had only one missing digit, so I filled in cell D3 with the digit 1.

The next step was more of a challenge. I saw that row 4 was missing two digits. I looked at the cell D4 for a while. The only possibilities were the digits 13 and 4. However, column D already contained a 4, so it must be that cell D4 contains a 3. Using this type of careful reasoning, the puzzle is easily completed.

The following Websites provide instruction on how to solve Sudoku puzzles:

- How to play Sudoku—a Beginner's Guide: http://www.su-doku.net/howtoplay.php.
- How to Solve Sudoku Puzzles: http://www.paulspages.co.uk/sudoku/howtosolve/.
- How To Do a Sudoku (video 6:36): http://www.youtube.com/watch?v=z6mGHf9bq3I.
- Tips of Playing Sudoku (video 4:35): http://www.metacafe.com/watch/746646/tips_of_playing_sudoku/.
- How To Play Sudoku (tutorial): http://www.sudokuessentials.com/how_to_play_sudoku.html.

My 10/15/2011Web search of the expression *free Sudoku puzzles* produced about 3 million hits. The Website Sudoku Place 4x4 Puzzles http://sudokuplace.com/4x4.asp provides 4 x 4 puzzles with four different levels of difficulty. See also:

- http://www.websudoku.com/?level=1. Here you can download Sudoku for the Mac and the PC so that you can play offline without being connected to the /web.
- http://mypuzzle.org/sudoku/. Here you can find 6 x 6 and 9 x 9 Sudoku puzzles of varying levels of difficulties.

The notation I have used to identify the cells, rows, and columns on a Sudoku board is called algebraic notation and is similar to the notation used in chess. See http://en.wikipedia.org/wiki/Algebraic_notation_%28chess%29. Figure 4.12 shows a chessboard. The white pawn at E2 can move to E4.

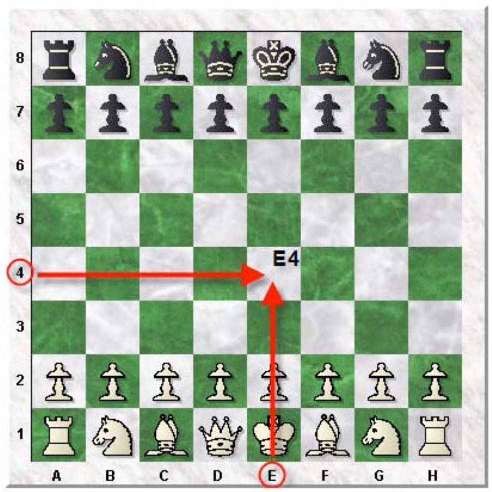



Figure 4.12. Algebraic notation used in chess.

**KenKen Puzzles**

KenKen is a "numbers" type of game that gives the player practice in doing simple arithmetic and thinking ahead.

The left panel of Figure 4.13 shows a 3 x 3 KenKen puzzle, and the right panel shows the same puzzle with notation that can be used in talking about or writing about the individual cells.

The goal is to fill the digits 1 to 3 into all of the squares, subject to two rules:

1. Each row and each column must contain all 3 of the digits.
2. Each of the regions (called cages) surrounded by a heavy black line must contain digits that combine arithmetically to the given number in the upper left corner of the cage, using the arithmetic operation given immediately after that number.

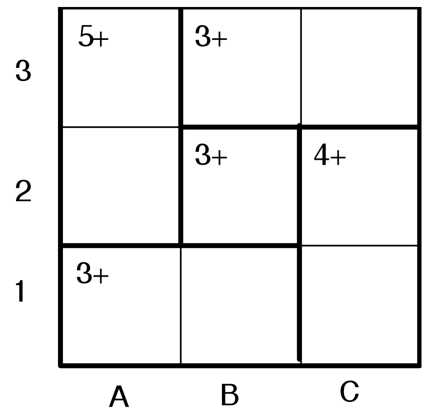



Figure 4.13. A 3 x3 KenKen puzzle.

Notice that the puzzle contains 5 cages. Four of the cages are two blocks in size, while one contains a single block. Before reading the next paragraph, see if you can figure out how to solve the puzzle. To get started, notice that the cage consisting of a single block must contain one of the digits 1, 2, and 3, and the digits in this cage must sum to 3.

See a 2:53 video introduction to the game at http://www.kenken.com/latestnews_video.html that uses the above example. The narrator for the instruction video is Will Shortz. He is well known in the crossword puzzle industry. In his analysis of this puzzle, he first observes that there is a cage in the middle of the board that contains only one box (B2). The box B2 must contain the digit 3 because the sum of the digits in that block must be 3. A solution is given in Figure 4.14.

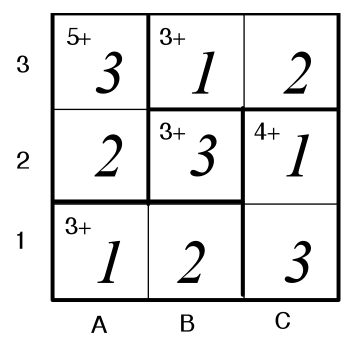



Figure 4.14. Solution to the 3 x 3 easy KenKen puzzle,

Another introductory video is given at http://www.youtube.com/watch?v=sTwlE7tSXlk. It discusses 3 x 3 KenKen puzzles suitable for use with first grade students.

A more complex 4 x 4 KenKen puzzle is given in Figure 4.15. It involves all four of the arithmetic operations addition, subtraction, multiplication, and division. Notice the cage at C3. It contains the digit 3 in its upper left corner, but does not contain an arithmetic operation. This is a "gift—the number that goes in this cage (this box) is a 3. (Some authors just put a 3+ in the corner to indicate that the digits in that cell have to add to 3.) This gives you a start on solving the puzzle.

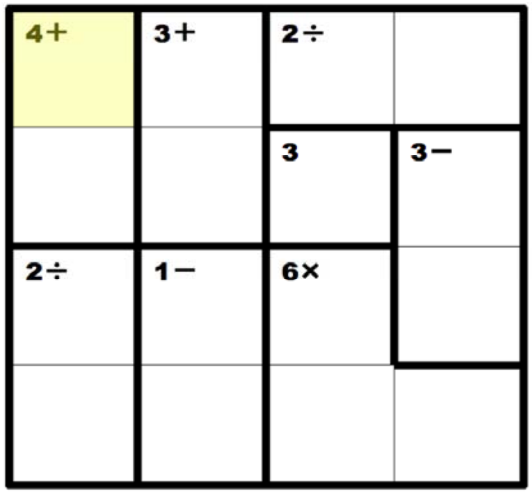



Figure 4.13. A 4x4 KenKen puzzle.

Continue to explore the puzzle. A 3-block cage includes the bottom right corner. The three numbers in this cage must multiply together to make 6. The only possibility is 1 x 2 x 3. From this you can conclude that the cell D1 contains the number 3.

Consider the cage in the upper left corner. The two numbers in that cage must be 1 and 3. From this you can conclude that block A4 contains the number 3 and block A3 contains the number 1.

By now you are probably getting some general ideas of how to attack a KenKen puzzle. The process uses mental arithmetic. Also notice the value of writing down some of the possibilities for a particular cage or of having a good memory that can be used in place of such writing. With practice, you will improve your mental arithmetic and memory enough so that you can do simple KenKen puzzles without such writing aids—you figure out mentally what number goes into a particular square and write it in.

Quoting from the Website http://www.kenken.com/aboutus_faq.html#K:

- Can a KenKen puzzle always be solved without guesswork?

  Yes, a puzzle can always be solved without random guesswork. However, there are some instances in which small samples of trial and error must be used to eliminate certain solutions. This is found mostly in larger puzzles.

- Do I need math skills to solve a KenKen puzzle?

  Basic arithmetic skills are needed to solve a puzzle. Some puzzles will only use addition, some addition and subtraction, and some will use all four operations. The beauty of KenKen is that you can pick whatever type of puzzle you like!

- Is there only one unique solution to a KenKen puzzle?

  Each KenKen puzzle is created with only one unique solution.

**Additional Types of Puzzles**

There are many other kinds of puzzles available free on the Web. A few are illustrated in this section.

**Puzzles from *Puzzle Choice***

Puzzle Choice: http://www.puzzlechoice.com/pc/Puzzle_Choicex.html. See the menu on the left side of the Web page. Quoting from the Website:

> If you like puzzles and games then there are many different types of printable and interactive CROSSWORDS for you to choose from plus a daily US style crossword.
>
> Check out our WORD SEARCH puzzles or take a look at the WORDPLAY section for anagrams, brainteasers, and other printable word games.
>
> Test your trivia knowledge with a QUIZ or give your mind a workout with some original LOGIC or NUMBER PUZZLES.
>
> ONLINE GAMES includes jigsaws, mazes, memory games and a choice selection of classic puzzles and games.
>
> Kids young and old should visit the KID'S CHOICE section for a variety of fun and educational puzzles and games.

Figure 4.14 is an example of one of the computer-based puzzles in the KID'S CHOICE section (see the menu on the left side of the Website). Commercial or homemade versions of this puzzle often consist of a board with 15 holes that can hold a marble. Begin with a triangle of 14 marbles and one empty space. (The puzzle can also use a triangle with 10 holes or a triangle with 6 holes. It is interesting to experiment with the one empty space being at different positions.)

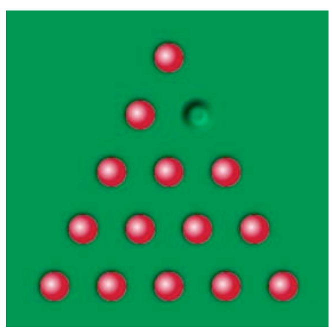


Figure 4.14. Fourteen marbles puzzle.

Remove marbles by jumping over one marble at a time. The goal is to end with as few marbles as possible remaining on the board. The picture below shows the situation after one of the two possible first jumps.

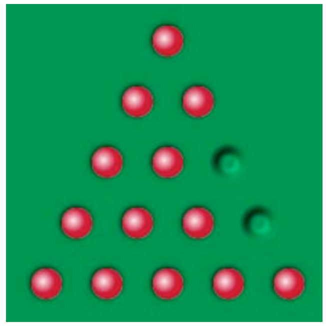


Figure 4.15. Fourteen marbles puzzle after one “jump.”

Figure 4.16 shows a small shows a picture of a paper template used for a board. The markers can be coins or other small objects.

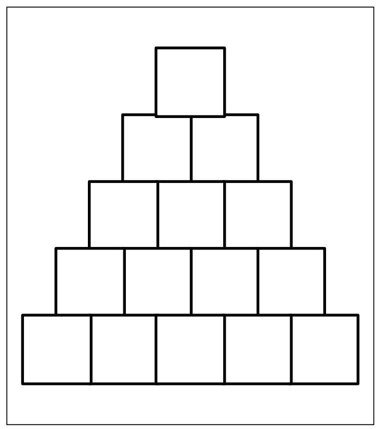


Figure 4.16. Picture of template for a paper playing board.

**Math Puzzles from Aims Education Foundation**

The AIMS Puzzle Corner at http://www.aimsedu.org/Puzzle/ provides over 100 interesting math-oriented puzzles. Notice that in the menu on the left side of the Website page, **Solutions** is one of the choices.

The puzzles are categorized by type, and within each category are listed in order of increasing difficulty. The puzzles have not been assigned a grade level appropriateness because we have discovered that the ability to do a puzzle varies by individual not grade level.

**Liquid-Measuring Puzzles**

Liquid measures logic puzzles are a type of math problem that can be solved using a strategy named *working backward.* Here is an example of a water-measuring puzzle:

> Given a 5-liter jug, a 3-liter jug, and an unlimited supply of water, how do you measure out exactly 4 liters? (Two solutions are provided at http://www.scientificpsychic.com/mind/aqua1.html.)

In working backward, we start at the end. In the final step of solving the puzzle we pour some water and end up with exactly 4 liters in the 5- liter jug. What are the possible situations immediately before taking the final pour to produce 4 liters? What are some ways to make the number 4 that are relevant to the water-pouring puzzle? Notice that 4 = 5 – 1; 4 = 3 + 1; 4 = 2 + 2; 4 = 1 + 3.

This simple arithmetic analysis suggest ways to attack the problem. For example, consider 4 = 5 - 1. How can we manage to pour exactly one liter out of the 5-liter jug? We could do this if there were 2 liters of water in the 3-liter jug. Just pour from the 5-liter jug until the 3-liter jug is full. This type of thinking (working backward) has led to the new problem of getting 2 liters of water in the 3-liter jug. Can you figure out how to do this? A solution to the problem is given in Figure 4.17.

| | **Water in Jugs** | |
|---|---|---|
| | 3-liter jug | 5-liter jug |
| Given: empty 3-liter jug, empty 5-liter jug, unlimited supply of water | 0 liters | 0 liters |
| 1. Fill the 5-liter jug with water from the unlimited supply. | 0 liters | 5 liters |
| 2. Fill the 3-liter jug from the 5-liter jug. Now the 3-liter jug contains 3 liters and the 5-liter jug contains 2 liters. | 3 liters | 2 liters |
| 3. Empty the 3-liter jug. | 0 liters | 2 liters |
| 4. Pour the 2 liters in the 5-liter jug into the 3-liter jug. Now the 5-liter jug is empty and the 3-liter jug contains 2 liters. | 2 liters | 0 liters |
| 5. Fill the 5-liter jug from the unlimited supply. Now the 5-liter jug contains 5 liters and the 3-liter jug contains 2 liters. The 3-liter jug can accept 1 more liter without overflowing. | 2 liters | 5-liters |
| 6. Fill the 3-liter jug by pouring 1 liter from the 5-liter jug. Voila! The 5-liter jug now contains 4 liters and the 3-liter jug contains 3 liters. You have succeeded in measuring 4-liters. | 3 liters | 4 liters |

Figure 4.17. A solution to the problem of obtaining 4 liters of water.

My 10/17 2011 Web search of *puzzle problem water measuring* produced about 4 million hits. There are many water-measuring problems. According to Ivars Peterson, such problems date back to the 13th century. See http://www.maa.org/mathland/mathtrek_06_02_03.html. Peterson's article gives additional examples and discusses some of the underlying mathematics of how to solve this type of problem.

**Science-based Magic Tricks**

You might think of a magic trick as a type of puzzle. This section provides access to a variety of magical tricks that can be explained by their underlying science. See the excellent (7:10) video at http://www.youtube.com/watch?v=4EABdAEt_fM.

Arthur C. Clark was a prolific writer of science and science fiction. He is often quoted for his statement that: "Any sufficiently advanced technology is indistinguishable from magic." To a child, our world is full of magic, and the child accepts this situation as, "that's just the way things are." Imagine an adult from 1,000 years ago encountering a flashlight, airplane, digital camera, electronic toys and Web-based games.

- Nicholas Academy http://nicholasacademy.com/scienceexperiments.html. Scroll down the page until you come to Science Experiment of the Week. There you will find a number of "magical" science tricks and explanations of the underlying science. The explanations are a very important educational part of these tricks. You want children to learn to "understand" the magic of science.
- Science Tricks. See 10 quirky science tricks at http://www.youtube.com/watch?v=i_f3SkxTWxc.
- Welcome to the Magic Page http://webtech.kennesaw.edu/jcheek3/magic.htm. Contains links to a number of different magic trick resources. Be aware that many of the sites linked to are commercial.

**Final Remarks**

The Web abounds in puzzles and offers myriad types and levels of challenge. A typical puzzle is entertaining and mentally challenging. You can think of puzzles as "fun" brain exercises that require active participation.

Many of the examples given in this chapter illustrate a category of puzzles. Examples include crossword puzzles, jigsaw puzzles, Sudoku puzzles, KenKen puzzles, and so on. Both children and adults enjoy such puzzles. Many adults experience great joy in playing alongside children. In the process, they role model the fun and value of being a lifelong learner. They may help the children they play alongside with to become lifelong enjoyers of the puzzles.

# Chapter 5. Educational Games

All the world's a game,

And all the men and women active players:

They have their exits and their entrances;

And all people in their time play many parts.

(David Moursund—Adapted from Shakespeare)

When I was a child, I spent many hours playing the game Monopoly. A similar statement holds for my children and for some of my grandchildren. I played because it was fun. However, through this playing I learned a lot about counting, money, strategic planning, informal probability, and about interacting with other children. Monopoly and other board and card games that I played as a child contributed substantially to my education.

A game has rules that the players must learn and follow. A game that has two or more players involves interaction among the players. Playing a game well requires planning ahead—thinking about the consequences of one's moves and actions.

All of these statements apply to the processes of making the decisions and carrying out the day-to-day activities of life in a society of people. Thus, there can be considerable transfer of learning from game playing to the game of life.

Most young children have considerable difficulty learning and understanding the idea that their actions have consequences. The book Moursund (2008) *Becoming more responsible for your education* has an eighth-grade reading level. (Download from http://i-a-e.org/downloads/doc_download/39-becoming-more-responsbile-for-your-education.html.) It is an excellent book for parents to read alongside of their young teen-age children and to discuss with their children.

A computer can take the place of one or more people in a game that requires two or more people. For example, you can play chess, checkers, or Monopoly against a computer. There are many games available on handheld game machines and cell phones.

My recent Web search for *free computer games* returned a huge number of hits. Some of these games can be played online, and some can be downloaded to your computer. In both cases, the Website is apt to contain quite a bit of advertising. Often a site provides some free games and some games for sale. Or, a site might provide a free—but somewhat limited—version of a game and then sell the full version of the game. As a final warning, sites are apt to change substantially over time. Thus, when this book mentions a game site, it may have changed considerably by the time a reader accesses the site.

A networked computer system can also provide access to other human players who may be located thousands of miles away from you. Some of the massively multiplayer games involve thousands of participants all playing at the same time. Some are free and some charge to play. The Website http://play-free-online-games.com/games/games_all.html provides free access to a number of massively multiplayer games,. However, most of the games have "extra features" that are provided for a cost that is specified.

Will Wright, the video-game designer responsible for the "Sims" titles, says that video games are better at inspiring students to learn than actually teaching them. For a 29-minute talk by Wright, see http://www.bafta.org/awards/video-games/will-wright-video-games-lecture-in-2007,254,BA.html.

There has been a lot of research on use of games in education. The next several sections are designed to help you decide for yourself whether use of games is educationally sound for the children that you work with, and how to make the use of games more educationally sound.

Warning! Please be aware that some games involve much more social interaction than others. Some games are addictive and can lead to antisocial behavior.

**Play is a Child's Job**

You have probably heard the statement that "play is a child's job." There has been a lot of research on how children learn through play. One of the things that we know is that varied, active, and interactive play environments contribute substantially to a child's development.

Babies take pleasure in batting at a mobile hanging over a crib, or discovering and playing with their toes and colorful, simple toys. As babies become toddlers and continue to grow, they learn to play with other children. This is a major step forward in a child's overall social development and it opens new opportunities for play.

Eventually a child's level of development reaches a stage where the child can participate in simple card games such as Go Fish (see http://www.pagat.com/quartet/gofish.html) or a board game that involves moving a piece around a board based on numbers produced by a spinner, dice, or drawing a card. These are major intellectual achievements for a young child. With appropriate help from older children and/or adults, a child learns that games have rules, games involve taking turns, and games have winners and losers.

> With help from older children and/or adults, a child learns that games have rules and games involve taking turns. Playing well requires learning to think ahead and to make good decisions.

Every day you make decisions that vary considerable in importance and long-term consequences. As a child's brain matures, it gets better at foreseeing the consequences of possible decisions and actions. Children gradually get better at understanding and accepting the consequences of their actions. This is a very important part of growing up and becoming a responsible adult.

However, this is a long, slow process. Many of one's decisions and actions are slow to "bear fruit" or to produce significant effects. In contrast to this, many of the games that children play include relatively immediate feedback on the decisions, moves, and other actions a player makes. Thus, games can be a useful aid to children learning to plan ahead and learning that their decisions can have both immediate and long term consequences.

> Games provide quick feedback on the decisions, moves, and other

| | | |
|---|---|---|
| | actions a player makes. Thus, games can help children learn to plan ahead and learn that their decisions have consequences. | |

Most children will not automatically make a transfer of learning from a game-based environment to the non-game environment of their everyday lives. In transfer of learning, an adult, either as a player or as a supervisor of game playing, can contribute mightily to the learning of children.

**Competitive Games**

I like to play solitaire card games. When I was younger, I used a deck of playing cards. Now, I play the games on a computer. It is convenient to have the computer scuffle the cards and do the layout. If the computer program is well designed, then one can make the ”plays” more rapidly on a computer than when playing “by hand.” Moreover, the computer knows the rules and prevents certain types of errors and certain types of cheating.

However, one loses the smell of a fresh deck of cards, the fun of scuffling a deck, the hand and arm movements of dealing out and playing the cards, and so on.

Here’s a question for you. Is a solitaire card game a competitive game? When you are all alone, playing a solitaire card game, you can keep track of your wins and “not wins.” But, who are you competing with? You might argue that you are competing with yourself, or you are competing with your won/loss record from previous days. However, the nature of this competition is not like the head to head competition in sports and board games.

Take a look at the “fill in the names of the states” game at http://www.surfnetkids.com/games/united_states_geography.htm. It is a solitary-type of one player game. The computer gives you the name of a state and your task is to click on the outline of the state. Immediate feedback is provided if you click on the wrong location.

Simple enough. You can use this game to learn the map locations of the 50 states. With practice, you improve in speed and accuracy. The “competition” in this game is that of playing against oneself. The satisfaction comes from getting better at playing the game, and in eventually becoming quite fast at placing all 50 state names into their correct locations and making few or no errors.

Now imagine the same type of setting, but with students competing against each other in timed contests. Who can get the most names onto the map in one minute? Who is the fastest in the class at correctly filling in all of the names?

This simple example illustrated the idea of competition against oneself versus competition against others.

Many games are competitive, involve winning or losing. This immediately raises a difficult question. Some parents want their children to be very competitive, and others don’t. Moreover, there is research to support the contention that girls (on average) like to participate in collaborative games rather than in competitive games, with the opposite being true for boys. Quoting from Tucker-Ladd (2000):

> It takes Alfie Kohn [in the book No Contest: The Case Against Competition, 1986] an entire book to summarize the massive data indicating that competition in

> our society is harmful. Yet, our culture proclaims (without adequate supporting data) just the opposite, that competition is efficient, healthy, and fun. **Actually, hard research data documents that people achieve more if they work cooperatively with others (than if they work competitively). We are so brainwashed, we find that hard to believe. (Think of it this way: trying to do your best is very different from trying to beat everyone else.)** On the other hand, we can readily accept that a competitive job, school, or social situation, where someone wins by making others fail, causes dreadful stress, resentment of the winner, contempt for the losers, low self- esteem, and major barriers to warm, caring, supportive relationships.
>
> What is the solution? Kohn recommends replacing competition with cooperation, i.e. working together, assuming responsibility for helping each other do our best, and uncritically valuing each other's contributions. [Bold added for emphasis.]

You might want to further explore the issue of competition versus cooperation/collaboration. An excellent 20-minute video on competition and collaboration is available at http://www.ted.com/index.php/talks/howard_rheingold_on_collaboration.html.

