

Computers in Education for Talented and Gifted Students: A Book for Elementary and Middle School Teachers

"Ability will never catch up with the demand for it."
(Confucius)

"An intellectual is someone whose mind watches itself." (Albert Camus; French novelist, essayist and playwright, who received the 1957 Nobel Prize for literature.)

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About Dave Moursund, the Author

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- Assistant Professor and then Associate Professor, Department of Mathematics, Michigan State University; Associate Professor, Department of Mathematics, University of Oregon.
- Associate Professor and then Full Professor, Department of Computer Science, University of Oregon; served as Head of the Computer Science Department at the University of Oregon for six years.
- Full Professor in the College of Education at the UO for more than 20 years.
- Founded the International Society for Technology in Education and headed up this organization for 19 years.
- Author or co-author of about 40 books and several hundred articles in the field of computers in education.
- Served as a major professor for about 50 doctoral students (six in math, the rest in education).

In recent years, one of my major goals has been to contribute to improving our overall educational system. For more information about me and for free (online, no cost) access to a number of my books and articles, go to <http://darkwing.uoregon.edu/~moursund/dave/>.

(Dave Moursund, 1/1/2006)

Preface

“The principal goal of education in the schools should be creating men and women who are capable of doing new things, not simply repeating what other generations have done.” (Jean Piaget, 1896-1980)

“Our schools, teachers, and students might be a lot better off if schools embraced the idea that education means learning what to do when you don’t know what to do.” (Eliot Eisner. Back to the whole child. *Educational Leadership*, September 2005.)

This book explores various roles of Information and Communication Technology (ICT) in talented and gifted (TAG) education. The three goals of this book are:

- To help improve the educational opportunities and education of TAG students.
- To increase the general knowledge of teachers about the field of computers in education.
- To explore some possible changes designed to improve our educational system. Many of the ideas in this book are applicable to all students, not just TAG students.

Most of the content of this book has been written specifically for preservice or inservice “regular education” elementary and middle school teachers. When I say “you” in this book, I mean “the reader,” but I am assuming that most readers will be preservice and inservice regular education teachers. Other possible readers include parents, TAG teachers, TAG students, school administrators, and so on. The book assumes some familiarity with education in general, but does not assume specific previous knowledge about TAG education.

There is sufficient material in this book to support a 1-credit course or a workshop that is a couple of days in length. Alternatively, parts of the book can be used to support a unit within a 3 or 4-credit computers in education course. Each chapter ends with a short list of questions that can be used for discussion in classes or in workshops, or as written assignments.

Cognitively Challenged and Cognitively Gifted Students

The article *Giftedness and the gifted* (ERIC Digest, 1990) says, “using a broad definition of giftedness, a school system could expect to identify 10% to 15% or more of its student population as gifted and talented.”

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This book explores a variety of measures of giftedness. One measure is rate of learning. A cognitively gifted may have a learning rate that is perhaps one-and-a-half to two or more times the rate of average students. In an elementary or middle school classroom of 25 to 30 students, perhaps two or three students will have this superior rate of learning. Such students tend to get good grades and their accumulated knowledge and skills moves well ahead of average students over a period of years.

There are many different definitions of what constitutes being cognitively gifted. Historically, TAG education is most often focused on students who are exceptionally cognitively talented relative to average students. Chapter 1 explores definitions of TAG. It also provides some general background and overview information to support later chapters of the book.

A student may be TAG in some areas and not in others. Indeed, a TAG student may also be a special education student. As an example, a professional acquaintance of mine has a child who is severely autistic. This child is also profoundly gifted, with an IQ of over 180! Stephen Hawking (n.d.) is often named as an example of such a person. Our educational system is challenged by the difficulty in identifying and appropriately working with students with multiple exceptionalities (OTECa, n.d.; Willard-Holt, 1999).