### Computer-based Games

Computers have brought some important new dimensions to the world of play. Here are a few examples:

- A computer can provide quick access to thousands of different games and puzzles—many are free.
- There are many battery powered, handheld, easily portable, and quite sophisticated electronic game devices.
- A computer system can manage many of the details of a game and can be a player in the game. If you happen to want to play a game of checkers, chess, or poker, you can find free versions on the Web where the computer system displays the set up board on its screen and serves as an opponent whose skill level you can adjust.
- A computer can facilitate games in which there is simultaneous play by two or more people. Thus, for example, a computer system can help me to find an online opponent in chess, or facilitate my playing in an online bridge game. A computer can facilitate the simultaneous play of many thousands of people in a massively multiplayer online game. See http://en.wikipedia.org/wiki/Massively_multiplayer_online_game.

Computers can be used in interactive, online, edutainment that combines game-like features with educational features. Perhaps you are familiar with airplane pilot trainers, spaceship crew trainers, and car driver trainers. These are examples of very high quality computer-assisted learning devices. Simpler—and less expensive—versions of such systems are available as computer games.

For various groups of children and adults, computer games have surpassed television in terms of average hours of play per week. Indeed, it is appropriate to talk about a computer game being addictive and a person being addicted to computer games. Quoting from Rideout et al. (2010):

> Over the past five years, young people have increased the amount of time they spend consuming media by an hour and seventeen minutes daily, from 6:21 to

> 7:38—almost the amount of time most adults spend at work each day, except that young people use media seven days a week instead of five.
>
> Moreover, given the amount of time they spend using more than one medium at a time, today's youth pack a total of 10 hours and 45 minutes worth of media content into those daily 71/2 hours—an increase of almost 21/4 hours of media exposure per day over the past five years.

Personally, I find this data to be frightening. In a year, average children spend well over twice as many hours (not even counting multitasking) consuming media as they spend in school. Thus, as you work with children, you are faced by the dual challenges:

1. Providing the opportunity for the children to gain the social, educational, and entertainment values of games and puzzles, be they non-computerized or computerized.
2. Helping children learn to deal with the addictive-like and other undesirable characteristics of many games and puzzles.

This chapter includes links to some good sources of information and free online games. However, its main purpose is to help you learn to increase the educational value of the games played by the children you work with.

**The Game of Tic-Tac-Toe**

As a child, you likely learned to play Tic-Tac-Toe (TTT). TTT is a two-player game, with players taking turns. One player is designated as X and the other as O. A turn consists of marking an unused square of a 3x3 grid with one's mark (an X or an O). The goal is to get three of one's mark in a file (vertical, horizontal, or diagonal). Traditionally, X plays first.

The website http://en.wikipedia.org/wiki/Tic-tac-toe#Number_of_terminal_positions provides consider information about the game. Figure 5.1 shows a sample game.

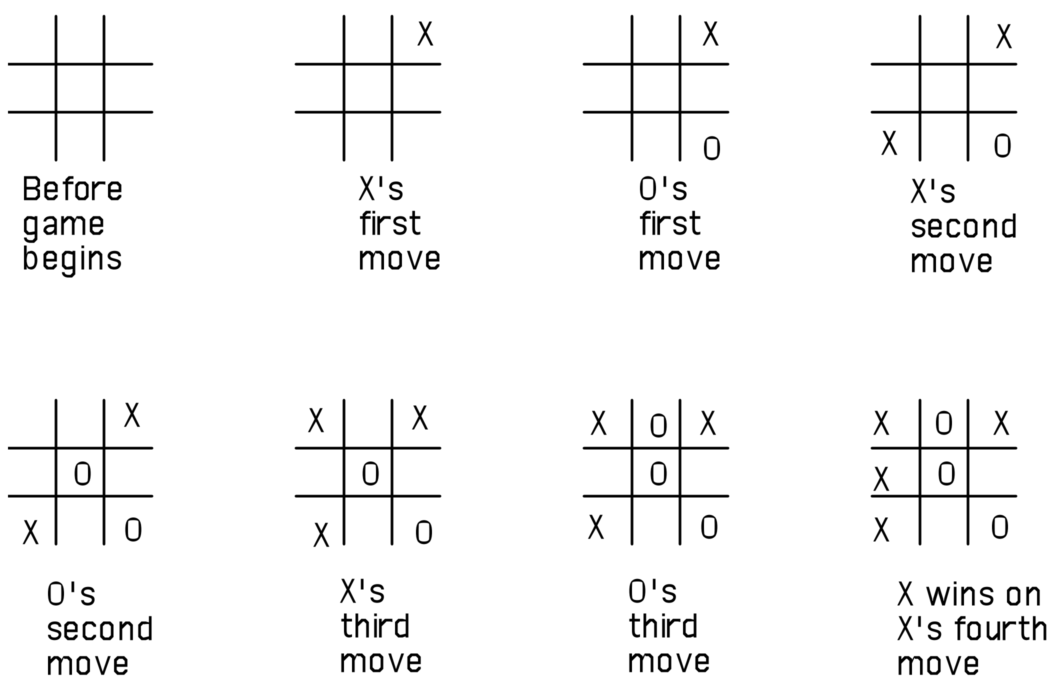


Figure 5.1. Example of a Tic-Tac-Toe game.

TTT is a competitive game that can be played by two people using pencil and paper. It can also be played against a computer. See http://www.freearcade.com/TicTacToe.flash/TicTacToe.html. This Website is set up so that the human player is X and always plays first. Begin play by clicking on the board position for your first move. The computer's level of play can be set from 0 (terrible) to 3 (very good).

When young children are first learning to play TTT, they typically play rather poorly—they tend to make random moves. Eventually, a beginner develops some strategies that may lead to better-than-random results. Still more experience and some thinking may lead to the development of still better strategies.

This trial and error approach to self-improvement, with no intervention from a better player, gives a child a chance to learn on his or her own. Compare this with merely having a better player teach the beginner a few good strategies. Rote memorization of some strategies will lead a beginner to play well.

If the primary goal is to learn to play well, then such instruction rapidly achieves the goal. If the primary goal is to learn to learn and to gain an understanding of the game through the school of hard knocks, then it is better if there is a different type of intervention from a teacher. The intervention might be in terms of asking questions that help the learner to think about why they lost a game, or why they made a particular move. It should encourage the development of strategies, but should not focus on the teaching of strategies that are specific to just to the game.

Here is an example of a strategy specific to TTT. If you are playing first against a player who is not too good, then place your first X in the center square. This will increase your chance of winning and decrease your chance of losing.

But why? Does learning to make my first move in TTT be in the center help me in dealing with the problems I encounter in everyday life or in playing other games?

The TTT board has three rows, three columns, and two diagonals. To win, your opponent must get three in a row in one of these eight files. By making your first move in the middle square, you block four of these eight files. No other first move blocks as many files.

Here is a more general way to say this. In playing a competitive game, make moves (take actions) that decrease your opponent's possible moves or actions. In chess, for example, a very useful strategy is to make moves that decrease the mobility (the freedom of movement) of your opponent's pieces.

## A Philosophy of Learning

Here are three important ideas from the previous section.

1. While learning to play a competitive game, learners experience winning, losing, and tying.
2. In game playing, through experience and thinking you can learn a great deal on our own. You can also practice metacognition and get better at it. You might well discover some good strategies on your own, and this is an important success.

3. You can get better at playing a game through instruction from a teacher or coach who has more knowledge, skill, and experience. A good teacher can help you to discover some useful strategies, or can directly teach you some strategies.

These three ideas are applicable in many game learning and other learning situations. Keep these ideas in mind as you help children learn to play games. You want to help the child learn to apply these ideas in learning other games and in non-game learning environments. Thus, stress transfer of learning.

Let’s discuss these ideas in a little more detail.

1. Competitiveness. Children vary considerably in their interest in and inclination toward competitiveness. Perhaps you have heard the following two statements:
   - “It’s not whether you win or lose—it’s how you play the game.” (Grantland Rice, sports writer.)
   - “Winning isn’t the only thing— it’s everything.” (Vince Lombardi, football coach.)

   I strongly recommend that you think about it very carefully before pushing a child toward either of these extremes.
2. Learning to learn on your own, through experience, metacognition, and reflection, is a very important part of a good informal and formal education. There are many games that can provide a relatively low risk environment in which to practice such learning.
3. A good teacher can help a person make decisions about what to learn and can help speed up the learning process. The teacher is faced by the issue of teaching for understanding and transfer of learning versus teaching for a high level of performance on a test or in a competition.

The third point helps us to understand a major issue in our educational system. It is much easier for a teacher to have a child memorize without understanding than it is to teach for understanding. It is very important to memorize some (indeed, a great many) facts. However, it is also very important for students to learn to think using the facts that they have memorized. The amount of emphasis on memorization versus the amount of emphasis on learning for that supports understanding and thinking varies from student to student. One size does not fit all!

## Some Games Related to TTT

There are many TTT types of games that are far more challenging than TTT. Here are some examples:

- TTT variations. See http://mathlair.allfunandgames.ca/tictactoe.php.
- Figure 5.2 shows Gomoku on a 12x12 board. The game can be played online at http://www.5stone.net/en/. To win, you have to get 5 in a row. (Gomoku is often called Five-in-a-Row.) Using just a 4 x 4 or 5 x 5 piece of such a board, you can play a game where the goal might be to get three in a row.

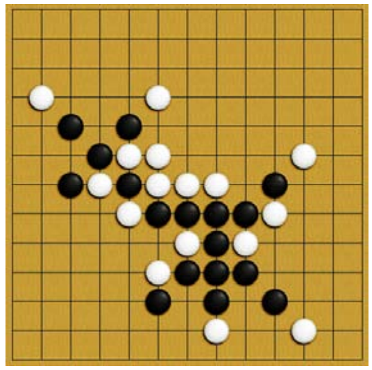


Figure 5.2. Black got five in a row and won this Gomoku game.

- Three dimensional TTT. Use a Web search engine to search for *free Mac three dimensional tic tac toe* or for *free PC three dimensional tic tac toe*. You will get lots of hits.
- Hex (a connection game). See http://en.wikipedia.org/wiki/Hex_%28board_game%29. Quoting from this website:

> Each player has an allocated color, Red and Blue being conventional. Players take turns placing a stone of their color on a single cell within the overall playing board. The goal is to form a connected path of your stones linking the opposing sides of the board marked by your colors, before your opponent connects his or her sides in a similar fashion. The first player to complete his or her connection wins the game. The four corner hexagons each belong to *two* sides.

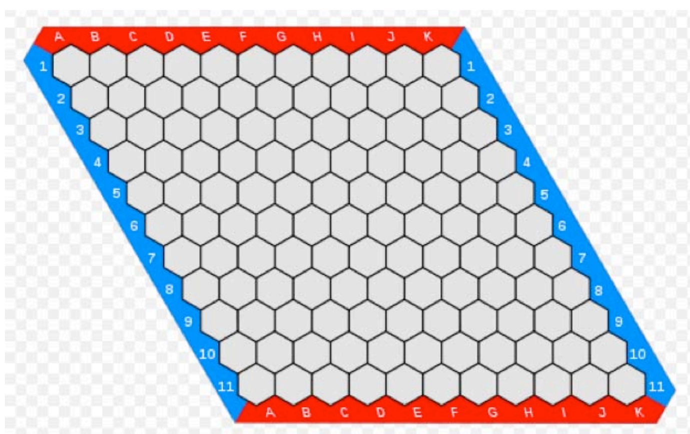



Figure 5.3. An 11 x11 Hex board.

- Connect Four. See http://search.teach-nology.com/web_tools/games/connect4/index.html. In Connect Four, columns are formed from the bottom up. For an “n in a row” version, see http://www.pomakis.com/c4/online/c4.cgi?76450.

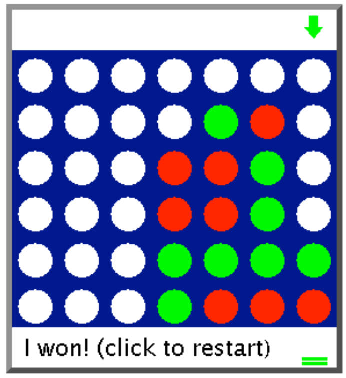



Figure 5.4. The computer, playing green, won this game of Connect Four.

**Some Free Educational Games**

TTT and the related games mentioned above have educational value, but they were not designed as educational games. Of course, a good teacher finds ways to make them educational.

It is possible to design games that are both educational and entertaining. These are called edutainment games. Here are some examples and sources of edutainment games. They are listed in alphabetical order.

- Adventures of Josie True. See http://www.josietrue.com/. Click on the screens to get the overall story line. Then participate in solving a mystery. A variety of games are available at this Website. Quoting from the Website:

  > The Adventures of Josie True is the award winning **science and mathematics web adventure game.** The design was targeted at middle school girls in order to come at learning software design from a new angle. The project was funded by the National Science Foundation in 1999.
  >
  > Integral to the research was player testing and research with our target audience, girls age 9-11 years old. We conducted experiments ranging from visual comparisons to interaction research using various game designs with the 5th grade curricular content. We also employed existing research to create better educational software through design.

- Fantastic Contraption. See http://fantasticcontraption.com/. An online physics puzzle game with many levels. Requires you to watch a 30-second ad before beginning to play.
- Food Force (United Nations World Food Program). See http://www.wfp.org/how-to-help/individuals/food-force. To play this game requires that you download and install the software onto your machine. There are several missions one can undertake. Quoting from the Website:

  > To underline the game's main objectives of teaching children about global hunger and WFP's [Word Food Program's] efforts to fight it, each mission begins with a briefing on the task ahead by a member of the Food Force team of virtual aid workers.
  >
  > It is followed by feedback on the player's performance and an educational video filmed on the frontlines of WFP's work in the field.

> The Food Force site also includes more information about WFP and features a special section for teachers with downloadable lesson plans on what hunger is, why it exists and how to end it. A How to Help section provides ideas on fundraising and school involvement.

- Immune Attack from the Federation of American Scientists, for PC (not Mac). See http://fas.org/immuneattack/ to download the software to your machine. Quoting from the Website:

> The Federation of American Scientists (FAS) presents Immune Attack™, an educational video game that introduces basic concepts of human immunology to high school and entry-level college students. Designed as a supplemental learning tool, Immune Attack aims to excite students about the subject, while also illuminating general principles and detailed concepts of immunology.

- NIEHS (**National Institute of Environmental Health Sciences)** Kids Pages: See http://kids.niehs.nih.gov/. The games at this site vary considerably in their educational and entertainment values.
- PowerUp from IBM, for Windows (not for Mac). See http://www.powerupthegame.org/. The goal in this game is to save our planet. Quoting from the Website:

> Our atmosphere is choked with carbon dioxide and other greenhouse gases. The planet is heating up. Extreme weather threatens almost every ecosystem and all of our citizens, and storms have destroyed much of the renewable energy infrastructure including wind turbines, hydroelectric generators and solar towers. Fossil fuel plants work overtime to pick up the slack, pumping tons of poison gases into the air, and there are strange, new threats. There have been scattered reports of what people are calling "SmogGobs:" dense clouds of carbon based emissions that seem almost alive. Scientists can not explain the phenomenon - but citizens are blaming these SmogGobs for sickness and even death of loved ones. World leaders have appealed for help, but it may be too late..."

- Simulation Games. See http://puzzling.caret.cam.ac.uk/index.php?section=styleselect&redirect=home.

Quoting from the Cambridge Centre for Applied Research in Educational Technology (CARET) site:

> Welcome to the new look of CARET's Brainteasers & Puzzles!
>
> CARET's projects are selected to promote best practice in e-learning and the application of educational technology. We aim to develop generic tools and systems to support the delivery, assessment and evaluation of pedagogically sound online education, and to establish Cambridge University as a world-leader in this area.

Currently, the site contains 27 highly educational games and puzzles. For a good example, example, consider Sunny Meadows: http://puzzling.caret.cam.ac.uk/game.php?game=6&age=1. Quoting:

> In every ecosystem there is a food chain. In the food chain, species can be consumers (who eat other species), or producers (who are eaten by other species) or both. In this game, there is a simple food chain of foxes, rabbits and plants.

A possible educational use of this simulation would be to have a person play the game or do the puzzle until reaching a certain level of success, and then explain how/why the success is achieved.

- WolfQuest. See http://www.wolfquest.org/. Quoting from the Website:

> Learn about wolf ecology by living the life of a wild wolf in Yellowstone National Park. Play alone or with friends in on-line multiplayer missions, explore the wilderness, hunt elk, and encounter stranger wolves in your quest to find a mate. Ultimately, your success will depend on forming a family pack, raising pups, and ensuring the survival of your pack.
>
> The WolfQuest experience goes beyond the game with an active online community where you can discuss the game with other players, chat with wolf biologists, and share artwork and stories about wolves.

**Math Games**

There are many games, puzzles, and instructional materials on the Web that are designed to help children learn math. My Web search of *free online math games* returns millions of hits. See, for example, Helping Your Child Learn Mathematics available in English and Spanish at http://www.ed.gov/parents/academic/help/math/index.html. Quoting from the site:

> This booklet is made up of fun activities that parents can use with children from preschool age through grade 5 to strengthen their math skills and build strong positive attitudes toward math.

This book can direct you to sites such as the one given above and some given below. However, it cannot tell you which of the specific activities will best fit the children you are working with. The sites give you an opportunity to "play together, learn together." For you, part of the learning is to learn what works best with a specific child.

Fifteen free games at various grade ranges of students are available at http://www.crickweb.co.uk/.

A large number of "drill type" games are available at http://www.sheppardsoftware.com/math.htm.

**Tangrams**

Tangrams are a nice example of a physical and virtual manipulative. This is a Chinese puzzle consisting of a square cut into five triangles, a square, and a rhomboid, to be reassembled into different figures with no overlapping pieces (Tangram, n.d.). Figure 5.5 shows the seven pieces and the pieces arranged into a running person. A Tangram game is available for free online play at http://www.apples4theteacher.com/tangrams.html. (Ten examples are shown. Use the **Help** button for directions.) Also see the nice site http://pbskids.org/cyberchase/math-games/tanagram-game/.

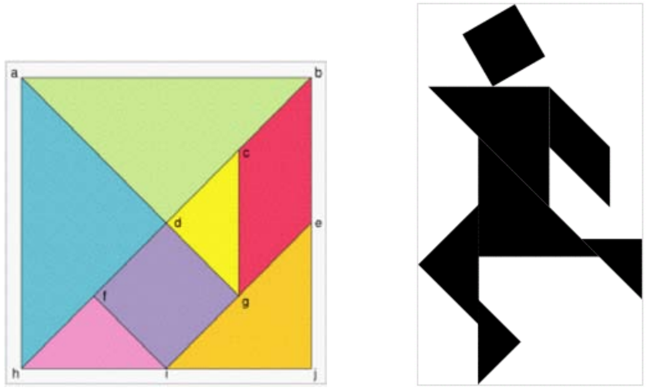
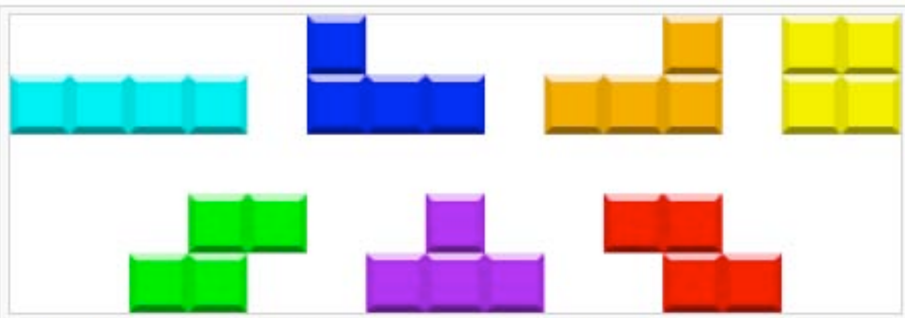



Figure 5.5. The seven Tangram pieces made into a running person.

**Tetris**

There are relatively few computer games that women enjoy more than men. Tetris is one of these. It is a solitaire (one-player) electronic game. Tetris (sometimes called Penta is available on a many handheld, game machine, and computer platforms.



The seven one-sided tetrominoes in their *Tetris Worlds* colors. Top row, left to right: *I, J, L, O.* Bottom row: *S, T, Z.*

Figure 5.6. The 7 tetrominoes used in Tetris games.

Quoting from http://en.wikipedia.org/wiki/Tetris:

> Seven randomly rendered tetrominoes or tetrads—shapes composed of four blocks each—fall down the playing field. The object of the game is to manipulate these tetrominoes with the aim of creating a horizontal line of blocks without gaps. When such a line is created, it disappears, and the blocks above (if any) fall. As the game progresses, the tetrominoes fall faster, and the game ends when the stack of tetrominoes reaches the top of the playing field.

A Web search using the expression *free online Tetris* returns a very large number of hits. For example, http://www.freetetris.org/ provides many different versions. Experiment with different versions until you find one that fits your needs.

Playing this game requires hand-eye coordination, as well as quick recognition of figures in two dimensional space and quick decision-making. I am relatively poor in all of the abilities that it takes to become good at this game. Thus, it is not surprising that I do not enjoy playing Tetris.

However, I find it educational to introspect as I play the game, and I find it interesting to see how practice makes me better at the game. At a beginner's level, the game can be set so that the pieces fall very slowly and one can experience success. One's mind/brain/body adjusts (that is, learns) to the demands of the game. I find it interesting to see/sense this learning occurring and to discover that I get better with practice. Through playing this game, I have gained increased appreciation for the learning capabilities of my mind/brain/body.

**Card Games**

An ordinary 52-card deck of playing cards has four suits of 13 cards each. The cards in a suit are labeled 2, … 9,10, J (Jack), Q (Queen), K (King), A (Ace). Notice the use of the digits 2 to 10, but then special names for the remaining cards. In some card games the Ace is both the lowest and the highest ranked card. Thus, a child learning to play card games is faced with a somewhat peculiar numbering/ranking system.

Playing cards provide a good example of how one can incorporate several different aspects of education into one activity. Playing cards have a long history and are an important component of art. See http://i-p-c-s.org/history.html and http://en.wikipedia.org/wiki/Playing_card. Card games involve working with numbers (rankings), developing sand using strategies, learning and following rules, and so on.

Blue Rider back Bicycle Playing Cards by USPCC

There are a very large number of games that can be played with one or more decks of ordinary playing cards. Computer versions of many of these games are available. As a child you may have played Go Fish. This game can also be played online against a computer opponent. An example is available at http://kids.aol.com/games/card-shark/.

However, play by hand using a deck of cards and being face to face with a child is a far better educational and socializing activity than playing against a computer opponent. There is a deep message here. Many parents tell their children "go watch TV" or "go play a computer game." Contrast this with a parent and child sitting together, with the parent reading to the child, the parent watching TV with a child, or the parent playing a game with a child. The parent-to-child social interaction and sharing is a very valuable component of the learning experience.

> Playing by hand using a deck of cards and being face to face with a child is a far better educational and socializing activity than playing against a computer opponent.

Card games provide an excellent environment to practice strategic planning. Card games often involve counting and sequencing, and thus contribute to gaining number sense. And, of course, playing a variety of card games helps to build one's "card sense" and helps one develop some intuitive understanding for card-based probability.