Auxiliary Brain (Distributed Intelligence)

A human brain can do lots of things better than the very best of current multimillion-dollar supercomputers. On the other hand, even inexpensive microcomputers can do lots of things much better than a human brain. These facts have been evident since the first electronic digital computers were built more than 60 years ago. These facts are true for cognitively challenged students and for cognitively gifted students. One way to think about a computer is that it is a type of auxiliary brain—a tool designed as an accommodation to certain types of weaknesses found in all human brains.

The cost effectiveness of electronic computers has improved by a factor of more than a **billion** since the mass production of computers began in 1951. (This figure comes from the fact that a microcomputer is more than a million times as fast and costs less than 1/1,000 as much as the UNIVAC I.) Computers have become much faster, have larger primary and secondary storage memory devices, and have much improved software. Human-machine interfaces and telecommunications systems have been substantially improved. This rapid pace of improvement in ICT systems seems likely to continue well into the future.

From the very beginning, computers were often called “brains” or “electronic brains.” Even an inexpensive handheld calculator can be thought of as a brain tool, as a supplement to your brain, as an auxiliary brain. Another way to think and talk about this situation is to use the term *distributed intelligence*. Various aspects of intelligence can be distributed among a team of people and ICT systems working together to solve a problem or accomplish a task.

Our educational system has not done very well in preparing students to work in an environment in which increasingly powerful auxiliary brains are becoming more and more available. Most students are not learning to work in a distributed intelligence environment, where the ICT components of that environment are growing steadily more capable, year after year. This book contains a number of ways to address auxiliary brain, distributed intelligence issue in TAG education. Many of these are applicable to the education of all students.

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Other Big Ideas and Themes

Joseph S. Renzulli is one of the world's leading TAG educators. Renzulli feels that TAG education opportunities should be a regular part of the curriculum for all students in a regular classroom. Some of Renzulli's schoolwide ideas are discussed in Chapter 3.

Here is a list of some other Big Ideas woven into this book:

1. Empowering students. Helping students learn to learn and to be self-reliant learners, able to self-assess and to self-direct their learning efforts. This includes topics such as:
 - Expertise. Helping students to increase their levels of expertise in required curriculum areas and in areas of their choice.
 - Self-knowledge and metacognition. Helping students to learn about themselves—their capabilities, limitations, interests, and drives.
 - Self-assessment. Helping students learn to assess their own learning, abilities, and cognitive progress.
 - Transfer of learning. Helping students learn to learn in a manner that promotes transfer of learning and increases their ability to make use of their learning in novel settings.
2. Human intelligence and artificial intelligence. Chapter 2 provides general background and summarizes some of the current research in this area.
3. Problem solving. ICT provides aids to problem solving and to increasing expertise in every discipline. Chapter 4 provides an introduction to roles to ICT in solving challenging problems and accomplishing challenging tasks. It takes an approach of considering the ICT tools as augmentative devices, aids to the mind and brain.
4. Project-based learning. Chapter 5 contains an introduction to ICT-Assisted PBL. ICT-assisted PBL can be used to create teaching and learning environments that are especially suited to TAG students. However, the general ideas presented in Chapter 5 are applicable to all students. Appendix 1 contains a number of PBL activities designed especially for TAG students.
5. Computer games. Chapter 6 introduces computer games in education. Computer games are now being recognized as a powerful aid to learning and cognitive involvement. The creation and study of games can be an intrinsically motivating project for TAG students. The topics of developing games and learning to play games fits in well with ICT-Assisted PBL and is applicable to all students.

You should notice that all of these ideas are relevant to all students, not just to TAG students. However, the primary focus in this book is on exploring these ideas for TAG students.

Reference Materials

This book is designed to be read online, although some people will undoubtedly print it out and read it off-line. This book contains a large number of references. Most of the items in the References section of this book include links to Websites. When searching the literature, I try to pick references from Websites that are apt to be long lived. However, I still find that about 10 to

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15 percent of such links are broken within the first year after publication. I apologize for any inconvenience this may cause you.