**Solitaire Card Games**

There are many solitaire card games. The most commonly played one is called Klondike. For many years, Microsoft has provided a free electronic version of Klondike in its Windows operating system. Thus, it is probably the most widely played electronic game in the world.

Klondike uses a standard 52-card deck of playing cards. The card deck is shuffled and then dealt out, as illustrated Figure 5.7. If you are not familiar with the game, you might want to read a little about its rules at http://en.wikipedia.org/wiki/Klondike_solitaire.

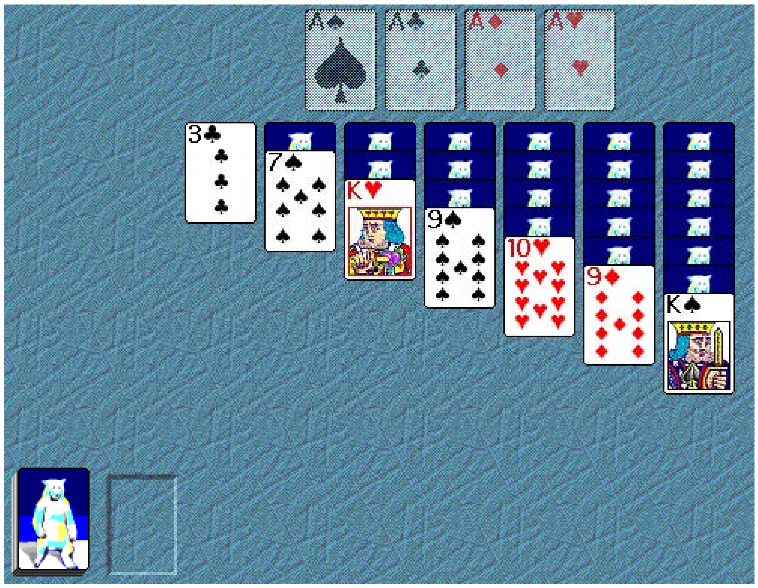


Figure 5.7. The start of a game of Klondike solitaire.

Solitaire card games vary considerably in their intellectual challenges. Some require "deep" thinking as one plans a large sequence of card moves. Others are sort of mindless. The game Eight Off is available along with a number of other solitaire card games at http://www.acecardgames.com/en/. It is one of my favorite solitaire games, and it is quite challenging to play the game well. See Figure 5.8.

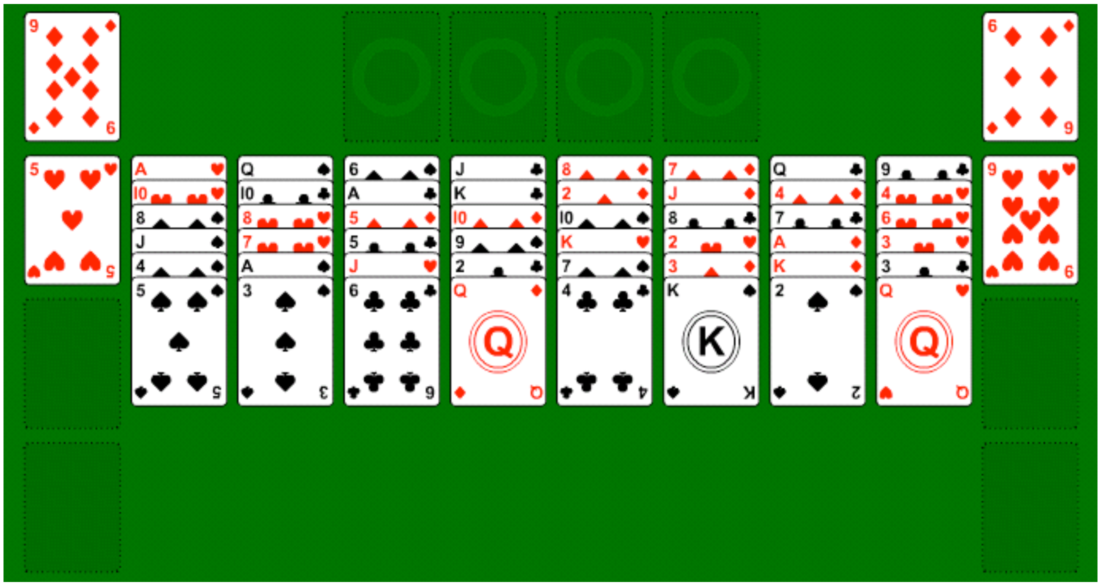


Figure 5.8. The start of a game of Eight Off.

**Final Remarks**

Education has many goals, and there is a huge amount of research and practitioner knowledge about teaching and learning. Games can be used in helping to create a teaching and learning environments that stress:

- Intrinsic motivation—students being engaged because they want to be engaged.
- Learning to learn. Learning about one's strengths and weaknesses as a learner.
- Learning to deal with competition, winning, and losing.
- Becoming better at solving challenging problems and accomplishing challenging tasks.
- Transfer of learning from one game-playing environment to another, and from game-playing environments to other environments.
- Social interaction, if two or more are playing.

# Chapter 6. Virtual Aids to Learning and Teaching

> "Learning without thinking is labor lost; thinking without learning is dangerous." (Chinese Proverb.)
>
> "They know enough who know how to learn." (Henry B. Adams; American novelist, journalist, and historian; 1838–1918.)

In the context of computing, **virtual** means "not concrete or physical." For instance, a completely virtual university does not have actual buildings but instead holds classes over the Internet or via some other distance education method. There is a steadily growing collection of free virtual aids to learning and teaching available over the Web. This chapter provides some examples.

**The Web is a Virtual Library**

The invention of reading and writing eventually led to the development of libraries. Information could be collected in a central location, be used by a number of different people, and passed on from generation to generation. Probably the most important idea in problem solving in the sciences is building on the previous work of others. Reading and writing, books, physical libraries, and now computerized libraries have greatly aided and speeded research progress.

Your mental picture of a library is probably one of a free, open collection of resources that are easy to browse and to borrow. The picture in Figure 6.1 is representative of the *chained library* that was common until about 1800. Each book is attached to a chain that is long enough to move the book to a reading desk.

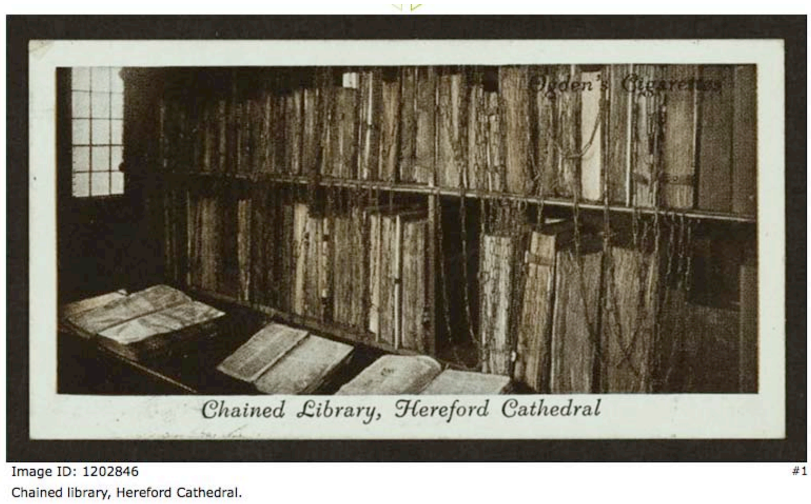



Figure 6.1. Chained library.

The chains eventually went away, and libraries grew in size. Beginning in 1883 and continuing over a period of 46 years, 2,509 Carnegie libraries were built in the United States and many others were built in other countries.

The US Library of Congress is a huge physical library of about 140 million items. Nowadays, a Web search engine searches through a virtual library that is at least 20 times as large—and that is only part of what is actually available on the Web.

Figure 6.2. US Library of Congress reading room.

You can think of the Web as a virtual library containing billions of items. In the "good old days," physical libraries made use of card catalogs to help people find the physical items that might interest them. Each item in the library was described on one or more cards. The collection of these alphabetized cards was housed in drawers and was called a card catalog.

Figure 6.3. Card catalog drawers.

The cards in a card catalog don't contain very much information about the actual physical items. You are familiar with the idea of a book such as the one you are now reading having a Table of Contents and an Index. As computers became available, people developed the idea of replacing a card catalog with a much more extensive indexing system. One approach was to have each academic discipline develop a list of descriptors (a thesaurus) that would be used to index each book and article published in the discipline. A researcher could then use the computer to simultaneously search many thousands of books and journals for the occurrence of a particular index term.

As computers became still more powerful, it was decided that a still better approach is to index all materials using the information-carrying words in the document. Words such as *like*, *the*, *and*, *or*, *what*, *it*, and so on are not used in creating the index. A computer can store a list of the excluded words and can index a book on its remaining words in seconds.

You may have noticed that search engines are very fast. A search engine is able to do searches so rapidly because much of the search work is done before you key in your search terms. Each search engine creates an index of all of the terms its programmers think a user might want to search on. Every document in the computer's storage system is then indexed under all of these terms, and the results are stored in the computer. This computerized index of all of the documents is used to process a user's search request and quickly find documents that might be of interest to the user.

When I do a Web search and get 200,000 hits in .19 seconds, this does not mean that the computer has searched through billions of documents in .19 seconds. Most of the work was done in advance of me making my request.

**Virtual Manipulatives**

Moyer et al. (2002) defines a virtual manipulative as "an interactive, Web-based visual representation of a dynamic object that presents opportunities for constructing mathematical knowledge." (p. 373).

Many virtual manipulatives are computer simulations of physical manipulatives. This situation provides a good example of the "computational" in sub disciplines such as computational math, computational biology, and computational physics. It also helps to illustrate computational thinking. (See http://iae-pedia.org/Computational_Thinking.) Computational thinking often involves developing computer models and simulations as an aid to representing and solving a problem. It involves thinking about the use of one's human brain and a computer brain in problem solving.

Math teachers have long make use of physical manipulatives such as those shown in Figure 6.4. In recent years, computerized versions of these types of manipulatives have become available.

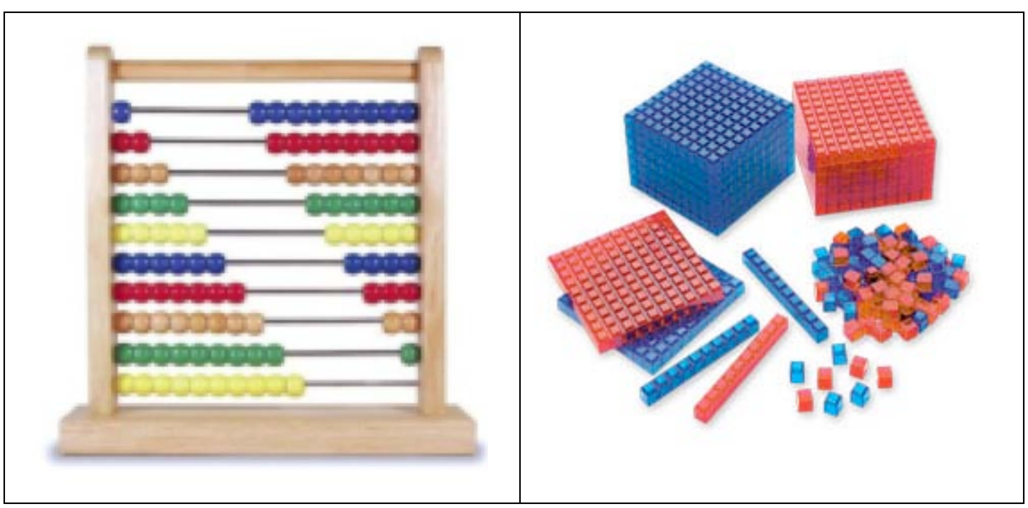


Figure 6.4. Physical (concrete) math manipulatives.

The underlying foundation for use of physical and virtual math manipulatives in summarized in the following quote from Hartshorn and Boren (1990):

> Experiential education is based on the idea that active involvement enhances students' learning. Applying this idea to mathematics is difficult, in part, because mathematics is so "abstract." One practical route for bringing experience to bear on students' mathematical understanding, however, is the use of manipulatives. Teachers in the primary grades have generally accepted the importance of manipulatives. Moreover, recent studies of students' learning of mathematical concepts and processes have created new interest in the use of manipulatives across all grades.

Math educators often make use of math manipulatives (both concrete and virtual) in helping their students to better understand mathematics. Such hands-on physical and virtual manipulatives are now a common component of elementary school math instruction.

The availability of both physical and virtual manipulative raises an interesting math education question. In terms of student learning, is one type of manipulative more effective than the other? It turns out that a relatively simple research question such as this is really not so simple. What do we mean by "more effective?"

For example, do we look at long-term retention and use of the learning, so that we have to study the students for five or ten years? Do we look at gains in physical manual dexterity and "mousing" dexterity? Do we look at the possible long-term values of learning to move computer representations of physical objects around on a computer screen?

Clements (1999) compares concrete and virtual manipulatives for use in math education and summarizes the research literature. Quoting from his paper:

> Students who use manipulatives in their mathematics classes usually outperform those who do not, although the benefits may be slight. This benefit holds across grade level, ability level, and topic, given that use of a manipulative "makes sense" for that topic. Manipulative use also increases scores on retention and problem solving tests. Attitudes toward mathematics are improved when students have instruction with concrete materials provided by teachers knowledgeable about their use.

Quoting The Math Forum @ Drexel (n.d.):

> Individual students learn in different ways. When manipulatives are used, the senses are brought into learning: students can touch and move objects to make visual representations of mathematical concepts. Manipulatives can be used to represent both numbers and operations on those numbers. In addition to meeting the needs of students who learn best in this way, manipulatives afford the teacher new ways of visiting a topic.

My Web search of *virtual math manipulative* returned about 74,000 hits. Many seem to be just glorified drill and practice programs that I do not consider to be math manipulatives. Here are a few that I consider to be math manipulatives.

- National Library of Virtual Manipulatives http://nlvm.usu.edu/en/nav/vlibrary.html. A free trial version can be down loaded. Notice that materials are available for the full grade range Pre-K to 12 of precollege math. The materials are available in English and Spanish. See http://nlvm.usu.edu/en/nav/grade_g_1.html for a large collection of Pre-K to 2 math manipulatives that can be used online. See http://nlvm.usu.edu/en/nav/grade_g_2.html for a large collection of grades 3-5 math manipulatives that can be used online.
- Tangrams. http://nlvm.usu.edu/en/nav/frames_asid_268_g_1_t_3.html?open=activities.
- Function Machines. See http://nlvm.usu.edu/en/nav/frames_asid_191_g_3_t_2.html and http://www.mathplayground.com/functionmachine.html.

**Virtual Field Trips**

There are many excellent education-oriented videos available on the Web. Viewing a wildlife safari video is a little bit like being on safari. You might think of it as a virtual safari or a virtual field trip.

Some science and technology museums have created videos of parts of their exhibits. The article Platoni (2008) *Internet Explorers: Virtual Field Trips Are More Than Just Money Savers* provides useful educational background on this topic.

Additional background information is available in the eSchool News *Gas prices fuel rise in virtual field trips* at http://www.eschoolnews.com/2008/07/14/gas-prices-fuel-rise-in-virtual-field-trips/. Quoting from this article:

> As schools grapple with budget cuts and rising fuel costs, many districts are finding it necessary to reduce or eliminate field trips, leaving students and teachers with a surprisingly attractive option—virtual field trips.
>
> Virtual field trips typically involve students using video conferencing software or using a simple web browser to visit an online destination, such as the web site of a national museum, that offers virtual tours through the facility and up-close, three-dimensional views of geological formations, art work, and so on. They are different from Webquests, which tend to be inquiry-based activities in which students use the internet to answer a set of questions.

Quoting from the Website http://webquest.org/index.php:

> A WebQuest is an inquiry-oriented lesson format in which most or all the information that learners work with comes from the web. The model was developed by Bernie Dodge at San Diego State University in February, 1995 with early input from SDSU/Pacific Bell Fellow Tom March, the Educational Technology staff at San Diego Unified School District, and waves of participants each summer at the Teach the Teachers Consortium.
>
> Since those beginning days, tens of thousands of teachers have embraced WebQuests as a way to make good use of the Internet while engaging their students in the kinds of thinking that the 21st century requires. The model has spread around the world, with special enthusiasm in Brazil, Spain, China, Australia and Holland.

Here are a few examples of virtual field trip sites arranged in alphabetical order:

- Bronx Zoo. View videos at http://www.bronxzoo.com/.
- Exploratorium Online Exhibits. See http://www.exploratorium.edu/exhibits/f_exhibits.html

<table>
<tr>
<td>The Exploratorium is one of the world's leading science and technology museums. Visit the Exploratorium Homepage at http://www.exploratorium.edu/. There you will find a variety of interactive educational materials. For example, test your reaction time in a virtual baseball environment at http://exploratorium.edu/baseball/.</td>
<td>
</td>
</tr>
</table>

- Koshland Science Museum of the National Academy of Science. See http://www.koshland-science-museum.org/exhibits/. Many excellent videos are available at this site.
- National Zoo. See http://nationalzoo.si.edu/default.cfm. The National Zoo, which belongs to the Smithsonian Institution, offers virtual tours of the zoo, including up-close views of zoo animals via a live webcam.
- Science Museum in the UK. See http://www.sciencemuseum.org.uk/. Quoting from the Website: "The Science Museum was founded in 1857 with objects shown at the Great Exhibition held in the Crystal Palace. Today the Museum is world renowned for its historic collections, awe-inspiring galleries and inspirational exhibitions."
- Smithsonian Institution. See http://2k.si.edu/. The Virtual Smithsonian.
- U.S. Department of the Interior's National Park Service. See http://www.windowsintowonderland.org/. The National Park Service offers many virtual field trips to well-known locations such as Death Valley National Park (Calif.), Grand Canyon National Park (Ariz.), and Alaska's Sitka National Historical Park.
- Virtual Museum of Science Virtualology. The site http://virtualology.com/virtualsciencecenter.com/ provides access to a pictures, video, text, and links to related materials.

**Virtual Astronomy**

You know about ground-mounted and orbiting telescopes. This section contains examples of virtual telescopes.

- Celestia. See http://www.shatters.net/celestia/ for this downloadable software. [Author's note: While this Website has opened correctly for me in the past, when it was rechecked on 11/1/2011 something seemed to be wrong with the site.] Quoting from the Website:

  > The free space simulation that lets you explore our universe in three dimensions. Celestia runs on Windows, Linux, and Mac OS X.
  >
  > Unlike most planetarium software, Celestia doesn't confine you to the surface of the Earth. You can travel throughout the solar system, to any of over 100,000 stars, or even beyond the galaxy.
  >
  > All movement in Celestia is seamless; the exponential zoom feature lets you explore space across a huge range of scales, from galaxy clusters down to spacecraft only a few meters across. A 'point-and-goto' interface makes it simple to navigate through the universe to the object you want to visit.

- Google Earth. See http://earth.google.com/. This is a downloadable system. However, be aware that in the instructions for doing the download, there is a box Google has checked for you. If you don't uncheck it, you will end up with Google Chrome as your default Web browser. (Google: Shame on you!) Quoting from the Website:

  > Google Earth lets you fly anywhere on Earth to view satellite imagery, maps, terrain, 3D buildings, from galaxies in outer space to the canyons of the ocean. You can explore rich geographical content, save your toured places, and share with others.

- Stellarium. See http://www.stellarium.org/. Stellarium is downloadable software that runs on Windows, Linux, and Mac OS X. Quoting from the Website:

  > Stellarium is a free open source planetarium for your computer. It shows a realistic sky in 3D, just like what you see with the naked eye, binoculars or a telescope.

**Virtual Calculators**

An inexpensive electronic calculator can be thought of as a scaled down, limited purpose computer. More sophisticated calculators can be thought of as computers in disguise.

Many computer systems and many pieces of computer application software contain built-in calculators. These are often called virtual calculators . A Web search of the term *virtual calculator* will return millions of hits.

Martindale's Calculators On-Line Center includes a list of more than 24,000 different virtual calculators.  See http://www.martindalecenter.com/Calculators.html. This is not a good site for finding a particular virtual calculator, such as a virtual HP-84. I include the site in this book just because it demonstrates that there are a great many different types of calculators, and that such calculators can be simulated by computer programs. Quoting 01/24/2011 from the Website:

> Currently the Calculators On-Line Center contains over 24,240 Calculators & Spreadsheets, over 4,070 Courses, Lectures, Manuals, Handbooks, & 1,000's of Movies, Videos, Simulations & Animations.

**Virtual Microscope**

This section provides access to a variety of virtual microscopes.

- Intel Microscope. See http://micro.magnet.fsu.edu/optics/intelplay/simulator/index.html. Quoting from the Website:

  > Welcome to our Java-powered Intel® Play™ QX3™ Computer Microscope simulator. This interactive Java tutorial explores how the hardware (QX3 microscope) and computer software work together to produce digital images. Instructions for operation of this tutorial are outlined below the applet window.

- Microscopy Pre-lab Activities from University of Delaware. See http://www.udel.edu/biology/ketcham/microscope/. Includes a 7-minute video introduction to a virtual microscope. Quoting from the Website:

  > Test your skill. Practice what you have learned. The virtual scope has all the same controls found on the real thing. Microscope controls:
  >
  > • turn knobs (click and hold on upper or lower portion of knob)
  >
  > • throw switches (click and drag)
  >
  > • turn dials (click and drag)
  >
  > • move levers (click and drag)
  >
  > • changes lenses (click and drag on objective housing)
  >
  > • select a specimen (click on a slide)
  >
  > • adjust oculars (in "through" view, with the light on, click and drag to move oculars closer or further apart)

- The Virtual Microscope. See http://virtual.itg.uiuc.edu/. The site includes downloadable software and a number of educational (training) videos. Quoting from the Website:

  > The Virtual Microscope is a NASA-funded project that provides simulated scientific instrumentation for students and researchers worldwide as part of NASA's Virtual Laboratory initiative. This site serves as home base for the Imaging Technology Group's contributions to that project—namely virtual microscopes and the multi-dimensional, high-resolution image datasets they view. Currently we provide 90 samples totaling over 62 gigapixels of image data. **The Virtual Microscope, which is available for free download supports functionality from electron, light, and scanning probe microscopes, datasets for these instruments, training materials to learn more about microscopy, and other related tools.**

- Virtual Electron Microscope . See http://school.discoveryeducation.com/lessonplans/activities/electronmicroscope/. Quoting from the Website:

  > Grade level 4–6 students will understand the following:
  >
  > 1. How microscopes have contributed to our knowledge of life science.
  >
  > 2. The basic differences between plant and animal cells.

**Virtual Manipulatives and Science Activities**

Many of us learn best in a "hands-on" environment in which we can do things and then see the results of what we are doing. Thus, for example, in science education it is now common to make use of a wide range of both physical and virtual experiments and explorations.

- Lunar Lander. See http://phet.colorado.edu/sims/lunar-lander/lunar-lander_en.html. Learn about thrust as you attempt to land on the moon.
- Interactive Simulations. See http://phet.colorado.edu/index.php. This excellent site at the University of Colorado at Bolder contains more than 80 interactive simulations. These vary in level from elementary school to college. For a specific example, see http://phet.colorado.edu/sims/projectile-motion/projectile-motion_en.html. Quoting from the Colorado Website:

  > PhET [Physics Education Technology] Interactive Simulations is an ongoing effort to provide an extensive suite of simulations to improve the way that physics, chemistry, biology, earth science and math are taught and learned. The simulations are interactive tools that enable students to make connections between real life phenomena and the underlying science that explains such phenomena. Our team of scientists, software engineers and science educators use a research-based approach–incorporating findings from prior research and our own testing–to create simulations that support student engagement with and understanding of scientific concepts.

- Projectile Motion. See http://phet.colorado.edu/sims/projectile-motion/projectile-motion_en.html. This is a fun and educational simulation. You get to select between a variety of projectiles: tank shell, golf ball, baseball, bowling ball, football, pumpkin, adult human, piano, and Buick car. You get to select the angle of inclination of the cannon, the initial velocity, and whether there is air resistance or you are firing the cannon in a vacuum.

  The simulation does not include instructions. You learn to use the simulator by trial, error, and thoughtful experimentation.

- National Council of Teachers of Mathematics. See http://illuminations.nctm.org/ActivitySearch.aspx. This site contains 107 activities organized by grade level. I explored quite a few of the activities. My impressions were that the simulations are useful in exploring math, but that the instructions are inadequate and the user interface is not as good as it should be. As an example of the latter, I expected to click on the word **Instructions** to get the instructions. Instead, I had to click on the plus sign in front of the word **Instructions**. After I read the instructions, I wanted to get back to the simulation. Trial and error eventually led me to click on the minus sign in from of the word **Instructions**.
- Roller Coaster. See http://www.learner.org/interactives/parkphysics/coaster/.

  > Try your hand at designing your own roller coaster. You will be building a conceptual coaster using the physics concepts that are used to design real coasters. You won't need to compute any formulas.
  >
  > You will decide the following—the height of the first hill, the shape of the first hill, the exit path, the height of the second hill, and the loop.

When you're done, your coaster will need to pass an inspection for both safety and fun.

**Final Remarks**

The previous chapter used the quote, “Play is a child’s job.” There is a nice article by that title at http://www.educationupdate.com/archives/2007/DEC/html/spec-play.html.

In this book I go one step further, emphasizing the theme of **play together, learn together.** Parents and other caregivers can create a child’s environment that contains a wide range of toys that are developmentally appropriate, that engage children, and that children can learn from. However, such an environment is substantially improved if parents and other care providers are actively engaged in a play together, learn together environment.

Computer technology has opened up a new vista of play together, learn together opportunities. This chapter provides a number of examples of virtual edutainment that may well be new to adults and that provide excellent opportunities for children and adults to play together, learn together.

# Chapter 7. Digital Photography, Videography, and Graphics

> I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks. (Thomas A. Edison; American inventor and businessman; 1847–1931; quotation from 1922.)
>
> "The mind is not a vessel to be filled but a fire to be kindled." (Plutarch; Roman historian; 46 AD–120 AD.)

Computer technology has greatly changed the fields of photography and videography. When I was a child, cameras used film that was developed using chemical processes. The film, the developing, and the printmaking were expensive. Movie making didn't involve making prints, but movie cameras and projectors were expensive and complex, and editing was a complex and time-consuming process.

Now, all of that has changed. Preschool children use digital cameras. Digital cameras are built into cell phones. There are "toy" cameras, as well as "toy" microscopes, and binoculars with built-in digital cameras. Instant gratification! Moreover, digital cameras provide instant feedback, which is a great aid to learning.

Quoting from http://en.wikipedia.org/wiki/Videography:

> Videography refers to the process of capturing moving images on electronic media (e.g., videotape, hard disk, or solid state storage, streaming media). The term includes methods of electronic production and post production. It is the equivalent of cinematography, but with images recorded on electronic media instead of film stock.

Digital photography and videography, computer graphics and computer animation, computer storage of images, computer editing of images, computer printing and projecting of images, and other computer-based aids to creating and editing graphics have become routine tools of hundreds of millions of people.

The last section of this chapter provides links to free, powerful graphics-oriented software packages. I am amazed at the quality and quantity of graphics software that is being made available free.

**Virtual Digital Photography**

You might want to play with some of the free educational simulators before continuing with the history and other sections of this chapter. One way to increase your skills in photography is to make use of instructional materials based on virtual photography. There are some great (and free) simulators available on the Web.

- SimCam. See http://www.photonhead.com/simcam/. Quoting from the site:

> The SimCam is an online camera simulator designed to teach basic photographic principles. Whether you are interested in film or digital photography, the concepts are the same. This site allows you to explore changes in shutter and aperture, film speed, and camera shake. See Figure 7.1.

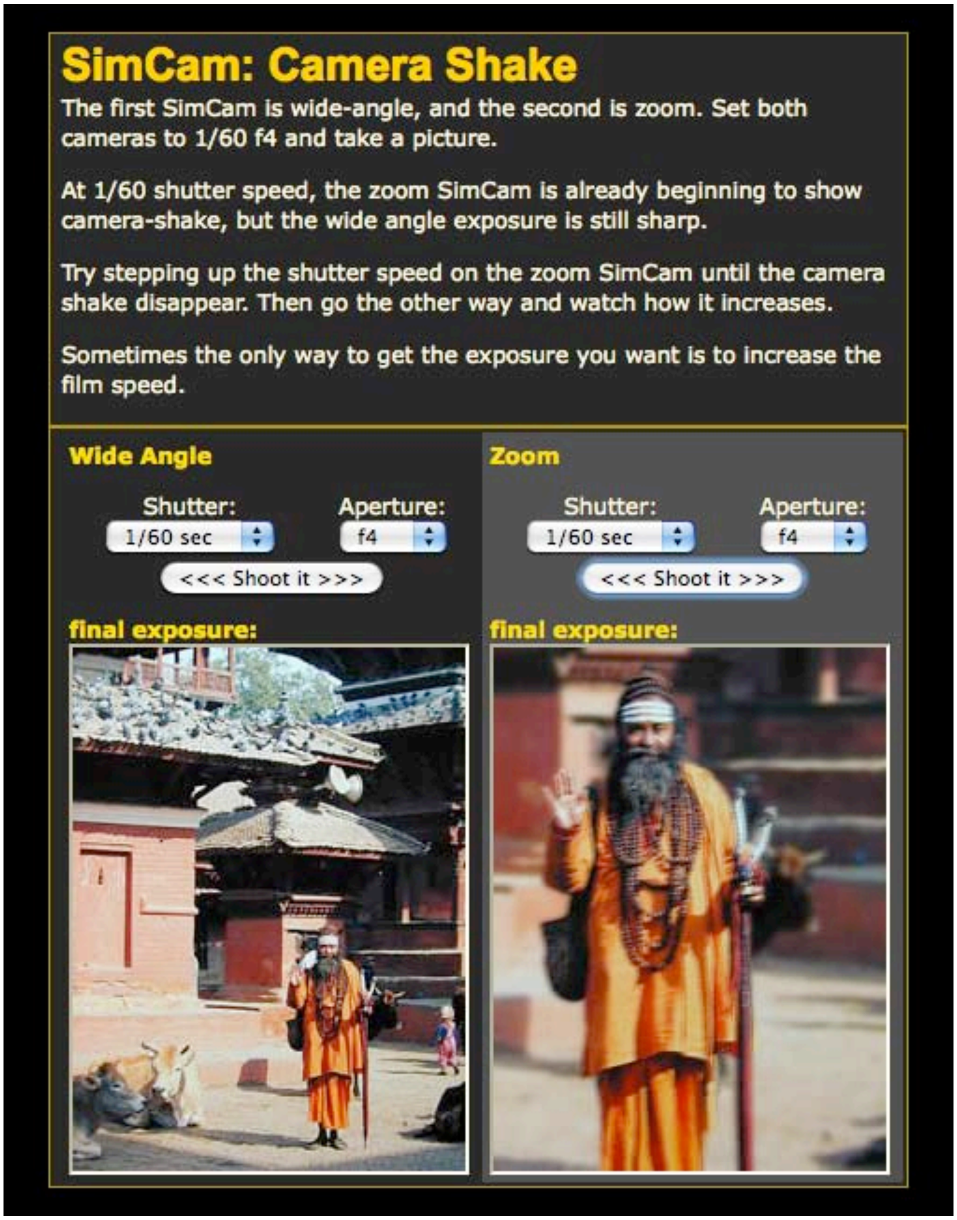



Figure 7.1. A camera shake example from the SimCam site.

- Camera Simulator. See http://www.kamerasimulator.se/eng/?page_id=2. Quoting from the Website:

> With this camera simulator you can try different aperture and shutters to affect a photos light, depth and motion blur. Try also to change the camera's light

sensitivity by manipulating its ISO value. A higher ISO value gives higher sensitivity to light, which allows faster shutter speeds. The disadvantage is that the picture is more grainy.

- Infoborder Online Digital Camera Simulator. See http://www.infoborder.com/News/2009/May/simulator.php. Quoting from the site:

> Camera Simulator 1.0 is the first online simulator (19 of May 2009) which presents some important options of a particular camera. User can see the camera during it's work. User can make some pictures from different point of view in different environment. User can try zooming function. It is possible to objects come closer of course as much as the camera's optical lens support. One of the key functions of the digital imaging is the auto focusing systems. User also can see how auto focus systems work, how picture on the display after zooming get sharper.

**Brief History**

The technology of photography and videography has changed immensely since the early days of their beginning successes. Quoting from the History of Photography http://en.wikipedia.org/wiki/History_of_photography:

> The word photography derives from the Greek words 'photos'—meaning light and 'graphein'—to draw. The word was popularized by Sir John Herschel in 1839. Modern photography began in the 1820s with the first permanent photographs.

First known photograph, taken by Joseph Nicéphore Niépce in 1825 by the heliograph process. The image is of a 17th Century Flemish engraving showing a man leading a horse.

Figure 7.2. A photograph taken in 1825.

One way to look at the fields of photography and videography is to study how steady improvements in the underlying technology reduced the technical demands on the user. Quoting from the Wikipedia http://en.wikipedia.org/wiki/Brownie_%28camera%29:

> Brownie was the name of a long-running and extremely popular series of simple and inexpensive cameras made by Eastman Kodak. The Brownie popularized

> low-cost photography and introduced the concept of the snapshot. The first Brownie, introduced in February 1900, was a very basic cardboard box camera with a simple meniscus lens that took 2¼-inch square pictures on 117 roll film. With its simple controls and initial price of $1, it was intended to be a camera that anyone could afford and use, leading to the popular slogan, "You push the button, we do the rest."

Motion picture cameras, film, and projectors were developed in the 1880s. Eventually the technology became suitable for use by the general public. Quoting from the Wikipedia http://en.wikipedia.org/wiki/Movie_camera:

> Movie cameras were available before World War II often using the 9.5 mm film format. The use of movie cameras had an upsurge in popularity in the immediate post-war period giving rise to the creation of home movies. Compared to the pre-war models, these cameras were small, light, fairly sophisticated and affordable. While a basic model might have a single fixed aperture/focus lens, a better version might have three or four lenses of differing apertures and focal lengths on a rotating turret.

You may enjoy a two-minute television broadcast that was made in 1936 and recorded on film as a motion picture. See http://misteridigital.wordpress.com/2007/09/24/the-history-of-video-tape-and-camera/. This illustrates that television existed well before the start of World War II. A major problem was the need for a better medium for recording and editing TV productions.

The development of a video tape recorder (VTR) in the early 1950s made possible the storage of images on magnetic tape. Ampex sold the first VTR for $50,000 in 1956. The first VCassetteR or VCR were sold by Sony in 1971—a combination of a TV set and a VCR cost $1,395. This is somewhat over $7,000 in today's dollars.

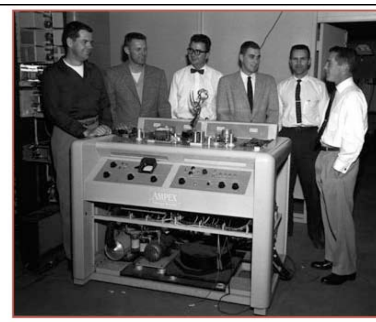


Figure 7.3. Ampex VRX-1000—The first commercial Videotape Recorder.

Early video recordings onto magnetic tape were done using an analog (as opposed to a digital) process. However, at the same time, the computer industry was developing digital storage on magnetic tape. Quoting from http://www.columbia.edu/acis/history/701-tape.html:

> In 1949, IBM began to plan for a new storage and i/o medium to take the place of punched cards. The new medium would be more compact, faster, cheaper, and reusable. Magnetic tape technology had been used for audio recording and playback since World War II, and it was adapted for computer use—initially in a prototype called the Tape Processing Machine (TPM), 1950-51.

Notice the close together dates of the development of digital storage on magnetic tape and the first VTR. Perhaps you have heard the statement, "and the rest is history." Digital technology has improved at a rapid rate and the cost of computers to process digital information has declined very rapidly. Thus, you can now buy a cell telephone that includes a built-in color digital still and video camera, recorder, and playback device.

**Learning to Use the Digital Photography and Videography Tools**

The low cost of digital still and video cameras, storage devices, and editing facilities mean that even young children can learn to use these tools.

You realize, of course, that there is a huge amount of learning required to become a "professional level" photographer or videographer. A person can learn through trial and error, through making use of instructional materials available in books, magazines, and on the Web, through taking courses, and so on. There is a substantial amount of free instructional material available on the Web. (Google: *free lessons digital photography*.) Here are some examples that appealed to me.

- Adobe Digital School Collection Teacher Resources. See http://www.adobe.com/education/instruction/adsc/. To access the materials, you have to create a free Adobe account that includes name and password. Quoting from the Website:

  > Technology integration is a key mechanism for augmenting classroom instruction while helping students learn lifelong communication skills for the digital age. Use these lesson plans—which incorporate technology education through the use of Adobe® Digital School Collection software—when teaching about math and science, language arts, history/social studies, and visual and performing arts.

- Digital Photography Tutorials. See http://www.cambridgeincolour.com/tutorials.htm. Quoting from the Website:

  > Learn how to take and edit digital photographs using visual tutorials that emphasize concept over procedure, independent of specific digital camera or lens. Topics range from basic camera tips to advanced techniques.

- Geoff Lawrence.com. Quoting from http://www.geofflawrence.com/

  > This free digital photography tutorial site is designed to show you how to take better photographs. With a little knowledge and thought before taking a photo, you can turn a 'snap' into a picture that will delight your viewers rather than bore the pants off them.

- Photography Course. Quoting from http://photographycourse.net/

  > This Free Photography Course offers free photography lessons ranging from the basics of film, optics, cameras and light to web page layout and digital photography. FIRST, a Basic Primer, an introductory textbook lesson covering film, optics, and flash for those who have never studied the art and science of photography. Back To Basics. You MUST have this solid foundation, it won't take that long! You don't need to memorize all of this information, but it is essential that you are aware of these important fundamentals.

- ShortCourses.com: The On-line Library of Digital Photography. See http://www.shortcourses.com/.

  > The site provides free access to a number of instructional materials. Also, you may enjoy experimenting with one of the animations in a lesson on Understanding

Exposure at http://www.photocourse.com/itext/exposure/. You can play with a picture, changing the amount of exposure.

- Videomaker. See http://www.videomaker.com/learn/. Quoting from the Website:

  > Learn Videography, video editing, and lighting. A large part of our mission is to provide you with the information you need to improve your skills in video production. And after 20 years of publishing, we have a lot to offer. This is the place to start for videography training. Here you will find hundreds of articles about audio/video software, video editing hardware, and help with video lighting techniques. Let the learning begin!

**Creating Computer Graphics**

Good quality graphics software packages are available free on the Web. Here are a few examples:

- Art Pad. See http://artpad.art.com/artpad/painter/. Provides a pallet of colors and a small paint brush for doing the types of drawing and scribbling that one often sees done by children just learning how to use coloring crayons and color pencils. It has additional features that will interest somewhat older children.
- Art Rage. See http://www.artrage.com/artragedown.html for a free Starter Edition for Mac and Windows. Quoting from the Website:

  > Art Rage is a great little program that enables you and the students to make your own virtual artwork. There is a 'cut down' version of the program that you can use for free which is very good. [Author's note: Remember, full versions of the software are not free.]

- Beautiful Dorena. See http://www.dryreading.com/dorena/index.html. Macintosh only. This free software was developed by Craig Hickman who developed Kid Pix much earlier in his career.
- Blender. See http://iae-pedia.org/Blender. This is a professional-level downloadable tool . Quoting from the Website:

  > Blender is a free open source 3D content creation suite, available for all major operating systems. With Blender you can:
  >
  > 1. Make 3D models.
  >
  > 2. Produce animations.
  >
  > 3. Create physics simulations.
  >
  > 4. Develop interactive 3D content and games.
  >
  > 5. Edit video and image sequences (slideshows).

- Freebytes Guide to Free Graphics software. See http://www.freebyte.com/graphicprograms/.

  Provides brief description and links to a lot of free graphics software.

- Kid Pix is a commercial graphics product that is available both for Mac and Windows. It is widely used in elementary schools as well in children's homes. A very inexpensive home edition is available at http://www.k12software.com/view_details.php?PHPSESSID=bbc324dc0b86e63160142d09da2c7dac&ID=2744.

- Open Source Software Packages. See http://iae-pedia.org/Open_Source_Software_Packages

  This site includes brief descriptions and links for 10 different graphics packages.

- Picasa for Mac and Windows. See http://picasa.google.com/mac/. This takes you to the Mac download site. See the right end of the menu at the bottom of the page for a PC download. Quoting from the Website:

  Picasa is free photo editing software from Google that makes your pictures look great. Sharing your best photos with friends and family is as easy as pressing a button!

- Stykz. See http://www.stykz.net/Home.html. Stykz is a free downloadable multi-platform stick figure animation program. Quoting from the Website:

  Stykz is frame-based, letting you to work on individual frames of your animation; onionskinning lets you to see what was in the previous frame so you can make adjustments accordingly.

  Figures can be rotated, scaled, flipped, duplicated, colorized, and relayered. Select multiple figures by shift-clicking or creating a selection rectangle and align them using the alignment options in the Property palette.

- Sumo Paint. See http://www.sumopaint.com/app/. A free online comprehensive pixel-level "paint" program.

- The Color Wizard for Windows. Free Children's Coloring Book. Quoting from the Website http://graphicssoft.about.com/gi/o.htm?zi=1/XJ/Ya&zTi=1&sdn=graphicssoft&cdn=compute&tm=3&f=00&tt=14&bt=1&bts=1&zu=http%3A//www.imagisoft.com/wizard.htm:

  *The Color Wizard* teaches children how to use light, shadows, reflections, texture, perspective, and color, to create their own masterpiece. It is much more than an ordinary coloring book! Paint with over 700 different colors. Apply highlights and shadows. Press the Artist Icon for art lessons, or the Book Icon to read the story behind the picture you are coloring.

- Tux Paint. See http://tuxpaint.org/download/. Tux Paint is a free, downloadable award-winning drawing program for children ages 3 to 12 (for example, preschool and K-6). It combines an easy-to-use interface, fun sound effects, and an encouraging cartoon mascot who guides children as they use the program. Kids are presented with a blank canvas and a variety of drawing tools to help them be creative.

**Final Remarks**

Digital photography, digital video, and computer graphics provide an excellent example of powerful uses of Information and Communication Technology in informal and formal education. Children and adults of all ages can learn to use these tools.

There is a wide range of free computer tools in this area. They range from tools for the very young novice to professional level tools for experts. These tools have greatly changed the worlds of photography, filmmaking, animation, and commercial art.

Such tools empower children. They allow relatively young children to do things that used to cost a lot of money and could only be done by adults. The idea of using computers to empower students is a very important aspect of changes that can be made in education via appropriate access to and use of computers. See http://iae-pedia.org/Empowering_Learners_and_Teachers.

# Chapter 8. Educational Videos

> Books will soon be obsolete in the schools. ... Scholars will soon be able to instruct through the eye. It is possible to touch every branch of human knowledge with the motion picture. (Thomas A. Edison; American inventor and businessman; 1847–1931; quotation from 1913.)
>
> "The most dangerous experiment we can conduct with our children is to keep schooling the same at a time when every other aspect of our society is dramatically changing." (Chris Dede, written statement to the PCAST panel, 1997.)

A huge and steadily growing collection of videos is available on the Web. They vary tremendously in quality and in educational value. This chapter provides links to some free educational videos and video collections.

**Free Educational Videos**

See http://www.watchknow.org/Default.aspx. This is a 22,000-item collection of educational videos for children ages 3 to 18. As of 12/17/2010 the list included Computers and Technology (828 videos), Mathematics (2,816 videos), Science (4,522 videos), and Hobbies and Crafts (365 videos). Some of these materials are videos, some are virtual manipulatives, some are interactive tests.

You may find that these videos are slow to load. The videos vary tremendously in educational quality and value. For example, suppose you want to learn a little bit about drawing female and male faces. Then two good examples are available at http://www.watchknow.org/Video.aspx?VideoID=14460 (9:36) and http://www.watchknow.org/Video.aspx?VideoID=14459 (10:22).

These videos show how to draw **manga** faces. The word 'manga' will probably enhance the interest of kids, especially boys. See http://en.wikipedia.org/wiki/Manga.

Once I stumbled on these nice videos, I did a Web search on *drawing faces.* I got lots of hits! Part of a good education is learning to describe the information you want to retrieve in a manner that leads to a list of relevant hits on the web.

**STEM Videos**

- Biology. Fantastic voyage inside a cell. See http://www.ted.com/talks/view/id/147.

  This 9:49 video presents the work of Mr. Bolinsky's group's work on doing scientific images and animation. It includes a 3 minutes of a longer video showing the vast and complex inner workings of a cell responding to a special situation.

  See also Biovisions at Harvard, available at http://multimedia.mcb.harvard.edu/. See the menu on the left side of the screen.