Dave Moursund

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Chapter 1

Introduction

“...the Gods do not grace all men alike in speech, person, and understanding. One man may be of weak presence, but heaven has adorned this with such good conversation that he charms every one who sees him; his honeyed moderation carries his hearers with him so that he is leader in all assemblies of his fellows, and where ever he goes he is looked up to. Another may be as handsome as a God, but his good looks are not crowned with discretion.” (Homer, approximately 6th century B.C.)

This chapter contains background information that helps support the remainder of the book. It also contains an introduction to some of the content presented in later chapters. It assumes that you have read the Preface.

Please notice that this chapter and subsequent chapters contain a large number of Web-based references. Some are in-line “clickable” references, inserted to help encourage you to browse them while reading this short book. For example, I found the ERIC Digest article Giftedness and the Gifted (1990) (<http://ericec.org/digests/e476.html>) to be an excellent introduction to TAG education, even though the article is now rather old. Take a brief look at it, to see whether the article appeals to you. Notice how TAG education is not a new topic and that approaches to TAG education have been slow to change.

The Davidson Institute’s GT-CyberSource (Davidson, n.d.) provides access to hundreds of TAG articles and provides considerable information about TAG education in the United States (http://www.gt-cybersource.org/ReadArticleNew.aspx?NavID=2_0) See also (NWREL, 1999).

Talented and Gifted

While the two terms *talented* and *gifted* do not have exactly the same meaning, most people use them interchangeably. For example, World Book Dictionary (World Book Multimedia Encyclopedia Version 9.0, 2004) defines these two terms:

Talented: having natural ability; gifted.

Gifted: having natural talent or special ability; unusually able; talented.

Sometimes an attempt is made to differentiate between the two terms. For example, giftedness may be defined by a score on a general IQ test, while talent may be defined by knowledge, skills, and performance in a specific discipline area such as math, music, or writing.

A somewhat similar approach is to talk about ability versus attainment:

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Ability tests measure a persons potential, for instance to learn the skills needed for a new job or to cope with the demands of a training course. Ability tests are not the same thing as Tests of Attainment. (Career Counseling Center, n.d.)

From this point of view, abilities are gifts, while talents are what one develops from his or her abilities. This fits in well with the brief discussion of intelligence and IQ given later in this chapter.

The Web contains a huge number of sites that discuss TAG education. For example, a Google search on 12/22/05 on the expression *talented and gifted education* produced nearly three million hits.

The literature for each specific state is also quite large. For my home state Oregon, a 12/22/05 Google search on *Oregon Talented and Gifted Education* produced 726,000 hits. Moreover, each state has one or more TAG Associations (<http://www.gifted.uconn.edu/stategt.html>), and most of these have Websites. (Did you click on the link to see if your state is listed, and then go on to use the Web to search for more information about TAG in your state?)

The importance of and/or funding for TAG education in the United States varies widely from state to state. At a national level, TAG is considered important, but it receives relatively little funding and is not mandated.

Without a federal law to protect the legal rights of gifted children, the responsibility for such mandates rests with the states. Approximately 30 states have a mandate to serve gifted children, while the remaining ones have permissive legislation (Council of State Directors of Programs for the Gifted, 1994). The National Association for Gifted Children has written a position paper supporting the concept that each state should mandate by law educational opportunities for gifted children. (Karnes and Marquardt, 1997)

[Note to readers: This book contains a large number of brief quotes. As illustrated above, I have used a smaller font size, and indented and referenced such materials.]

However, the U.S. Federal Government does support the National Research Center on the Gifted and Talented (<http://www.gifted.uconn.edu/nrcgt.html>) (NRC/GT, n.d.). Quoting from its Website:

The work of The National Research Center on the Gifted and Talented (NRC/GT) is guided by emerging research about the broadened conception of human potential and the need to develop "high-end learning" opportunities for all of America's students. Programs and services designed to challenge the highest levels of learning and creativity; to promote high expectations, rigorous standards, and greater engagement with subject matter should be an integral part of every school's overall program. ... Accordingly, our orientation and related research has been to apply the strategies of high-end learning to total school improvement and to focus our research on developing gifts and talents in young people based on a broad array of both traditional and emerging indicators of potential for high performance.

Definitions of Giftedness

There are many different definitions of TAG. The literature often refers to the following statement by former U. S. Commissioner of Education Sidney P. Marland contained in his August 1971 report to the U.S. Congress.

Gifted and talented children are those identified by professionally qualified persons who by virtue of outstanding abilities are capable of high performance. These are children who require

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differentiated educational programs and/or services beyond those normally provided by the regular school program in order to realize their contribution to self and society (Marland, 1971).

It is quite common to use IQ tests to identify or help identify TAG students, and there are good reasons for using this approach. Quoting from an excellent article in *Scientific American*:

The debate over intelligence and intelligence testing focuses on the question of whether it is useful or meaningful to evaluate people according to a single major dimension of cognitive competence. Is there indeed a general mental ability we commonly call "intelligence," and is it important in the practical affairs of life? The answer, based on decades of intelligence research, is an unequivocal yes. No matter their form or content, tests of mental skills invariably point to the existence of a global factor that permeates all aspects of cognition. And this factor seems to have considerable influence on a person's practical quality of life. **Intelligence as measured by IQ tests is the single most effective predictor known of individual performance at school and on the job** (Gottfredson, 1998). [Bold added for emphasis.]

The following quote from the ERIC Clearinghouse on Disabilities and Gifted Education defines three levels of giftedness in terms of scores on the Weschler Intelligence Scale for Children.

Highly and profoundly gifted students are children whose needs are so far beyond "typical" gifted that they require extraordinary resources. When tested with a Weschler Intelligence Scale for Children (WISC), their scores range from 145 to 159 for highly gifted and above 160 for profoundly gifted. In those ranges, these children are as different in intellectual abilities from gifted children (usually 130 to 144) as gifted are from a typical regular education population. **IQ scores do not tell the whole story; however, they are a useful indicator of individual differences, particularly when used to inform instruction** (ERIC, Profoundly Gifted, n.d.). [Bold added for emphasis.]

A 1993 report from the U.S. Department of Education provides some history of TAG education and definitions used at the Federal level. Quoting from *National Excellence* (1993):

More than 20 years have elapsed since the last national report [the Marland report] on the status of educating gifted and talented students. Much has changed since that report alerted Americans to the pressing needs of these youngsters and challenged policymakers to provide them with a better education.

National Excellence: The Case for Developing America's Talent discusses these changes. It also describes the "quiet crisis" that continues in how we educate top students. **Youngsters with gifts and talents that range from mathematical to musical are still not challenged to work to their full potential.** Our neglect of these students makes it impossible for Americans to compete in a global economy demanding their skills. [Bold added for emphasis.]

The *National Evidence* report contains the following definition of and statement about TAG:

[Definition] Children and youth with outstanding talent perform or who show the potential for performing at remarkably high levels of accomplishment when compared with others of their age, experience, or environment.

These children and youth exhibit high performance capability in intellectual, creative, and/or artistic areas, possess an unusual leadership capacity, or excel in specific academic fields. They require services or activities not ordinarily provided by the schools.

Outstanding talents are present in children and youth from all cultural groups, across all economic strata, and in all areas of human endeavor.

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Identification of TAG Students

Efforts to identify TAG students, as well as programs to support their special needs, vary widely throughout the country. Montgomery County, Maryland provides an example of a comprehensive effort to identify TAG students (Aratani, 2005).

In Montgomery County, educators begin identifying students as gifted and talented at the end of second grade, using what they call global screening, a process that includes parent and teacher input and test scores from specially designated exams. If a child is not identified as gifted and talented at that time, parents can appeal the decision. They also have the option of asking that their child be reevaluated at any time during his or her school career, said system spokesman Brian Edwards.