Free biology videos are available from The National Academics Press. Use the link given below to access a free online copy of the 2009 book, *A New Biology for the 21st Century: Ensuring the United States Leads the Coming Biology Revolution* and a short video about the book. The page containing the video provides links to a number of biology and other science videos.

http://www.nap.edu/catalog.php?record_id=12764&utm_medium=etmail&utm_source=National%20Academies%20Press&utm_campaign=NAP+mail+new+11.03.09&utm_content=web&utm_term

- Brain Science.
  - Information Age Education: http://iae-pedia.org/No_Cost_Educational_Videos#Brain_Science.
  - Markram, Henry (2009). *Henry Markham builds a brain in a supercomputer.* http://www.ted.com/talks/henry_markram_supercomputing_the_brain_s_secrets.html (14.51).A video about modeling the human brain.
  - Neuroscience for Kids. An excellent University of Washington site, at http://faculty.washington.edu/chudler/neurok.html.
  - Oregon Health and Science University: http://www.ohsu.edu/xd/education/schools/research-institutes/brain-institute/brain-awareness/index.cfm.
- Computer Science and Computer History. See http://iae-pedia.org/No_Cost_Educational_Videos#Computer_Science_and_Computer_History. Here are three good examples of these materials:
  - The Computer History Museum in Mountain View, California provides a considerable and growing collection of videos. An outstanding example is a (5:47) video titled Charles Babbage and his Difference Engine #3, available at http://www.youtube.com/watch?v=KBuJqUfO4-w&feature=channel_page. Ava Lovelace played a major role in the early history of computers and is considered to be the first computer programmer. See a (5:37) video about her at http://www.youtube.com/watch?v=g0Kq85fQLWE, and read about her at http://www.well.com/~adatoole/bio.htm.
  - Computer Science for Children (50 minutes). http://www.youtube.com/watch?v=j28hg8XHugU&NR=1. This is a live presentation before an audience of middle school students.
  - Nicholas Negroponte: One laptop per child. http://www.ted.com/index.php/talks/nicholas_negroponte_on_one_laptop_per_child_two_years_on.html (16.36). A pioneer in the field of computer-aided design, Negroponte initially gained great success in founding and directing MIT's Media Lab, which helped drive the multimedia revolution and now houses more than 500 researchers and staff. Learn more about Negroponte and his laptop project at at http://iae-pedia.org/Nicholas_Negroponte.
- Math Education Videos. See http://iae-pedia.org/Math_Education_Free_Videos.

- Science and Technology. See http://iae-pedia.org/No_Cost_Educational_Videos#Science_and_Technology.
- Soap and Other Bubbles. See http://iae-pedia.org/No_Cost_Educational_Videos#Soap_and_Other_Bubbles.
- Teachers' Domain. See http://www.teachersdomain.org/about.html. Quoting from the Website:

  > Teachers' Domain is an online library of more than 1,000 free media resources from the best in public television. These classroom resources, featuring media from NOVA, Frontline, Design Squad, American Experience, and other public broadcasting and content partners are easy to use and correlate to state and national standards.
  >
  > Teachers' Domain resources include video and audio segments, Flash interactives, images, documents, lesson plans for teachers, and student-oriented activities. Once you register, you can personalize the site using "My Folders" and "My Groups" to save your favorite resources into a folder and share them with your colleagues or students.
  >
  > Teachers' Domain strives to strengthen teacher knowledge by providing innovative teaching methods that incorporate technology in the classroom and inspire students to learn. [Author's note. This last sentence suggests to me the idea of play together, learn together. Video materials suitable for use with students often help to improve a teacher's knowledge and skills.]

- What is a Wiki? See http://www.commoncraft.com/video-wikis-plain-english (3:34).

**Technology, Entertainment, Design Videos**

Quoting from the Website http://www.ted.com/pages/view/id/5:

> TED is a small nonprofit devoted to Ideas Worth Spreading. It started out (in 1984) as a conference bringing together people from three worlds: **Technology, Entertainment, Design.** Since then its scope has become ever broader. Along with the annual TED Conference in Long Beach, California, and the TEDGlobal conference in Oxford UK, TED includes the award-winning TEDTalks video site, the Open Translation Program, the new TEDx community program, this year's TEDIndia Conference and the annual TED Prize.

As of 10/26/2011 Website http://www.ted.com/talks had 1050 educational and entertaining videos. Most are about 19 minutes in length, but some are quite a bit shorter. All feature people telling their stories to the attendees at the annual TED Global Conference. These presentations are of high quality and probably most suitable for high school students and adults.

Here are some of the education-oriented TED videos that I found to be particularly interesting. Remember, these are aimed at an adult audience. Many are suitable for secondary school students.

- Armstrong, Rachel (2009). *Architecture that repairs itself?* Retrieved 10/26/2011 from http://www.ted.com/talks/rachel_armstrong_architecture_that_repairs_itself.html (7:32).

> Venice, Italy is sinking. To save it, Rachel Armstrong says we need to outgrow architecture made of inert materials and, well, make architecture that grows itself. She proposes a not-quite-alive material that does its own repairs and sequesters carbon, too.

- Bezos, Jeff (2003). *Jeff Bezos on the next web innovation.* Retrieved 10/26/2011 from http://www.ted.com/index.php/talks/jeff_bezos_on_the_next_web_innovation.html (17:14). Quoting from the Website:

> The dot-com boom and bust is often compared to the Gold Rush. But Amazon.com founder Jeff Bezos says it's more like the early days of the electric industry.
>
> About Jeff Bezos. As founder and CEO of Amazon.com, Jeff Bezos defined online shopping and rewrote the rules of commerce, ushering in a new era in business. Time magazine named him Man of the Year in 1999.

- Blackmore, Susan (2008). Memes and "temes" (techno memes). Retrieved 10/26/2011 from http://www.ted.com/index.php/talks/susan_blackmore_on_memes_and_temes.html (19:31).

> Susan Blackmore studies memes: ideas that replicate themselves from brain to brain like a virus. She makes a bold new argument: Humanity has spawned a new kind of meme, the teme, which spreads itself via technology.

- Debevec, Paul (2009). *Paul Debevec animates a photo-real digital face.* Retrieved 10/26/2011 from http://www.ted.com/talks/paul_debevec_animates_a_photo_real_digital_face.html (6:06).

> Paul Debevec's digital inventions have powered the breathtaking visual effects in films like The Matrix, Superman Returns, King Kong and The Curious Case of Benjamin Button.

- Goldin, Ian (2009). *Navigating our global future.* Retrieved 10/26/20101 from http://www.ted.com/talks/ian_goldin_navigating_our_global_future.html 97:07).

> As globalization and technological advances bring us hurtling towards a new integrated future, Ian Goldin warns that not all people may benefit equally. But, he says, if we can recognize this danger, we might yet realize the possibility of improved life for everyone.

- Markram, Henry (2009). *Henry Markham builds a brain in a supercomputer.* Retrieved 10/26/2011 from http://www.ted.com/talks/henry_markram_supercomputing_the_brain_s_secrets.html (14:51).

> Henry Markram says the mysteries of the mind can be solved—soon. Mental illness, memory, perception: they're made of neurons and electric signals, and he plans to find them with a supercomputer that models all the brain's 100,000,000,000,000 synapses.

- Robinson, Ken (2006). *Ken Robinson says schools kill creativity.* Retrieved 10/26/2011 from http://www.ted.com/index.php/talks/ken_robinson_says_schools_kill_creativity.html (19:29) Quoting from the Website:

Sir Ken Robinson makes an entertaining and profoundly moving case for creating an education system that nurtures (rather than undermines) creativity.

- Rosling, Hans (2007). New insights on poverty and life around the world. Retrieved 10/26/2011 from http://www.ted.com/index.php/talks/view/id/140 (19:01).

  Mr. Rosling has spent a lot of time in Africa, and he has a lot of objections to the idea of "developed and undeveloped world", instead just saying folks are just at different stages because they've started at different places. He makes an interesting point that Africa has moved incredibly rapidly from a very "pre medieval" level of development to where maybe Europe was in the early part of the 20th century in 50 years.

  This talk presents a modern, computer-based way of viewing complex statistical data. The representations are far removed from the traditional graphs that most people use.

- Russell, Alan (2006). Why can't we grow new body parts? Retrieved 10/26/2011 from http://www.ted.com/talks/view/id/142 (19:29).

  Alan Russell studies regenerative medicine–a breakthrough way of thinking about disease and injury, using a process that can signal the body to rebuild itself. The video shows some of the latest developments in regenerative medicine, and presents a vision of a future that is much different than today's medicine.

  One of the education ideas that Russell mentions is the need for interdisciplinary education and the need for teams of people from different disciplines to learn to work together on difficult problems. This is an important aspect of an Information Age education.

**Miscellaneous Topics**

- Annenberg Media. Retrieved 10/26/2011 from http://www.learner.org/resources/browse.html.

- Diet Coke and Mentos Candy. See the geyser experiment (Retrieved 110/26/2011) at http://www.nsf.gov/news/news_videos.jsp?org=NSF&cntn_id=111567&media_id=62417 (4:59). Also see (Retrieved 10/26/2011) http://www.stevespanglerscience.com/experiment/00000109.

- First Tech Support Guy. See (Retrieved 1/8/2011) http://www.youtube.com/watch?v=9J9-Qr7oz-4. This is a 2:37 video in Norwegian, with English subtitles. It is a parody on technology support, based on the tech support needed to deal with a book.

- Humorous five-minute video of Father Guido Sarducci. (Retrieved 10/26/2011). http://www.youtube.com/watch?v=kO8x8eoU3L4. The first part of the transcript is given below.

  I find that education, it don't matter where you go to school, Italy, America, Brazil, all are the same—it's all this memorization and it don't matter how long you can remember anything just so you can parrot it back for the tests. I got this idea for a school I would like to start, something called the Five Minute University. The idea is that in five minutes you learn what the average college graduate remembers five years after he or she is out of school. It would cost like twenty dollars. That might seem like a lot of money, twenty dollars just for five minutes, but that's for like tuition, cap and gown rental, graduation picture, snacks, everything.

- Jumping Rope. See (Retrieved 10/26/2011) http://www.kingsfirecrackers.com/ (6:24).

  One of my friends asked me what jumping rope had to do with STEM. Here are two quick answers. First, physical activity is good for the brain. See *Research on how exercise improves brain functioning* at http://i-a-e.org/myblog-admin/research-on-how-exercise-improves-brain-functioning.html. Second, think about the physics of jumping rope.

- Metamorphosis of a Cube. See (Retrieved 10/26/2011) http://erikdemaine.org/metamorphosis/SoCG99_final/Apr13_halfsize_cmp.mpg (On my computer, this loads a great deal faster if I copy and paste the address into a browser.)

- National Geographic..http://video.nationalgeographic.com/video/index.html.

  See hundreds of free, high quality educational and entertaining videos.

- School Video News. See http://www.school-video-news.com/. Your online eMagazine for K-12 TV/Video Production.

- Science Channel; How Its Made. See http://science.discovery.com/fansites/howitsmade/episode-guide/episode-guide.html. Provides free access to a large collection of videos.

- Steve Spangler Science. See http://www.stevespanglerscience.com/who-is-steve-spangler.html for information about Steve Spangler. On the right side of the page is a list, "Top 10 Experiments." Each is accompanied by one or more short videos.

- World's largest model train exhibit. (5 minute video.) See http://dvice.com/archives/2009/03/astonishing_mos.php.

- Yo-yo. See http://www.begin2spin.com/index.php and http://entertainment.howstuffworks.com/easy-yo-yo-tricks.htm. How doe a yo-yo fit in with STEM education? Perhaps you have heard of gyroscopes and gryo-stabilization. *How to make a boomerang* at http://www2.eng.cam.ac.uk/~hemh/boomeranghandout2006.pdf is a good play together, learn together activity.

**Final Remarks**

The 1913 forecast by Thomas Edison given at the beginning of this chapter has not yet come to pass. However, the Web is a valuable and growing warehouse of educational videos. These are playing a steadily increasing role in informal and formal education.

The next chapter discusses distance education. Virtual manipulatives and online video are contributing greatly to this field.

# Chapter 9. Distance Education

"The medium is the message." (Marshall McLuhan; Canadian educator, philosopher, scholar, and communication theorist; 1911–1980.)

"An educated mind is, as it were, is composed of all the minds of preceding ages." (Bernard Le Bovier Fontenelle; mathematical historian; 1657-1757.)

*Distance education*—often referred to as distance learning or online education— is now a routine component of informal and formal education systems in the United States and in other parts of the world. Opportunities exist to get K-12 education, community college education, technical school education, bachelor's degrees, master's degrees and doctorates through distance learning. Students of all ages are taking advantage of these opportunities.

In addition, a great many courses are available free to those who do not need credit and the help from online instructors.

Whenever you engage in the use of any electronic storage or communication device (including all telecommunication systems, email, and the Web) you are engaged in a type of distance learning. All Computer-Assisted Learning can be considered as a type of distance learning. Whether you are reading this from a hard copy printed document, directly from a CD-ROM or DVD-ROM, or from an electronic copy that has been loaded onto a computer, you are engaged in distance learning.

The 23-page booklet (Watson et al., 2010) may be useful to you in learning more about distance education.

I like to put a distance education spin on Marshall McLuhan's statement that "the medium is the message." Today's distance education is highly dependent on computers. A student engaged in using a computer for distance education has access to a computer system that can be used for a wide variety of purposes. As stressed in this book, one of the uses is representing and solving the problems in a discipline. A modern distance education course carefully integrates the use of computers both as part of the content of the course and as an aid to using the content.

## Some Brain Theory

Information from outside your body comes into your body through senses such as sight, hearing, touch, taste, and smell. The sense organs filter the incoming information, passing some of it into one's brain and ignoring most of what is sensed.

The brain processes information it receives. Most of this processing takes place at a subconscious level. However, you can focus your attention on incoming information and combine it with stored knowledge in your brain. Through this type of conscious though and focused attention, you can direct your subconscious to carry out various information retrieval, processing, and storage tasks. This overall process is how problems are solved, tasks are accomplished, and learning occurs.

This is a highly simplified picture of what goes on. But, think about it in terms of a child listening to a parent or teacher, a child reading a book or viewing a video, a child playing with a toy or a friend, and so on. The child is receiving and processing information that comes from outside his or her brain. Thus, all of these "traditional" forms of informal and formal learning are actually forms of distance learning or distance education. We all engage in distance education during all of our waking moments!

We also all engage in non-distance education. For example, think of person who is immersed in a sensory deprivation tank. Even though there is no sensory information coming in, the person can still think. This thinking can direct the brains attention to information that is stored in the brain, and it can result in problems being solved and new information being stored in the brain.

Here is a summary of this somewhat simplified model of learning:

1. All of the learning you do occurs inside your brain and the rest of your body. The learning process is actually occurring at a completely subconscious level—learning involves biological and chemical changes at the cellular level in your brain and in the rest of your body.
2. The data that is processed in a manner that leads to learning can come from internal and external sources. In both cases, the learning that occurs is based on (constructed on) what has been learned in the past. This idea is the foundation of the learning theory called constructivism.
3. Paying conscious, alert attention to the topics you are trying to learn, reflecting on them, and doing metacognition on them can help direct the learning processes. The details of how a brain actually learns are still at the far frontiers of research in cognitive neuroscience.

**Feedback in Learning**

Feedback is essential to learning. Feedback can come from internal and external sources. Here is an internal source feedback example:

> I am hungry as I wander through the woods, doing my "hunter-gatherer" thing. I see some berries that are visually appealing. I cautiously taste and eat one. My taste system and stomach immediately rejects the berry. I gag, and I feel ill. In this one trial learning event I learn to never eat this type of berry again.
>
> Suppose, however, the berry tastes good and my stomach does not reject it. I eat quite a few, and then continue with my hunting and gathering. I eat a variety of other roots, fruits, and so on. Later in the day I grow ill, throw up, and nearly pass out. The cause or causes may be quite complex. For example, two of the things that I ate may have reacted with each other and produced a poison.

In the second example, my internal feedback mechanism is not up to the learning task at hand. However, a more learned person (such as one of my parents) might know immediately what the problem is and teach me what combination of potential foods to avoid. This is an example of feedback from an external source.

For a more academic example, suppose that you are writing an essay as a school writing assignment. Your brain is directing the writing process, including handing details of forming letters and words on a page or computer screen. From time to time you pause to think about what you have just written. Your brain provides you feedback—giving you its opinion of the quality of the work and changes that might be needed. All of this is an internal feedback process. A major goal in both informal and formal education is to help a student get better at self-assessment and self-generated feedback.

Now, suppose that you are writing using a word processor with a spelling checker and a grammar checker. Then the computer system is providing you with some external feedback.

After your essay is completed, you may have a colleague read it and provide feedback. Your teacher will read the essay and provide feedback. The feedback provided by a colleague or the teacher will likely be of a far different type than that provided by a computer. It is feedback coming from a human being who understands human-to-human communication, understands the meanings that are being communicated, and understands subtle nuances and emotions that are inherent to the communication.

In summary, as we think about learning from external and internal sources of information, we also need to think about feedback from external and internal sources. A good education helps develop one's knowledge and skills about the eternal and internal aspects of learning.

Think about this as you help your children in making use of informal and formal educational opportunities.

**The Medium is the Message**

Consider Marshall McLuhan's statement, "The medium is the message." In terms of distance education, the medium is the overall area we call Information and Communication Technology. This includes virtual libraries, such as the Web. It includes communication among people and between people and machines. It includes artificially intelligent computer systems that can solve a wide range of Science, Technology, Engineering, and Math problems, as well problems as well as problems in other disciplines.

The last sentence is particularly important. We have calculators, computer systems, and computerized instruments that can solve a wide range of the problems that we have traditionally taught students to solve using paper and pencil techniques. A number of these aids to representing and solving various types of problems are available free on the Web.

Thus, a computer-based distance learning system does two things:

1. It serves as an interactive medium than can provide information to a learner, receive information from a learner, and provide some feedback based on the information it receives from a learner.
2. It can provide powerful computer-based aids to solving or helping to solve a very wide range of problems.

Think about these two things the next time you make use of a computer application such as a word processor, graphics package, or a spreadsheet. Such pieces of software include built-in tutorials. That is, they include distanced education provisions designed to help you learn to make use of the computer application.

In addition, such applications software contains built-in *Help* features. Think of this as a "just in time" type of distance education.

### Free Virtual Public Schools

A growing number of states provide free public education coursework online. Indeed, in some cases it is possible to obtain an entire K-12 education through such systems. For information about distance education in the various states, see http://distancelearn.about.com/od/onlinepublicschools/a/OnlinePS.htm

The distance education movement is having a significant impact on both precollege and higher education systems of schooling. As an example, starting in fall 2009, precollege students in Florida can do their entire schooling via distance learning. See the Newsroom articles at http://www.flvs.net/.

### Free College-Level Course Materials

This book stresses children and their caregivers playing together and learning together. Many adults find that they don't know as much about the STEM areas as they would like to. Their education may have been weak in these areas or they may have forgotten much of what they learn learned. Many educational institutions are making course materials available free on the Web. People can make use of these free materials to help satisfy their desires to learn.

Of course, the institutions making these materials available are not providing free credit for learning the materials. Credits, certificates, degrees, feedback from instructors, and so on cost money!

Many of these courses are suitable for bright high school students who are thinking about going to college. Many are suitable for adults who want to sample some of the best college courses available. All of the courses introduce you to powerful ideas and ways of thinking that will exercise and stretch your brain. All provide you with ideas and topics that you can discuss with others, such as your children, grandchildren, students, and friends.

What follows are a few examples of such courses. If the idea of such courses interests you, some Web browsing will help you to find a large number of other courses.

- Massachusetts Institute of Technology. MIT OpenCourseWare (OCW). See http://ocw.mit.edu/OcwWeb/web/home/home/index.htm

    This site features video and audio clips, animations, lecture notes, and assignments from MIT courses. Students also will find introductory MIT courses, including chemistry, computers and electronics, engineering, math, and physics. Introductory math classes, for example, include courses on problem solving, mathematics for computer science, single-variable calculus, and linear algebra. Engineering courses include such topics as toy-product design and how and why machines work.

    For more information, see http://ocw.mit.edu/help/get-started-with-ocw/. I enjoyed viewing some of the lectures in a 1999 physics course taught by an outstanding professor Walter Lewin. See http://ocw.mit.edu/courses/physics/8-01-physics-i-classical-mechanics-fall-1999/.

- Carnegie Mellon University. See http://www.cmu.edu/oli/index.html. Carnegie Mellon University is a world leader in developing high quality computer-assisted learning materials. Quoting from the Website:

> Bill Gates, chairman of Microsoft Corp. and co-chair and trustee of the Bill & Melinda Gates Foundation came to Carnegie Mellon University on Tuesday, September 22, 2009 for the dedication of the Gates and Hillman Centers at the Pittsburgh campus. As part of his campus visit, Gates, accompanied by Foundation Senior Program Officer Josh Jarrett and Microsoft Corporate Vice President Anoop Gupta, met for nearly 90 minutes with the **Open Learning Initiative (OLI) team to discuss the past, present, and future of the project as it moves forward under support from the Bill and Melinda Gates Foundation.** [Bold added for emphasis.]

- Education-Portal.com. See http://education-portal.com/articles/Universities_with_the_Best_Free_Online_Courses.html. Quoting from the Website:

> No tuition money? No problem! There are many top universities that offer free courses online. This list ranks several of the best free university courses available for people who want to enhance their personal knowledge or advance in their current field.

- Habitable Planet: Approach to Environmental Science. See http://www.learner.org/courses/envsci/index.html. Quoting from the Website:

> The Habitable Planet is a [free, 13 unit] multimedia course for high school teachers and adult learners interested in studying environmental science. The Web site provides access to course content and activities developed by leading scientists and researchers in the field.

**Precollege Courses**

- Annenberg Media at (Retrieved 1/8/2011) http://www.learner.org/resources/browse.html.
- Hoagies' Gifted Education Page: (Free) Online High School Courses & Curriculum Materials. See http://www.hoagiesgifted.org/online_hs.htm. Scroll down about a page to get to course listings.
- Computer Science Unplugged. See http://csunplugged.com/. Quoting from the Website:

> Computer Science Unplugged is a collection of activities designed to teach the fundamentals of computer science without requiring a computer. Because they're independent of any particular hardware or software, Unplugged activities can be used anywhere, and the ideas they contain will never go out of date. Unplugged activities have been trialed and refined over 15 years in classrooms and out-of-school programmes around the world.

- Lifelong Kindergarten Projects (MIT). See http://llk.media.mit.edu/projects.php. Featured projects include Scratch, Crickets, Computer Clubhouse, Computer Clubhouse Village, and many more. Quoting from the Website:

> At Computer Clubhouse after-school centers, young people (ages 10-18) from low-income communities learn to express themselves creatively with new technologies. Clubhouse members work on projects based on their own interests, with support from adult mentors. By creating their own animations, interactive

stories, music videos, and robotic constructions, Clubhouse members become more capable, confident, and creative learners.

- Resources for Elementary School Students. North Clackamas School District. See (retrieved 1/8/2011) http://www.nclack.k12.or.us/182310131172649527/site/default.asp. A number of materials for students and teachers. This site provides an example of what a medium-sized school district with limited resources can do to help students, teachers, and parents.
- WebQuests. Quoting from http://webquest.org/index.php:

  **What is a WebQuest?** A WebQuest is an inquiry-oriented lesson format in which most or all the information that learners work with comes from the web. The model was developed by Bernie Dodge at San Diego State University in February 1995 with early input from SDSU/Pacific Bell Fellow Tom March, the Educational Technology staff at San Diego Unified School District, and waves of participants each summer at the Teach the Teachers Consortium.

  Since those beginning days, tens of thousands of teachers have embraced WebQuests as a way to make good use of the Internet while engaging their students in the kinds of thinking that the 21st century requires. The model has spread around the world, with special enthusiasm in Brazil, Spain, China, Australia and Holland.

  The Website http://webquest.org/search/index.php provides help in locating WebQuests on a wide range of topics.
- FreeReading. See http://www.freereading.net/index.php?title=Main_Page. Quoting from the Website:

  **FreeReading** is a free, high-quality, open-source reading program addressing literacy development for grades K-3. Leveraging the collective wisdom of researchers, teachers, reading coaches, and other education and industry professionals, FreeReading provides a high-quality, cost-effective alternative to static materials. By establishing a foundation of hundreds of research-based lessons and materials that users can download and use for free, FreeReading has created the framework for intervention programs supporting K-6 literacy. The collective wisdom within FreeReading is invaluable and can be more beneficial than any one reading program.

You might wonder why I included the last reference. Our educational system is built on the idea that students first learn to read and then read to learn. By the end of the third grade, students are expected to have made significant progress in learning to read well enough so they can read to learn. By the seventh grade, a great deal of curriculum is presented as reading material that students are expected to read and learn from.

Our educational system is aware of the need for students to learn to "read across the curriculum"—that is, to develop skills in reading in each discipline area. There is a lot of difference between reading a STEM book and reading a novel. If you work with children who are struggling in reading, then it is very important that they get help from you and others that will improve their reading skills.

**Final Remarks**

There is an increasing trend toward use of distance education in both informal and formal education throughout the world. Information and Communication Technology-based education is an everyday activity for many millions of adults and children. It is a steadily growing component of both precollege education and higher education.

We are also seeing some signs of school districts requiring that their students take at least one course via distance education, so that they will experience learning in such an environment. This is a key idea. We want children to learn to learn in various environments. Distance education is one of these environments.

# Chapter 10. Telling a Computer What to Do

> "Computers are incredibly fast, accurate, and stupid. Human beings are incredibly slow, inaccurate, and brilliant. Together they are powerful beyond imagination." (This quote is often mistakenly attributed to Albert Einstein. Most likely the correct attribution is Leo Cherne at the Discover America Meeting, Brussels, June 27, 1968.)
>
> "It goes against the grain of modern education to teach children to program. What fun is there in making plans, acquiring discipline in organizing thoughts, devoting attention to detail and learning to be self-critical?" (Alan Perlis; American computer scientist. 1922–1990.)

Consider a preschool child who has a battery powered train engine or car that runs on a track that the child can assemble. (See Figure 10.1.) The track can be assembled in various shapes. The process of putting designing the track layout and putting the track together is somewhat like programming a computer. The track builder is "telling" the electric train or car where to go. Put the train or car on the track, push the *on* button or switch, and the train or car automatically follows the directions.

Figure 10.1. Child playing with a toy train. Photo from fotosearch.

Chapter 7 of this book lists some free computer graphics programs. Using such programs consists of telling a computer want you want it to do. There are a number of similarities between computer programming and making use of computer graphics software.

**What is a Computer Program?**

A computer program is a detailed step by step set of instructions to a computer. A modern computer is a machine that can carry out billions of such instructions per second—without making any mistakes. Computer programming consists of figuring out how to solve a problem and then writing the detailed instructions telling the computer what to do to solve the problem.

The fundamental idea of computer programming is that of telling a computer a set (collection, sequence) of instructions in advance of the computer being asked to carry out the set of instructions. Primary school students can learn to do this—and at one time many received instruction in writing computer programs in the language Basic or Logo.

There is nothing magical about providing a set of instructions to a computer. For example, in playing a game on a computer, a person is telling a computer what move or action he or she wants to have the computer accept and process. When a person is writing an email message and then sending it, the person is telling the computer system the message and then directing the computer to send the message.

However, this level of telling a computer what to do is a very modest challenge relative to developing a large and complex set of instructions that a computer can follow to solve a complex and challenging problem. People who call themselves computer programmers think in terms of the challenge of writing programs that may be thousands of instructions in length. Indeed, teams of programmers attack problems that may require a program of millions of instructions in length.

This chapter provides a brief introduction to a few ideas about computer programming. It provides links and to some free computer programming languages quite suitable for use by children.

However, you need to be aware that very few young children get started in computer programming on their own. A helper who knows how to program—be it a younger child, a peer, an older child, or an adult—is almost always needed in getting started. With appropriate help, students at the first grade level can make progress in programming that is quite pleasing to themselves and their teachers.

**A Little History About Computer Programming**

In the very early days of electronic digital computers, computer programs were written in machine language—with each instruction telling the computer to carry out a specific set of operations that were wired into the circuitry. Thus, one instruction might tell the computer to add the numbers in two of its memory locations, while a different instruction might tell the computer the memory location in which to store the result.

The tiniest error in writing and encoding these instructions would lead to the computer getting incorrect answers, or not being able to carry out the instructions. It took about a year of instruction and practice to become skilled at programming in a machine language—and each brand of computer had its own machine language.

Eventually computer-programming languages were developed that were more user friendly—that is, better adapted the needs of humans wanting to use a computer. The first version of FORTRAN became available for an IBM computer in 1957, and soon it became available for many brands of computers. A scientist with a decent background in mathematics could learn to write useful programs in the language FORTRAN with just a couple of weeks of instruction. This represented a huge breakthrough in computer programming.

Over time, computer programming languages and computer systems became still more user friendly. Basic became available in the mid 1960s, and eventually became a quite popular programming language for both precollege and college students. With proper instruction, grade school students can learn to write computer programs in Basic.

When microcomputers started to become available in the mid to late 1970s, the programming language Basic was made available on these machines. Millions of students of all ages learned to program in Basic.

A graphics-oriented programming language named Logo was also developed for use of students of all ages. With it, even an elementary school student can direct a computer to draw a picture of a car or a rocket ship, and set the model car or rocket ship in motion across a computer screen. See http://en.wikipedia.org/wiki/Logo_%28programming_language%29.

The teaching of computer programming to elementary and middle school students has largely disappeared from the curriculum. High school students in many schools have access to an Advanced Placement computer science course and/or to some introductory computer programming courses. However, a relatively low percentage of students take such a course.

Meanwhile, a number of new computer programming languages have been developed that are well suited to the "modern" needs and interests of children. A later section in this chapter provides information about some programming languages that are available for free download from the Web.

## More About Telling a Computer System What to do

When you use a computer, part of what you do is "telling" the computer what you want it to do. This is such a straightforward and routine process that you likely do not think about it as a type of computer programming.

For example, you turn on your computer. This simple act tells the computer to carry out an extensive sequence of actions that we humans often call "booting up." Computer programmers have developed an extensive set of computer system programs that are called into action when you turn on your computer. The most commonly used set of these programs are called Windows (Operating System), Mac OS X (Operating System) and Linux (Operating System). It is interesting to note that Windows and Mac OS X are sold commercially, while Linux is made available free.

Suppose that you want to make use of the Web. A Web Browser is a computer program for "browsing" (using) the Web. A Browser is a sophisticated computer program. However, people developing a Browser try really hard to make the software "user friendly"—that is, easy to learn to use and easy to use.

Web Browsers http://en.wikipedia.org/wiki/List_of_web_browsers. The various Browsers have many features in common, but each has its own distinct features. Developers of Web Browsers typically make them available free. A good play together, learn together activity is for you and a child to explore various Web browsers. What features are easy to learn to use and to use? What features are difficult? Is one browser user-friendlier than another?

You tell a Web Browser what to do by specifying one or more search terms, or by using more advanced instructions. Thus, for example, I can tell Google to search for *David Moursund* or for "*David Moursund*". The first search will find documents that contain both the word David and the word Moursund. Thus, one of the hits may be an article talking about Sam Moursund and his friend David Jones. A search using the quoted expression "*David Moursund*" will only locate articles that contain the two words David Moursund adjacent to each other and in that order.

Each Web Browser has a number of advanced features for doing still more sophisticated searches. Learning to use the advanced features of a Web Browser is like learning a little bit about computer programming.

Let's continue with a few more examples. A piece of software such as a word processor typically includes a *Preferences* feature. I use Microsoft Word. I can specify the typefaces, type sizes, indents, and so on through the "styles" feature of Microsoft Word. I can set up a different set of styles of each type of document that I write, such as a personal letter, a professional article, a newsletter, and a book.

Moreover, I can tell Microsoft Word to automatically check for and correct some of my common spelling and keyboarding errors. For example, my fingers often keyboard *educatoin* when I mean *education*. Telling Microsoft Word to automatically correct certain errors is a type of computer programming.

For a still more complex example, perhaps you have used spreadsheet software. People develop spreadsheet models or representations of various problems, such as a budget or a payroll. Such a spreadsheet may include directions to the computer to add various columns of numbers, create a column of numbers by taking the products of numbers in two other columns, and so on. The directions may make use of build-in functions t that are much like the built in functions in a scientific calculator. A spreadsheet might make use of the "If-Then" decision-making feature that is common in most programming languages.

In summary, modern spreadsheet software is much like a limited-purpose computer-programming language. Mastering its capabilities and uses in much like learning computer programming.

Developing a spreadsheet model or representation of a problem illustrated the essence of computational thinking, one of the most important educational aspects of using computers. A modern education helps students to learn to think and solve problems using both their own brains and computer brains. This two-brain approach to solving problems and accomplishing tasks is called computational thinking. For more details, see http://iae-pedia.org/Computational_Thinking and http://iae-pedia.org/Two_Brains_Are_Better_Than_One.

### Creating Your Own Blog, Wiki, or Website

Millions of children and adults have created their own Blogs, Wikis, and Websites. This is now quite easy to do. It is easy to create a Blog or Wiki at no cost. If you want your own Website with a domain name that you select, you will need to pay to get a domain name. This can be done for under $10 per year.

#### Blog

The term Blog or BLOG comes from "weblog." A Blog is a diary or journal that is made available on the Web for others to read. A person can post text messages, photos, music, and video to their Blog. Often a blog is set up so that readers can add comments to the entries.

Use your Web Browser to search on *free blog* and you will find lots of free hosting sites. To learn more about Blogs, go to http://en.wikipedia.org/wiki/Blog.

**Wiki**

Likely you are familiar with the Wikipedia, a free encyclopedia. The software used for the Wikipedia is available free. More user-friendly and easier to use versions of Wiki software are also available free.

Use your Web Browser to search for *free Wiki hosting*. You will find a large number of sites that provide free hosting of small Wiki sites and provide detailed information on how to get started. My current favorite free hosting site is PBwiki at http://secure.pbworks.com/. Click on FOR PERSONAL in the menu at the top of the page.

**Website**

See *The Beginner's A-Z Guide to Starting/Creating Your Own Website* at http://www.thesitewizard.com/gettingstarted/startwebsite.shtml.

This site guides you through the process of setting up a Website. The process begins with getting a domain name. Use your Web Browser to search on *inexpensive domain name registration* and you will find a number of sites that provide this service. Next, you need a computer site to host your Website. There are quite a few sites that will host small Websites for free. Use your Web Browser to search on *free web hosting*.

Some Websites are better designed and more user friendly than others. Many people make their livings by designing high quality, user friendly Websites. Thus, you can hire someone to do this work for you.

However, many free templates (that is, complete Web designs) are available free on the Web. Also, there are many free courses on Web design. A Google search of *free online course on Web design* will provide you with numerous examples.

## Student-oriented Programming Languages

This section lists a few programming languages that are available for free download from the Web. For a much more extensive list, see http://www.freebyte.com/programming/languages/.

- Alice: http://www.alice.org/. Also see the 6/29/09 Science Daily article at http://www.sciencedaily.com/releases/2009/06/090623112115.htm.

  Quoting from the http://www.alice.org/ Website:

  > Alice is an innovative 3D programming environment that makes it easy to create an animation for telling a story, playing an interactive game, or a video to share on the web. Alice is a teaching tool for introductory computing. It uses 3D graphics and a drag-and-drop interface to facilitate a more engaging, less frustrating first programming experience.
  >
  > Alice is a teaching tool designed as a revolutionary approach to teaching and learning introductory programming concepts. The Alice team has developed instructional materials to support students and teachers in using this new approach. Resources include textbooks, lessons, sample syllabuses, test banks, and more. Other authors have generously joined our efforts, creating additional textbooks.

- Basic: http://www.nicholson.com/rhn/basic/. This Website contains information about the free Chipmunk Basic for Windows, Mac OS, and Linux operating systems. Additional free versions of Basic can be accessed through the Website http://www.thefreecountry.com/compilers/basic.shtml. Quoting from the http://www.nicholson.com/rhn/basic/ Website:

> Basic (an acronym for "Beginner's All-purpose Symbolic Instruction Code") is the name of a family of related high-level programming languages, developed, circa 1963 at Dartmouth College, to provide an accessible and easy-to-learn environment for non-science students to understand and use computers. In the early 1980's, the Basic programming language was built-in to the majority of personal computers sold.

Microsoft Small Basic (for Windows) is especially suitable for children and beginners. It includes Turtle Graphics, an important feature from the Logo programming language See http://msdn.microsoft.com/en-us/beginner/ff384126.aspx.

- Logo: http://www.thefreecountry.com/compilers/logo.shtml. Quoting from the Website:

  > The Logo programming language has been used to teach programming to children, as well as to create modeling environments for a variety of purposes. At its most basic form, the language allows you to program a "turtle" to move around the screen, drawing lines as it does so. Some of the implementations below have extended the language in a variety of ways, such as to add multiple turtles, multi-threading, image handling, a 3D world, etc.
  >
  > Berkeley Logo (http://www.eecs.berkeley.edu/~bh/) is a free implementation of Logo, complete with source code, for Unix, DOS/Windows and Macintosh.
  >
  > OpenStarLogo (http://education.mit.edu/openstarlogo/) is a version of the Logo programming language that allows you to control thousands of graphic turtles in parallel. The turtles are also able to interact with each other and their world, changing their behaviors according to what they detect.

- Scratch: http://scratch.mit.edu/. Available for Mac and Windows machines. Also see Resnick et al. (2009). Quoting from http://mashable.com/2007/07/22/scratch/:

  > Scratch is a new programming language designed by Mitchel Resnick and his associates at MIT's Lifelong Kindergarten research group.
  >
  > The service is designed for children 8 years old and up to learn the concepts that can be used from an early age for the foundation that allows for the continued learning of programming and other current skills. Helping to form the ability to think creatively, communicate and analyze, use technologies, collaborate, and design, Scratch has been likened to an improved version of Smalltalk, which supposedly offered programming learning tools that operated with the simplicity of building with LEGO pieces. A similar "snap and build" design is used with Scratch as well, and the site is full of other learning tools and resources, such as printable flash cards.

- Squeak: http://www.squeak.org/. Squeak is available for Linux, Mac, and Windows machines. Quoting from the Website:

  > Squeak is a modern, open source, full-featured implementation of the powerful Smalltalk programming language and environment. Squeak is highly-portable -

> even its virtual machine is written entirely in Smalltalk making it easy to debug, analyze, and change. Squeak is the vehicle for a wide range of projects from multimedia applications, educational platforms to commercial web application development. …
>
> Squeak is an excellent game development platform. Included in Squeak are a number of games to get you started. Of course, being Squeak all of the source code is included, and is ready for reuse. See http://www.squeak.org/Features/FunandGames/.

**Final Remarks**

Computers are now built into many of our everyday tools. For example, when you use a cell phone you are making use of a powerful computer built into this handheld device. You are communicating with a networked and highly computerized telecommunication system that spans the world.

However, such use of computers and computerized devices is quite far removed from providing a set of finely detailed step-by-step sets of instructions that make up a computer program. This is a great environment for learning and practicing many general ideas of problem solving.

Many children greatly enjoy learning how to do computer programming. This is an empowering approach to learning about some of the capabilities and limitations of computer technology.

# Chapter 11. Robots

Three laws of robotics. Created by Isaac Asimov (Russian born American author; 1920–1992).

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey any orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Nowadays, quite young children are apt to be exposed to walking, talking toys and other types of interactive robot-like toys and games. Children adapt easily to the button pushing and other types of activities needed to interact with such toys.

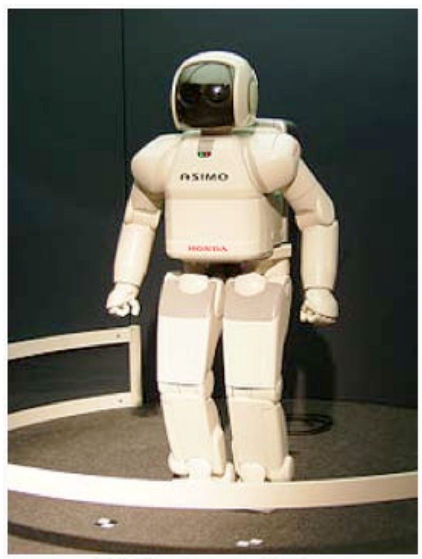



Figure 11.1. ASIMO, a robot.

Many types of robots have been developed and/or are under development. See http://en.wikipedia.org/wiki/Robot. For example, a factory robot may well be a machine that is bolted to the floor or to a wall, has an "arm" that includes a paint sprayer, and under computer control spray paints a car body.

Or, a robot may have mobility somewhat like a human being. Using its vision system and other capabilities, a robot might be able to walk, including walking up and down stairs. It might be able to pick up an object, carry it across a room, and set it down in a designated spot. It

Certainly you have heard of an airplane "auto pilot." This is a computerized device that can fly an airplane. Currently there are a number of research projects on the development of an "auto driver" for a car.

A substantial amount of research is going on to develop artificially intelligent robots. Eventually we will have such robots that can work in a field of crops, doing unsupervised weeding and harvesting.

A robot is controlled by a computer program. Kits are available that students can use to build a programmable robot. Many students are now involved in learning to build and program robots, and then having their robots compete in various robotic competitions. See http://iae-pedia.org/Robotics_and_Education and http://i-a-e.org/iae-blog/robotics-and-robotics-contests-in-precollege-education.html.

**Videos**

There is quite a bit of robot-oriented video material available on the Web. Here are some examples:

- 3:29 Video about a robotic pack animal. See http://www.youtube.com/watch?v=W1czBcnX1Ww.

Figure 11.2. A hefty shove does not tip over the robotic pack animal.


- 3:26 Video of Sony robots dancing. See http://www.youtube.com/watch?v=9vwZ5FQEUFg&feature=related.

Figure 11.3. Four dancing robots.

- 17:47 video. Bill Stone: Journey to the center of the earth ... and beyond! See http://www.ted.com/index.php/talks/view/id/141.

  This video starts off being about doing extensive exploration in underground caves (where you spend days walking into the caves), but then shifts to talking about space exploration.

  This part of the video shows robots currently under development and some visionary robotic ideas for underwater and under ice explorations.

  The video explores advances in technology that might someday lead to looking for life in the water under the miles-deep ice covering Europa, one of Jupiter's moons.

  The video also explores the possibility of similar equipment being used to explore for water on the moon. It presents a passionate argument for space travel.

- 7:49. Robots and artificial intelligence. See http://www.youtube.com/watch?v=P9ByGQGiVMg&feature=related. The menu on the right side of the screen provides additional videos about artificially intelligent robots.

## Cyber-physical Systems

Quoting from a July 14, 2009 press release (that includes a short video) at http://www.nsf.gov/news/news_summ.jsp?cntn_id=115211&govDel=USNSF_51:

> Scalpels that a surgeon uses to excise small tumors but never actually touches. Robots that can take the place of lab rats in clinical trials. Cars that can drive themselves through busy streets. These were just some of the cutting-edge technologies on display at the Hart Senate Office Building last week as the National Science Foundation (NSF) presented a luncheon briefing and open house for Senate members and their staff on cyber-physical systems (CPS), an emerging technological field that incorporates computing power to improve virtually every facet of modern life.
>
> The basic concept behind CPS is straightforward--combine computing power with existing systems to turn them into "smart" technologies such as airplanes that can detect each other and automatically adjust their flight paths accordingly, or bridges that can sense when they are being overloaded and are in danger of falling down. Experts believe that CPS technologies will increasingly affect our wellbeing, security, and competitiveness, in a variety of areas including aerospace, automobiles, civil infrastructure, energy, finance, healthcare and manufacturing.

Robotic surgery is the use of robots in performing surgery. See http://en.wikipedia.org/wiki/Robotic_surgery. Quoting from this article:

> Three major advances aided by surgical robots have been remote surgery, minimally invasive surgery and unmanned surgery. Some major advantages of robotic surgery are precision, miniaturization, smaller incisions, decreased blood loss, less pain, and quicker healing time. Further advantages are articulation beyond normal manipulation and three-dimensional magnification.

MIT's Media Lab has a Personal Robots Group that is undertaking a number of projects. See http://robotic.media.mit.edu/projects/projects.html. Click on a picture and then make use of the menu of various components of the research being done in that particular project. Quoting from the Website:

> The Personal Robots Group focuses on developing the principles, techniques, and technologies for personal robots. Cynthia and her students have developed numerous robotic creatures ranging from robotic flower gardens, to embedding robotic technologies into familiar everyday artifacts (e.g., clothing, lamps, desktop computers), to creating highly expressive humanoids—including the well-known social robot, Leonardo. Ongoing research includes the development of socially intelligent robot partners that interact with humans in human-centric terms, work with humans as peers, and learn from people as an apprentice.

## Robotics Competitions

There are many education-oriented robotics competitions. See a list a of competitions at http://robots.net/rcfaq.html. Here are links to videos taken at various robotics competitions for students.

- First Robotics Competition. See http://www.usfirst.org/roboticsprograms/frc.
- Junior FIRST Lego League Expo. See http://www.cnf.cornell.edu/cnf_jrfll.html.
- FIRST LEGO (Robotics) League. Quoting from the Website http://www.firstlegoleague.org/mission/support.

> The best way to summarize *FIRST* LEGO League is to say that it is a robotics program for 9 to 16 year olds (9 to 14 in US/CAN/MEX), which is designed to get children excited about science and technology -- and teach them valuable employment and life skills. FLL can be used in a classroom setting but is not solely designed for this purpose. Teams, composed of up to ten children with at least one adult coach, can also be associated with a pre-existing club or organization, homeschooled, or just be a group of friends who wish to do something awesome.
>
> See video from several of the national contests at: http://video.google.com/videosearch?hl=en&q=first+lego+league&um=1&ie=UTF-8&ei=1ByGSb-LBoG0sAPq1NmnDQ&sa=X&oi=video_result_group&resnum=5&ct=title#

### Final Remarks

Many children learn best in a "learn by doing" environment. Working along side their peers, older children, and adults, they learn to make things and do things. They can see the immediate results of their efforts.

There are many robotic toys. My 10/27/2011 Web search for *programmable robotic toys* returned over a million hits. A search for *videos of programmable robotic toys* provides access to several hundred videos. Most of these are ads for commercially available robots and robotic kits.

There are now programming languages, robots and robotic toys, and graphic arts application programs that provide environments in which children can "tell" a computer what they want it to do. That is, children can learn by doing and see the results of what they have learned and what they are able to do. These types of self-assessment and peer assessment environments are very useful in education.

# Chapter 12. Miscellaneous Other Topics

> "Try to learn something about everything and everything about something." (Thomas H. Huxley; English writer; 1825–1895.)
>
> "I was bold in the pursuit of knowledge, never fearing to follow truth and reason to whatever results they led." (Thomas Jefferson; third President of the United States; 1743–1826.)

There are many topics that I could have been included in this book but did not—partly to keep the book manageable in length and not be too overwhelming to readers. This chapter provides brief mention of some of the topics.