Edwards said the county does everything it can to ensure that all students have access to the programs. He noted that Montgomery is one of the few systems that screens all students for eligibility, rather than just a select few.

The Montgomery County approach is consistent with the research literature that recommends something more is needed than a single test with an arbitrary cutoff point. The following is quoted from an ERIC Digest article (Coleman, 2003):

The best identification practices rely on multiple criteria to look for students with gifts and talents. Multiple criteria involve:

- multiple types of information (e.g., indicators of student's cognitive abilities, academic achievement, performance in a variety of settings, interests, creativity, motivation; and learning characteristics/behaviors);
- multiple sources of information (e.g., test scores, school grades, and comments by classroom teachers, specialty area teachers, counselors, parents, peers, and the students themselves); and
- multiple time periods to ensure that students are not missed by "one shot" identification procedures that often take place at the end of second or third grade.

It is not always easy to identify TAG students. James Webb and Diane Latimer (1993) discuss identification and provide an excellent example of the challenge of distinguishing a TAG student from an Attention Deficit Hyperactive Disorder student and from a student who has both exceptionalities. The following table is quoted from their paper.

| Behaviors Associated With ADHD | Behaviors Associated With Giftedness |
|---|---|
| Poorly sustained attention in almost all situations | Poor attention, boredom, daydreaming in specific situations |
| Diminished persistence on tasks not having immediate consequences | Low tolerance for persistence on tasks that seem irrelevant |
| Impulsivity, poor delay of gratification | Judgment lags behind development of intellect |
| Impaired adherence to commands to regulate or inhibit behavior in social contexts | Intensity may lead to power struggles with authorities |
| More active, restless than normal children | High activity level; may need less sleep |
| Difficulty adhering to rules and regulations | Questions rules, customs and traditions |

Figure 1.1. Some similarities between ADHD and TAG.

Even within a specific discipline such as mathematics, it is not easy to identify TAG students. Quoting from Miller (1990):

Mathematical talent refers to an unusually high ability to understand mathematical ideas and to reason mathematically, rather than just a high ability to do arithmetic computations or get top grades in mathematics. When considering mathematical talent, many people place too much emphasis on computational skill or high ability in replicating taught mathematical procedures.

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Unless mathematical talent is correctly perceived, however, important clues can be overlooked and less important clues can be given too much significance.

Some characteristics and behaviors that may yield important clues in discovering high mathematical talent are the following:

- An unusually keen awareness of and intense curiosity about numeric information.
- An unusual quickness in learning, understanding, and applying mathematical ideas.
- A high ability to think and work abstractly and the ability to see mathematical patterns and relationships.
- An unusual ability to think and work with mathematical problems in flexible, creative ways rather than in a stereotypic fashion.
- An unusual ability to transfer learning to new, untaught mathematical situations.

Notice the emphasis on quickness of learning, understanding, problem solving, creativity, and transfer of learning. These are key aspects of being TAG in any particular discipline.

Expertise in a Discipline or Domain

In general terms, each discipline or domain of study can be defined by its unique combination of:

- The types of problems, tasks, and activities it addresses.
- Its tools, methodologies, and types of evidence and arguments used in solving problems, accomplishing tasks, and recording and sharing accumulated results.
- Its accumulated accomplishments such as results, achievements, products, performances, scope, power, uses, impact on the societies of the world, and so on.
- Its history, culture, language (including notation and special vocabulary), and methods of teaching, learning, and assessment.
- Its particular sense of beauty and wonder. A mathematician's idea of a "beautiful proof" is quite a bit different than an artist's idea of a beautiful painting.