## Home Schoolers

If we define home schooling in a broad enough sense, then every child is home schooled. During the first few years of life, this home schooling is provided by parents, foster parents, siblings, grandparents and other relatives, neighbors, baby sitters, nannies, and so on. Indeed, every person a child encounters can be considered as a teacher—as a source of information and as a provider of interaction and feedback.

It is important to keep in mind that a significant amount of the non-sleeping time of a student who is regularly attending a public or private school is spent outside of this formal school environment. That is, using a broad definition of home schooling, a majority of the student's time is spent in a home and community schooling (outside of a formal school) educational environment.

Some people decide to not place their children in public or private schools when the children reach "school age." Instead, they establish a home school environment, following a curriculum somewhat of their own choice and somewhat governed by state guidelines, rules, and regulations.

The Internet and other Information and Communication Technology are valuable aids to such home schooling. The Web is rich in resources for people doing formal or informal home schooling of children. My recent Web search of the quoted expression *"home school"* produced nearly a million hits.

## Global Warming

There are many major global problems. The video http://www.youtube.com/watch?v=Dtbn9zBfJSs (17:28) lists some of them and provides a discussion of possibly prioritizing how to use our resources in addressing these problems.

Global warming is a considerable concern to many people. See http://news.nationalgeographic.com/news/2004/12/1206_041206_global_warming.html. In brief summary, there are two main issues. First, are we experiencing global warming? Second, if "yes," is part or quite a bit of the cause the carbon dioxide and other materials the societies of our planet are releasing into the atmosphere? Here are some education-oriented resources.

**Global Warming Kids Site**. See http://epa.gov/climatechange/kids/index.html. Perhaps start with the video. The kid's page focuses on the science and impacts of global warming or climate change, and on actions that help address global warming issues. It is designed as a resource for both kids and educators. The site also features games, animations, events, and links to other relevant sites for kids and educators.

**Global Warming Wheel Card Classroom Activity Kit**. See http://www.epa.gov/climatechange/downloads/ActivityKit.pdf. Quoting from the Website:

The U.S. Environmental Protection Agency (EPA) presents the Global Warming Wheel Card Classroom Activity Kit for teachers of grades 6 through 8 who plan to incorporate the topic of global warming into their curriculum. The kit provides resources and activities for using EPA's Global Warming Wheel Card to educate students about global warming, its sources, and potential impacts. The activity kit also encourages students to think about ways to reduce their individual, family, school, and community contributions to the greenhouse effect.

**Household Emissions Calculator**. See http://www.epa.gov/climatechange/emissions/ind_calculator.html. Use the calculator to obtain a rough estimate of your household's greenhouse gas emissions and explore actions you can take to reduce them.

## Language Translation

A lot of money, time, and effort have been spent in trying to develop relatively high quality language translation software. This has proven to be a very difficult task. However, quite a bit of progress has occurred over the years. There are now free computer programs available on the Web that will translate from one language to another. You can find some of these programs via a Web search of *free language translation*. Here are three examples:

- http://babelfish.altavista.com/
- http://translate.google.com/#
- http://www.worldlingo.com/en/products_services/worldlingo_tanslator.html

Many of the free translation Websites accept either a block of text presented via cut and paste, or a Web address of a Website to be translated. While the quality of such computer translations has gradually improved over the years, they still leave much to be desired.

If you are fluent in reading two languages, you can check out the quality for yourself. Alternatively, you can have fun starting with some text in one language, having a computer program translate it into another language, and then having the computer translate this result back into the language you started with. You can then compare the original version of the text with the twice-translated version of the text. This activity will likely convince you that language translation by computer still has a long way to go.

Here is a fun activity. Have a computer language translator translate some text from language X to language Y and then back to language X. Compare the initial and final version of the language X text.

## Sounds and Music

A computer can be used to digitally record, edit, and playback sound. This capability has greatly changed the music recording industry. Now, with modestly priced hardware and software, a composer can lay down multiple tracks, listen to the results, and edit individual tracks. The composer can also draw on tracks laid down by others.

This brings a new dimension to music education. Even grade school students can learn to use a computer music system to compose and playback music. Here are a couple of sites that might get you and the children you work with started:

- Dallas Symphony Orchestra Kids. Retrieved 1/9/2011from http://www.dsokids.com/2001/rooms/musicroom.asp. The Webpage is quite active. Move your mouse around to see the active buttons. You can even play the piano. Quoting from the Website:

    > The Dallas Symphony Orchestra has started a club just for you... The DSOKids Club!
    >
    > The DSOKids club is for those who want to learn more about music and the people who make music. After submitting your information below, you will receive emails (about every other month or so) that will tell you about the exciting things happening at DSOKids.com, such as new games and features.
    >
    > To become a member, tell us about how old you are: 12 years old or younger, or 13 years old or older.

- The New York Philharmonic Kidzone. Retrieved 10/29/2011 from http://www.nyphilkids.org/main.phtml. Roll your mouse around to locate active buttons; click on such buttons to get started. Or, and on the sitemap button to get started.

**Some Early History of Electronic Music**

A number of people experimented with computer-generated music during the early days of electronic digital computers. Quoting from http://en.wikipedia.org/wiki/CSIRAC:

> CSIRAC (Council for Scientific and Industrial Research Automatic Computer, pronounced /'sa□ræk/), originally known as CSIR Mk 1, was Australia's first digital computer, and the fourth stored program computer in the world. It was first to play digital music and is the only surviving first-generation computer.
>
> The CSIRAC was constructed by a team led by Trevor Pearcey and Maston Beard, working in large part independently of similar efforts across Europe and the United States, and ran its first test program some time in November 1949.

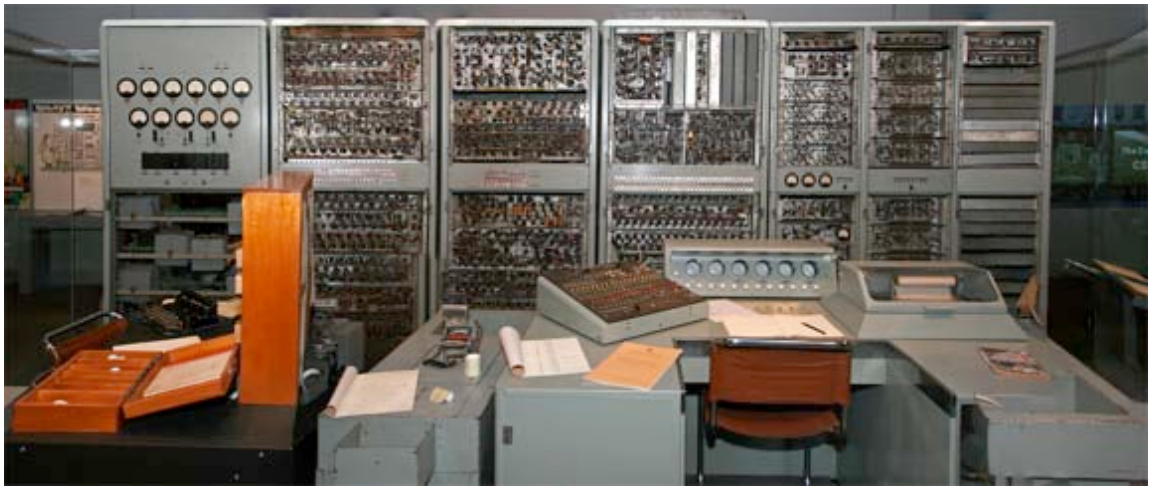


Figure 12.1. 1949 Council for Scientific and Industrial Research Automatic Computer

**Some Music Sites That Might Interest Children and/or Adults**

- Bad Vibes: http://sound101.org/badvibes/. Listen to some really bad sounds. This site provides you with an assortment of annoying sounds and allows you to classify each one on the basis of how bad it sounds to you.
- Classics for Kids: http://www.classicsforkids.com/index.asp. Quoting from the Website:

  Naomi Lewin brings classical music's great composers to life through music and stories.

  **Have fun online with classical music games. Compose your own music and share it with your friends;** repeat the rockin' rhythms; and listen to the music online.

  In the classroom, classical music can be an exciting tool. The Classics for Kids® lesson plans and teaching resources give teachers practical, effective plans and activities that use classical music to help children learn, and meet national and state standards. They are based on National Standards for the Arts and state Academic Content Standards for Music, as well as on Theory of Multiple Intelligences. The materials also incorporate various philosophies, including those of Orff, Dalcrose, and Koda.
- Free virtual piano: http://ababasoft.com/music/piano_machine.swf. Very simple (one octave) system lets you play, record, and playback.
- JamStudio.com: http://www.jamstudio.com/Studio/index.htm The site provides powerful facilities for authoring electronic music.
- San Francisco Orchestra: http://www.sfskids.org/. The San Francisco Orchestra Kids Site provides students with the opportunity to experiment with music composition. The basic elements of music (tempo, rhythm, pitch, harmony, and timbre) are introduced in a fun and interactive environment.

## Self-Assessment

Assessment and feedback from the assessment are critical components of learning. For example, as a young child is first learning to talk, the child hears words and attempts to imitate the words. External and internal feedbacks occur. An attempted imitation leads to external feedback from the person who spoke the word. Internally, the child hears the sound that he or she has made and compares it to the sound that he or she is trying to imitate.

This internal and external feedback situation continues throughout life. You undoubtedly remember doing math homework problems from a book, and making use of the answers that the book provides for some of the exercises. This is an example of external formative assessment.

You likely have experienced taking tests, and knowing at the end of the test how well you have done. That is, you self-assess your exam performance. Later you get assessment feedback from the teacher or from the machine that grades the test.

Computer-assisted learning systems (see http://www.k8accesscenter.org/training_resources/computeraided_reading.asp) provide computer-based instruction and feedback. One of the strengths of interactive computer-assisted instruction is that it can provide immediate feedback. That is, in this teaching and learning environment, a computer system assesses the learner's work and provides immediate feedback. This feedback may include suggestions of possible errors in thinking and understanding and suggestions of possible sources of additional help.

To learn more about computer-based assessment and feedback systems, see:

- http://iae-pedia.org/Self_Assessment
- http://iae-pedia.org/Self-assessment_Instruments

## Home Science Experiments

One can do lots of interesting and educational science experiments using materials that are standardly available in a household, or readily purchased at local stores. My recent Web searches produced:

- 2.9 million hits for *kitchen biology.*
- 10.9 million hits for *home biology experiments.*
- 1 million hits for *kitchen chemistry*.
- 2.9 million hits for *kitchen physics*.
- 9.3 million hits for *home science experiments*.
- 1.5 million hits for *science fair projects*.

Needless to say, I did not browse all of these sites. However, I spent some time looking at the home biology, chemistry, and physics sites. Here are a few that I found particularly appealing.

**Home Biology**

- A to Z Home's Cool Homeschooling: Biology experiments for kids. Retrieved 10/29/2011 from http://homeschooling.gomilpitas.com/directory/Biology.htm.

- Fast plants. Retrieved 10/29/2011 from http://www.fastplants.org/. Note that the seeds and other materials are not given away—this is a commercial Website. Quoting from the Website:

> What are Fast Plants®? Fast Plants® are a type of crucifer (a large group of plants that includes mustard, radish, cabbage, and more) that have been bred and selected to have a uniform, short flowering time (14 days) and grow well under in a small indoor space, with little soil, under artificial lights.
>
> How long is the Fast Plant® life cycle? The entire life cycle for Fast Plants® is extremely short, and under ideal growing conditions of continuous light, water, and nutrition, plants will produce harvestable seeds approximately 40 days after planting.

**Kitchen Chemistry**

- Anytime, Anywhere Chemistry Experience. Retrieved 10/29/2011 from http://uncw.edu/chem/Courses/Reeves/OnLineLabs/menu.html. This Website was developed using funding from a federal grant. The goal was to create chemistry lab experiences that could be done by students taking college freshman chemistry via distance education. The labs had to meet rigorous standards relative to the traditional on-site chemistry labs in the on-campus courses. The site gives details on nine labs.
- Crystal Ornaments. Retrieved 10/29/2011from http://homeschooling.gomilpitas.com/explore/crystals.htm. Contains directions for several different crystal-growth projects suitable for adult and child working together.
- Kitchen Chemistry. Retrieved 10/29/2011 from http://inventnow.org/investigation/kitchen_chemistry/. Carry our kitchen chemistry experiments on your computer. Similar non-virtual experiments can be carried out using readily available ingredients.

**Kitchen Physics**

- Hot air balloon. Retrieved 6/23/2010 from http://www.grc.nasa.gov/WWW/K-12/TRC/Aeronautics/Hot_Air_Balloon.html.

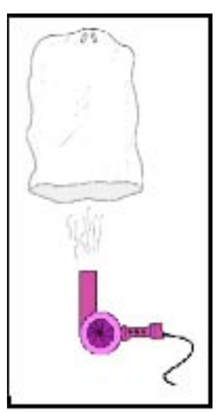


Figure 12.2. Using a hair dryer to fill a "balloon" with hot air.

Physics Experiments (n.d.). Retrieved 10/29/2011 from http://www.thenakedscientists.com/HTML/content/kitchenscience/wierd/. This site provides a large number of well-explained examples that can be used with children. Many of the examples include videos.

**Home Made Batteries**

It is fun to make a battery from a lemon or a potato. See http://en.wikipedia.org/wiki/Lemon_battery or http://www.monkeysee.com/play/6354-how-to-make-a-potato-battery. Figure 12.3 is a science fair potato battery project discussed in Moursund and Albrecht (2011).

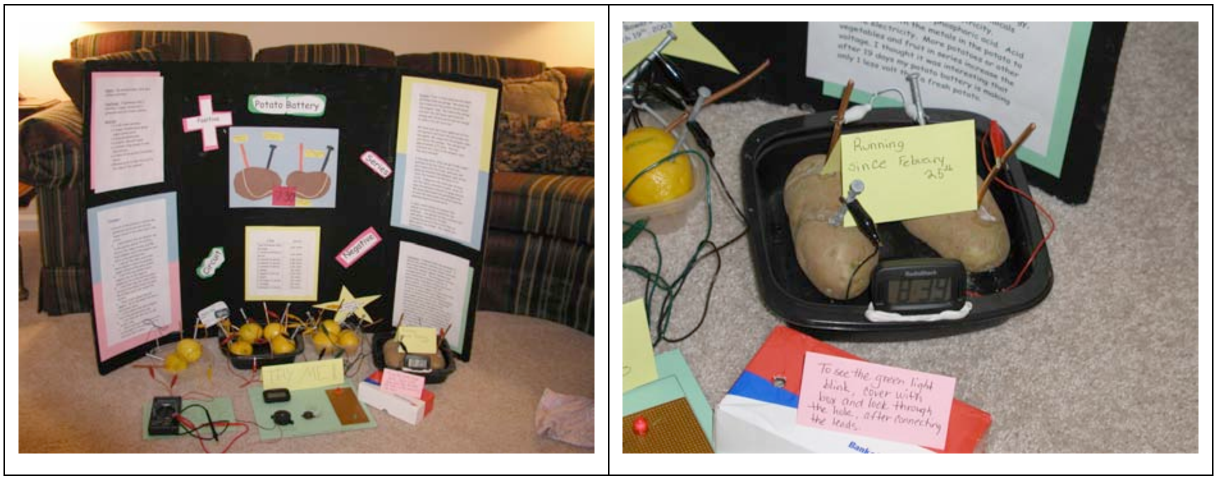



Figure 12.3. Potato battery.

## Education for the Future

This section consists of a copy of the free Information Age Education Newsletter. The issue was published in mid October 2009. The complete collection of these free newsletters is available at http://iae-pedia.org/IAE_Newsletter.

**Information Age Education Newsletter**

Issue Number 28        October 2009

This free Information Age Education Newsletter is written by David Moursund and produced by Ken Loge. For more information, see the end of this newsletter.

Che sarà, sarà

Whatever will be will be

The future's not ours to see

Che sarà, sarà

It's a great song. However, many people disagree with the message. For example, Jeff Hawkins and Sandra Blakeslee's book "On Intelligence" provides a nice description of how a human brain functions by continually making forecasts of the future. Moreover, there are a number of quite respectable university programs in future studies.

Every day you make a number of decisions that involve taking actions based on the decisions. You make a prediction that the decision and action will produce the results you want them to produce. Of course, there is a difference between making such predictions and having the predictions turn out to be good ones.

In addition, there is substantial difference between the challenges of making relatively accurate short-term forecasts and experiencing a reasonable level of success in making longer-term forecasts.

**Education and the Future**

A kindergarten or first grade student begins school. Our overall educational system has made a decision that this child's future will benefit by learning reading, writing, and arithmetic. Such forecasts typically include statements about how this education will benefit the country, the economy, and so on. People argue the merits of our educational system in terms of preparing children for responsible, productive adulthood. In summary, education is for the future.

However, we must also think about how education shapes the future. Here is a 1971 quote from Alan Kay, a pioneer in the development of laptop computers and a major contributor to other aspects of computer science and the field of computers in education:

"Don't worry about what anybody else is going to do… The best way to predict the future is to invent it." See http://iae-pedia.org/Alan_Kay.

Thus, as we work to improve our educational system we are faced by a double challenge:

1. Forecasting what the future will be like, so that we can design our educational system to appropriately prepare children for life in this future world that they and others are "inventing."
2. Understanding that our educational system—including how it is designed and implemented—contributes to changing the future.

An important aspect of this is that our educational system tends to be very slow to change. In many ways, it is a backward-looking system, rooted in the past. Out current educational system has many of the characteristics of the factory model of education developed to serve the needs of industrial age students and countries of a hundred or more years ago.

Our current educational system is challenged by current and predicted future national and world problems such as disease, hunger, homelessness, pollution, population growth, poverty, sustainability, terrorism, war, and so on. As we educate our children to become responsible, productive, caring adult citizens of our country and of the world, we need to think about whether our current educational system is appropriate to the task.

**Reading, Writing, Arithmetic, and Problem Solving**

One way to think about reading, writing, and arithmetic is their roles in representing and solving problems. Reading, writing, and arithmetic are powerful aids to the accumulation of information and to making use of accumulated information to help represent and solve problems in all disciplines.

There are two very important ideas here:

1. The steadily improving aids to the storage, processing, communication of, and communication with the steadily increasing collection of accumulated information.
2. Education and tools for making effective use of the information to help in representing and solving problems. See Moursund's free 2007 book on problem solving retrieved from http://i-a-e.org/downloads/doc_download/7-introduction-to-problem-solving-in-the-information-age.html.

Think about the first of these two items. The Internet and other communication systems are bringing steadily improving connectivity to the world. You are familiar with the Web as being a dynamic, virtual library that is by far the largest library in the world and that continues to grow very rapidly. The Web is a component of the Internet, and the Internet provides lots of different powerful aids to communication between people, between people and machines and between machines.

In designing a modern education system, it is reasonable to forecast continued steady improvement in something akin to the Internet and the Web, and in various aids to accessing , making use of, and contributing to the Web.

Thus, we need to look at our current K-12 educational system and analyze it in terms of how well it is preparing students for a responsible and productive adult life in which adults can readily communicate with each other, with machines, and with virtual libraries that are steadily growing "smarter."

The last sentence brings us to item 2 in the above list. We now live in a world in which information is processed (problems are solved) both by human brains and by computer "brains." See http://iae-pedia.org/Two_Brains_Are_Better_Than_One. How well is our education system doing in preparing students for responsible and productive adulthood in a world in which many of the problems and tasks they will face are best addressed by making appropriate use of a combination of human and computer brains? What constitutes a good math education in light of the ready availability of calculators, computers, and computerized tools? This is a very challenging question.

**Some Relevant Forecasts of Information Processing Technology**

Essentially every week brings new announcements of significant progress and/or forecasted progress in Information and Communicating Technology. See http://iae-pedia.org/What_the_Future_is_Bringing_Us. Computers are getting faster. Storage systems of greater capacity are being developed. Communication systems are getting faster and reaching more people. Information retrieval systems and computer systems are getting smarter.

> One way to think about this increase in overall capability and smartness is the improving ability of artificially intelligent systems to directly answer questions and solve problems that people pose. For example, think about the question, "How do I get from where I am now to the nearest pizza eatery?" GPS and related technology on a handheld cell phone can deal with this type of question. Wolfram Alpha has received a lot of publicity for its question answering capabilities, and we can expect that it and other competing systems will steadily improve over time. See from http://www.wolframalpha.com/.
>
> Thus, a good modern education includes a focus on understanding the capabilities and limitations of question-answering computer systems, and how to pose answerable questions.
>
> **Final Remarks**
>
> The previous issue of this Information Age Education Newsletter addressed some aspects of National Standards in education. To a large extent, such proposed National Standards, along with our current focus on state and national testing, are not paying enough attention to the future. In essence, they focus on doing better what we have been doing in the past. The world is changing much more rapidly than its educational systems.
>
> **About Information Age Education, Inc.**
>
> Information Age Education is a non-profit organization dedicated to improving education for learners of all ages throughout the world. IAE is a project of the Science Factory, a 501(c)(3) science and technology museum located in Eugene, Oregon. Current IAE activities include a Wiki with address http://IAE-pedia.org, a Website containing free books and articles at http://I-A-E.org, and the free newsletter you are now reading.
>
> To subscribe to this twice-a-month free newsletter and to see back issues, go to http://i-a-e.org/iae-newsletter.html. To change your address or cancel your subscription, click on the "Manage your Subscription" link at the bottom of this email message.

## Final Remarks

The following two quotes are used earlier in this book:

> "Children are the message we send to the future." (Abraham Lincoln; sixteenth US President; 1809–1865.)
>
> "Children are the world's most valuable resource and its best hope for the future" (John Fitzgerald Kennedy; 35th US President; 1917-1963.)

I feel that these to quotes are well worth rereading from time to time.

Every person is both a teacher and a student. We are all lifelong educators and students. Some of us become professional teachers. In my mind, this includes both parents and "school" teachers at all levels. Through formal and informal education and experience, we teachers can steadily improve our effectiveness. Teaching is a very demanding and challenging informal and formal profession.

Every informal or formal learning situation provides an opportunity to get better at learning to learn, and to learn more about oneself as a learner and as a teacher. Metacognition (thinking about one's thinking), introspection (getting to learning more about oneself), and reflection (contemplation about what you have done and are doing) are powerful aids to becoming a better learner and teacher. All contribute to greater understanding, transfer of learning, and long-term retention of what you are learning.

I hope that this book has been beneficial to you and the children you work with. Feel free to contact me (David Moursund; moursund@uoregon.edu) via email if you have questions or if you have suggestions for corrections, additions, or deletions to the book.

# References

"Spoken words fly away, written words remain." ("Verba volant, scripta manent. Latin proverb, possibly from Caius Titus.)

"The strongest memory is not as strong as the weakest ink." (Confucius, 551-479 B.C.)

This annotated collection of references is intended mainly for adults who want to learn more about education and roles of Science, Technology, Engineering, and Mathematics (STEM) in education. There are a number of resources of particular interest to teachers.

AAAS (n.d.). American Association for the Advancement of Science. Retrieved 10/29/2011 from http://www.project2061.org/. Quoting from the AAAS home Page:

> "Triple A-S" (AAAS), is an international non-profit organization dedicated to advancing science around the world by serving as an educator, leader, spokesperson and professional association. In addition to organizing membership activities, AAAS publishes the journal *Science*, as well as many scientific newsletters, books and reports, and spearheads programs that raise the bar of understanding for science worldwide.
>
> Founded in 1848, AAAS serves some 262 affiliated societies and academies of science, serving 10 million individuals. *Science* has the largest paid circulation of any peer-reviewed general science journal in the world, with an estimated total readership of one million. The non-profit AAAS is open to all and fulfills its mission to "advance science and serve society" through initiatives in science policy; international programs; science education; and more. For the latest research news, log onto EurekAlert! (http://www.eurekalert.org/) the premier science-news Web site, a service of AAAS.

AERA SIG (n.d.). American Educational Research Association. See http://www.ergobservatory.info/ejdirectory.html ] This Website lists over 265 open access journals in education. Quoting from the Website:

> The Education Research Global Observatory maintains a complete and current directory of open access peer-reviewed journals in education.

California Institute of Technology (n.d.). *Cool Cosmo.* Produced by NASA. Retrieved 10/29/2011 from http://coolcosmos.ipac.caltech.edu/. See, the Cosmic Kids section at http://coolcosmos.ipac.caltech.edu/sitemap.html#cosmickids. Quoting from the Cool Cosmos Website:

> In answering the wide public interest in space sciences, NASA has, for more than a decade, made Education and Public Outreach (EPO) an important element in their missions. This "Cool Cosmos" portal is the main gateway of the "Cool

Cosmos" EPO group at the Infrared Processing and Analysis Center and the SIRTF Science Center.

The "Cool Cosmos" portal is involving students in science with multi-disciplinary educational materials produced with the goal of engaging the young minds of future generations of scientists. The continuous positive response of the public has been an absolute motivation to create new and innovative methods to reach them. The "Cool Cosmos" team is a dynamic group that has made its vocation to revive the interest, excite the dreams and hopefully answer some of the questions to satiate the public thirst for knowledge of Space.

CIA (n.d.). *Central Intelligence Agency world fact book.* Retrieved 10/29/2011 from https://www.cia.gov/library/publications/the-world-factbook.

This is a huge and frequently updated collection of information developed and maintained by the United States Central Intelligence Agency. It can be used to retrieve a considerable amount of information about any country or major location in the world. For each country it contains a map and detailed information about the country and its people.

Clements, D. H. (1999). 'Concrete' manipulatives, concrete ideas. *Contemporary Issues in Early Childhood.* Retrieved 10/29/2011 from http://www.gse.buffalo.edu/org/buildingblocks/NewsLetters/Concrete_Yelland.htm. Here is the abstract of the article:

The notion of "concrete," from concrete manipulatives to pedagogical sequences such as "concrete to abstract," is embedded in educational theories, research, and practice, especially in mathematics education. In this article, I consider research on the use of manipulatives and offer a critique of common perspectives on the notions of concrete manipulatives and concrete ideas. I offer a reformulation of the definition of "concrete" as used in psychology and education and provide illustrations of how, accepting that reformulation, computer manipulatives may be pedagogically efficacious.

Crace, John (1/24/2006). Children are less able than they used to be. *The Guardian.* Retrieved 10/29/2011 from http://www.guardian.co.uk/education/2006/jan/24/schools.uk. Quoting from the article:

New research funded by the Economic and Social Research Council (ESRC) and conducted by Michael Shayer, professor of applied psychology at King's College, University of London, concludes that 11- and 12-year-old children in year 7 are "now on average between two and three years behind where they were 15 years ago", in terms of cognitive and conceptual development.

"It's a staggering result," admits Shayer, whose findings will be published next year in the British Journal of Educational Psychology. "Before the project started, I rather expected to find that children had improved developmentally. This would have been in line with the Flynn effect on intelligence tests, which shows that children's IQ levels improve at such a steady rate that the norm of 100 has to be recalibrated every 15 years or so. But the figures just don't lie. We had a sample of over 10,000 children and the results have been checked, rechecked and peer reviewed."

Dewar, Gwen (2008). In search of the smart preschool board game: What studies reveal about the link between games and math skills. *Parenting Science.* Retrieved 10/29/2011 from http://www.parentingscience.com/preschool-board-game-math.html.

This article reports on various research projects done using board games and young children. Quoting from the article:

"There is compelling evidence that certain kinds of board games boost preschool math skills. And these early skills are strongly predictive of math achievement scores later in life (Duncan et al 2008).

For instance, consider the research of Geetha Ramani and Robert Siegler (2008).

Ramani and Siegler asked preschoolers (average age: 4 years, 9 months) to name all the board games they had ever played.

The more board games that a kid named, the better his performance in four areas:

• Numeral identification

• Counting

• Number line estimation (in which a child is asked to mark the location of a number on a line)

• Numerical magnitude comparison (in which a child is asked to choose the greater of two numbers)."

Discover Engineering (n.d.). *National Engineers Week Foundation.* Retrieved 10/29/2011 from http://www.discoverengineering.org/.

Includes a variety of multimedia materials and "Cool Stuff" such as activities and games designed to help people becoming more knowledgeable about and interested in the field of engineering.

DOAJ (n.d.). *Directory of Open Access Journals.* Retrieved 10/29/2011 from http://www.doaj.org/. Quoting from the Website:

Welcome to the Directory of Open Access Journals. This service covers free, full text, quality controlled scientific and scholarly journals. We aim to cover all subjects and languages. There are now 5,952journals in the directory. Currently 2,508 journals are searchable at article level. As of today 494,827 articles are included in the DOAJ service.

FREE (n.d.). *Federal Resources for Educational Excellence.* Retrieved 10/29/2011 from http://free.ed.gov/index.cfm. This site provides a huge amount of information of interest to educators and students. For example, look at the Science section at http://free.ed.gov/subjects.cfm?subject_id=41. There you will find hundreds of pages of material. Quoting from the Website:

FREE makes it easier to find teaching and learning resources from the federal government.

More than 1,500 federally supported teaching and learning resources are included from dozens of federal agencies. New sites are added regularly.

FREE is among the most popular K-12 websites maintained by the U.S. Department of Education because of the many great resources being offered by contributing federal agencies.

Hartshorn, Robert and Boren, Sue (1990). Experiential Learning of Mathematics: Using Manipulatives. *ERIC Digest.* Retrieved 9/1/2011 from http://www.ericdigests.org/pre-9217/math.htm. Quoting from the article:

Research suggests that manipulatives are particularly useful in helping children move from the concrete to the abstract level. Teachers, however, must choose activities and manipulatives carefully to support the introduction of abstract symbols. Heddens divided the transitional iconic level (the level between concrete and abstract) further into the semiconcrete and semiabstract levels, in the following way:

The semiconcrete level is a representation of a real situation; pictures of the real items are used rather than the items themselves. The semiabstract level involves a symbolic representation of concrete items, but the pictures do not look like the objects for which they stand. (Heddens, 1986, p.14).

IEEE (n.d.). *Institute of Electrical and Electronics Engineers.* Retrieved 1/9/2010 from http://www.ieee.org/web/aboutus/home/index.html. Quoting from the Website:

"A non-profit organization, IEEE is the world's leading professional association for the advancement of technology.

The IEEE name was originally an acronym for the Institute of Electrical and Electronics Engineers, Inc.

IEEE has:

- more than 375,000 members in more than 160 countries; 45 percent of whom are from outside the United States
- more than 80,000 student members
- 329 sections in ten geographic regions worldwide
- 1,860 chapters that unite local members with similar technical interests
- 1,789 student branches in 80 countries"

The **Try Engineering** Page at http://www.tryengineering.org/home.php "is a resource for students (ages 8-18), their parents, their teachers and their school counselors. This is a portal about engineering and engineering careers, and we hope it will help young people understand better what engineering means, and how an engineering career can be made part of their future."

Information Age Education Wiki (n.d.). *A Wiki about information age education.* Retrieved 10/29/2011 from http://iae-pedia.org/.

Contains entries on topics such as Brain Science, Computational Thinking, Critical Thinking, Education for Increasing Expertise, Information Underload and

Overload, Open Source Software Packages, Open Source Textbooks, and Problem Solving.

ISTE (n.d.). *International Society for Technology in Education.* Retrieved 10/29/2011 from http://www.iste.org/. Quoting from the Website:

"The International Society for Technology in Education (ISTE) is the trusted source for professional development, knowledge generation, advocacy, and leadership for innovation. A nonprofit membership organization, ISTE provides leadership and service to improve teaching, learning, and school leadership by advancing the effective use of technology in PK–12 and teacher education. Home of the National Educational Technology Standards (NETS), the Center for Applied Research in Educational Technology (CARET), and the National Educational Computing Conference (NECC), ISTE represents more than 85,000 professionals worldwide. We support our members with information, networking opportunities, and guidance as they face the challenge of transforming education."

ISTE has developed National Educational Technology Standards (NETS) for students and teachers. See http://www.iste.org/AM/Template.cfm?Section=NETS for profiles of what ISTE believes students should know and be able to do at various grade levels.

Kaiser Family Foundation (1/20/2010). *Generation $M^2$: Media in the Lives of 8- to 18-Year-Olds.* Retrieved 10/29/2011 from http://www.kff.org/entmedia/mh012010pkg.cfm. Quoting from the research report:

A national survey by the Kaiser Family Foundation found that with technology allowing nearly 24-hour media access as children and teens go about their daily lives, the amount of time young people spend with entertainment media has risen dramatically, especially among minority youth. Today, 8-18 year-olds devote an average of 7 hours and 38 minutes (7:38) to using entertainment media across a typical day (more than 53 hours a week). And because they spend so much of that time 'media multitasking' (using more than one medium at a time), they actually manage to pack a total of 10 hours and 45 minutes (10:45) worth of media content into those 7½ hours.

*Generation $M^2$: Media in the Lives of 8- to 18-Year-Olds* is the third in a series of large-scale, nationally representative surveys by the Foundation about young people's media use. It includes data from all three waves of the study (1999, 2004, and 2009), and is among the largest and most comprehensive publicly available sources of information about media use among American youth.

Klingberg, Torkel (2009). *The overflowing brain: Information overload and the limits of working memory.* NY: Oxford University Press.

Working memory is used to retain and manipulate information during a short period of time. This ability underlies complex reasoning as well as slightly less complex activities as reading and understanding a sentence.

A number of Klingberg's papers are available free online (retrieved 1/9/2011) at http://www.klingberglab.se/pub.html.

Lehrer, Jonah (5/18/2009). Don't! The secret of self control. *The New Yorker.* Retrieved 10/29/2011 from http://www.newyorker.com/reporting/2009/05/18/090518fa_fact_lehrer?currentPage=all.

> This article presents a nice introduction to and overview of gratification and the marshmallow test research. On average, young children who deal well with delayed gratification are apt to be much more successful in their lives than those who do not deal well with delayed gratification.

Moursund David (n.d.). *Mathematics education digital filing cabinet.* Retrieved 5/3/2010 from http://iae-pedia.org/Math_Education_Digital_Filing_Cabinet.

> This Website presents and illustrates the idea of a teacher or a student creating and maintaining a personal electronic filing cabinet in a discipline such as mathematics. It contains examples of the contents of Moursund's math education electronic digital filing cabinet.

Moursund, David (2008). *Introduction to using games in education: A guide for teachers and parents.* Retrieved 11/1/2011 from http://pages.uoregon.edu/moursund/Books/Games/Games1.pdf. Eugene, OR: Information Age Education. Quoting from the book:

> The word *game* means different things to different people. In this book, I explore a variety of board games, card games, dice games, word games, and puzzles that many children and adults play. Many of these games come in both non-electronic and electronic formats. This book places special emphasis on electronic games and the electronic versions of games originally developed in non-electronic formats.

Moursund, David (2008). *Becoming more responsible for your education.* Eugene, OR: Information Age Education. Retrieved 1/9/2011 http://i-a-e.org/downloads/doc_download/39-becoming-more-responsbile-for-your-education.html. Quoting from the book:

> In this book, "you" means a person perhaps in the 7th or 8th through the 12th grade. Your mind and body are changing rapidly. Most people achieve physical maturity in their late teens. People achieve most of their mental maturity by their mid 20s. With proper physical and mental exercise, your brain will continue to increase in overall capabilities well past middle age. Many people continue to gain in wisdom throughout their lives.
>
> This book will help you move toward achieving your brain's potentials. It will help prepare you for lifelong learning and effective lifelong use of your brain.

Moyer, Patricia, Johnna Bolyard, and Mark Spikell (February, 2003). What are Virtual Manipulatives? *Teaching Children Mathematics.* Retrieved 1/9/2010 from http://www.edtechleaders.org/documents/algebra/1whatarevms.pdf.

NASA (n.d.). *National Aeronautics and Space Administration.* Retrieved 1/9/2010 from http://www.nasa.gov/. Quoting from the Website:

> Since its inception in 1958, NASA has accomplished many great scientific and technological feats in air and space. NASA technology also has been adapted for

many non aerospace uses by the private sector. NASA remains a leading force in scientific research and in stimulating public interest in aerospace exploration, as well as science and technology in general. Perhaps more importantly, our exploration of space has taught us to view Earth, ourselves, and the universe in a new way. While the tremendous technical and scientific accomplishments of NASA demonstrate vividly that humans can achieve previously inconceivable feats, we also are humbled by the realization that Earth is just a tiny "blue marble" in the cosmos. Check out our "Thinking About NASA History" folder online as an introduction to how history can help you.

NASA for Students (n.d.). Retrieved 1/9/2010 from http://www.nasa.gov/audience/forstudents/index.html.

This site provides access to a tremendous collection of student resources. Examples include:

- NASA for students in grades K–4.
- NASA for students in grades 4–8.
- NASA for middle school and high school students.
- MyNASA. Students 13 years and older may use MyNASA to help with homework and projects relating to NASA.
- NASA Kid's Club: Play Fun Gamers.

NCTE (November 2008). The code of best practices in fair use for media literacy education. *National Council of Teachers of English.* Retrieved 1/9/2010 from http://www.ncte.org/positions/statements/fairusemedialiteracy. Quoting from this document:

This document is a code of best practices that helps educators using media literacy concepts and techniques to interpret the copyright doctrine of fair use. Fair use is the right to use copyrighted material without permission or payment under some circumstances -- especially when the cultural or social benefits of the use are predominant. It is a general right that applies even in situations where the law provides no specific authorization for the use in question -- as it does for certain narrowly defined classroom activities.

NCTM (n.d.). *National Council of Teachers of Mathematics.* Retrieved 1/9/2010 from http://www.nctm.org/. Quoting from the Website:

"The National Council of Teachers of Mathematics is a public voice of mathematics education, providing vision, leadership and professional development to support teachers in ensuring equitable mathematics learning of the highest quality for all students."

NCTM has developed recommendations on national standards for math education. See Standards and Focal Points at http://www.nctm.org/standards/default.aspx?id=58.

There are a tremendous number of resources available on the NCTM site. For example:

- Activities at http://illuminations.nctm.org/ActivitySearch.aspx.
- Family Resources at http://www.nctm.org/resources/families.aspx.
- Illuminations at http://illuminations.nctm.org/.

NSTA (n.d.). *National Science Teachers Association.* Retrieved 5/3/2010 from http://www.nsta.org/. Quoting from the Website:

> "Headquartered in Arlington, Virginia, the National Science Teachers Association is a member-driven organization, 60,000-strong. We publish books and journals for science teachers from kindergarten through college. Each year we hold four conferences on science education: three regional events in the fall and a national gathering in the spring. We provide ways for science teachers to connect with one another. We inform Congress and the public on vital questions affecting science literacy and a well-educated workforce. And with your help, we can do even more."
>
> The NSTA has developed recommendations on national standards for science education. See http://www.nsta.org/publications/nses.aspx.

NAP (n.d.). *The National Academies Press.* Retrieved 1/9/2011from http://www.nap.edu/about.html. Quoting from the Website:

> The National Academies Press (NAP) was created by the National Academies to publish the reports issued by the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and the National Research Council, all operating under a charter granted by the Congress of the United States. The NAP publishes more than 200 books a year on a wide range of topics in science, engineering, and health, capturing the most authoritative views on important issues in science and health policy. The institutions represented by the NAP are unique in that they attract the nation's leading experts in every field to serve on their award-winning panels and committees. This is the right place for definitive information on everything from space science to animal nutrition.
>
> We offer many titles in electronic Adobe PDF format. **Hundreds of these books can be downloaded for free by the chapter or the entire book, while others are available for purchase.** Our frequently asked questions guide answers questions about purchasing and accessing our electronic books. [Bold added for emphasis.]

Platoni, Karla (2008). Internet Explorers: Virtual Field Trips Are More Than Just Money Savers. *Edutopia.* Retrieved 10/29/2011 from http://www.edutopia.org/virtual-field-trips. Quoting from the article:

> Now, at last, technology is catching up to virtual field trips' possibilities. A new generation of trips is merging highly interactive Web sites with engaging storytelling, vibrant art, and curricula tied to national standards, creating a compelling way to explore the natural world without leaving campus.
>
> Here are our top four picks—and you can't beat the admission price: free.

Resnick, Mitchel et al. (2009). Scratch: Programming for all. *Communications of the ACM.* Retrieved 5/3/2010 from http://cacm.acm.org/magazines/2009/11/48421-scratch-programming-for-all/fulltext. Quoting from the article:

> Since the public launch in May 2007, the Scratch Web site has become a vibrant online community, with people sharing, discussing, and remixing one another's projects. Scratch has been called "the YouTube of interactive media." Each day, Scratchers from around the world upload more than 1,500 new projects to the site, with source code freely available for sharing and remixing. The site's collection of projects is wildly diverse, including video games, interactive newsletters, science simulations, virtual tours, birthday cards, animated dance contests, and interactive tutorials, all programmed in Scratch.
>
> The core audience on the site is between the ages of eight and 16 (peaking at 12), though a sizeable group of adults participates as well. As Scratchers program and share interactive projects, they learn important mathematical and computational concepts, as well as how to think creatively, reason systematically, and work collaboratively: all essential skills for the 21st century. Indeed, our primary goal is not to prepare people for careers as professional programmers but to nurture a new generation of creative, systematic thinkers comfortable using programming to express their ideas.

Rideout, Victoria et al. (January 2010). Generation $M^2$: Media in the lives of 8 to 18-year olds. *A Kaiser Family Foundation Study.* Retrieved 1/9/2010 from http://www.kff.org/entmedia/upload/8010.pdf. Quoting from the Website:

> Generation $M^2$: Media in the Lives of 8- to 18-Year-Olds is the third in a series of large-scale, nationally representative surveys by the Foundation about young people's media use. The report is based on a survey conducted between October 2008 and May 2009 among a nationally representative sample of 2,002 3rd-12th grade students ages 8-18, including a self-selected subsample of 702 respondents who completed seven-day media use diaries, which were used to calculate multitasking proportions.

Stanford University (n.d.). *HighWire Press.* Retrieved 1/9/2011: http://highwire.stanford.edu/lists/freeart.dtl. Quoting from the Website:

> HighWire Press is the largest archive of free full-text science on Earth! As of 1/9/11, we are assisting in the online publication of 2,148,106 free full-text articles and 6,484,696 total articles. There are 22 sites with free trial periods, and 47 completely free sites. 284 sites have free back issues, and 1237 sites have pay per view!

The Math Forum @ Drexel (n.d.). *Using manipulatives.* Retrieved 6/20/2010 from http://mathforum.org/t2t/faq/faq.manipulatives.html. Here is a quote from Vanessa B. Stuart:

> "As manipulatives and cooperative groups become more widely used in mathematics classes, I wanted to know whether students perceived these aids and situations as being useful learning tools. Three-fourths of the students thought that using manipulatives when learning a new mathematical concept was helpful. Most of the comments indicated that using manipulatives first helped students see

the origin of the numbers in the formulas. Fewer than one-fourth of the students said that manipulatives were not helpful learning tools, stating that they were confusing."

Tucker-Ladd, Clayton E. (2000). *Psychological self-help.* Retrieved 1/9/2011: http://www.psychologicalselfhelpCo.org/Chapter9/chap9_93.html. Quoting from the document:

> Competition vs. Cooperation
>
> Humans seem preoccupied with the question, "Who is best?" In chapter 5, we talked about feeling anxious and inadequate in some tasks (relative to other people). In chapter 6, we dealt with depression and feeling inferior (as a person) to others. In chapter 7, the topics were hostility, discrimination, and feeling superior to others. In chapter 8, there was an extended discussion of dependency and women's socially assigned subordinate roles. Over and over it appears as though we are thinking about "Who is on top?" and "How do I measure up?" This destructive, competitive, win-lose situation, discussed fully by Kohn (1986), is connected with personally feeling superior--chauvinistic--or inferior to others.

Watson, John et al. (February 2010). A parent's guide to choosing the right online program. *International Association for K-12 Online Learning.* 23-page booklet retrieved 1/9/2011 from http://www.inacol.org/research/promisingpractices/iNACOL_ParentsGuide.pdf.

Wikipedia (n.d.). Wikipedia, the free encyclopedia. Retrieved 1/9/2011: http://en.wikipedia.org/wiki/Wikipedia. See also: http://iae-pedia.org/Wikipedia. Quoting from the Wikipedia Website:

> Wikipedia is a free, web-based and collaborative multilingual encyclopedia, born in the project supported by the non-profit Wikimedia Foundation. Its name is a portmanteau of the words wiki (a technology for creating collaborative websites, from the Hawaiian word wiki, meaning "quick") and encyclopedia. Wikipedia's 17 million articles (over 3.5 million in English) have been written collaboratively by volunteers around the world, and almost all of its articles can be edited by anyone who can access the Wikipedia website. Launched in January 2001 by Jimmy Wales and Larry Sanger, it is currently the most popular general reference work on the Internet.

Willis, Judy (10/5/2011). Three brain-based teaching strategies to build executive function in students. Edutopia. Retrieved 10/8/2011 from http://www.edutopia.org/blog/brain-based-teaching-strategies-judy-willis. The article includes links to a number of her other education-related articles. Quoting from the article:

> For young brains to retain information, they need to apply it. Information learned by rote memorization will not enter the sturdy long-term neural networks in the pre-frontal cortex (PFC) unless students have the opportunity to actively recognize relationships to their prior knowledge and/or apply new learning to new situations.

Wolpert, Stuart (1/27/09). Is technology producing a decline in critical thinking and analysis? *UCLA Newsroom.* Retrieved 10/29/2011 from http://newsroom.ucla.edu/portal/ucla/is-technology-producing-a-decline-79127.aspx. Quoting from the report:

As technology has played a bigger role in our lives, our skills in critical thinking and analysis have declined, while our visual skills have improved, according to research by Patricia Greenfield, UCLA distinguished professor of psychology and director of the Children's Digital Media Center, Los Angeles.

Learners have changed as a result of their exposure to technology, says Greenfield, who analyzed more than 50 studies on learning and technology, including research on multi-tasking and the use of computers, the Internet and video games.

Reading for pleasure, which has declined among young people in recent decades, enhances thinking and engages the imagination in a way that visual media such as video games and television do not, Greenfield said.

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