This section introduces the idea of a student developing a talent—gaining increasing expertise in a broad discipline or a narrower domain. You can think about your current level of expertise in disciplines such as art, dance, math, reading, writing, science, and social science, and other domains. In addition, you can select much smaller areas, such as mental arithmetic, drawing using a pencil, playing a specific musical instrument, dinosaurs, steam engine locomotives, or any other area in which have developed some talent. Within any area, you currently have a certain level of expertise (see Figure 1.2). Through study and practice, you can increase this level of expertise.

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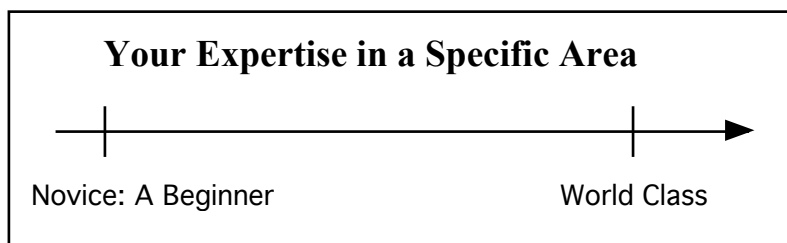


Figure 1.2. Expertise scale.

Practice using this scale by selecting several different areas, and rating your current level of expertise for each. Select some areas where your learning has been mainly informal, learning on your own. Select some other areas in which the learning has been more formal, such as in school. Select some areas where you feel you are naturally gifted, and others where you feel you are not naturally gifted.

Next, think about what you have done to achieve your current level of expertise in each of the areas you have selected, and what it takes to increase your level of expertise in each area. Are you good at learning on your own? What would it take to increase your expertise as a self-sufficient—learn on your own—type of person?

Think about the last sentence in the previous paragraph. It is talking about increasing your expertise as a learner. As a preservice or inservice teacher, what do you know about helping a student to increase his or her level of expertise as a learner in the various disciplines you teach? Is this type of instruction one of the areas of strength of our precollege curriculum, or is it one where substantial improvement might be possible?

My personal opinion is that our education system is weak in the area of helping students to learn to learn. That is, largely, students are left on their own as they work to increase their expertise as learners. TAG students on average are better able to develop this type of expertise at a faster rate and to a greater extent than average students. All students can benefit by explicit instruction designed to help increase their learning expertise.

In discussing expertise, it is interesting to select some narrow areas and to consider the idea that a young student can develop a high level of expertise relative to their peers, parents, and teachers. There is a significant amount of research literature on “Islands of Expertise” and the idea that with appropriate encouragement and help, a child can develop a number of different islands of expertise. Building an island of expertise tends to boost a child’s self esteem. It also provides a reference point for self-assessment (<http://members.tripod.com/~ozpk/000000selfassess>) in future learning activities (Crowley and Jacobs, 2002).

Brain Science and Expertise

The next chapter of this book discusses human and artificial intelligence. Both areas relate to current research in brain science.

Progress in brain science is helping us to understand what happens in the brain as one uses their current level of expertise in an area. It has also given us some insights into developing and using one’s areas of expertise. For example, consider the general area of dealing with problems. One hemisphere (the left, for most people) stores patterns of previously encountered problems,

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along with actions takes to solve the problems. The other hemisphere (the right, for most people) is designed to deal with novel situations. When presented with a novel, challenging problem, both the right hemisphere and the left hemisphere of a person's brain examine the situation and begin to work on the problem.

If the problem one is addressing can be handled by the left hemisphere, it does so, often operating very quickly to produce a solution. If the problem has considerable novelty, the right hemisphere struggles with it. Developing a solution may take a very long time. Of course, many problems fall between these extremes.

Now, the point to this brain science discussion is that increasing expertise in an area consists of a combination of:

1. Developing an increasing repertoire of patterns in one's left hemisphere that can quickly, often with little conscious thought, recognize and solve a problem.
2. Learning and gaining skill in using a variety of strategies for analyzing a problem, breaking off pieces that can be handled by the left hemisphere and pieces that require careful attention by the right hemisphere.
3. Developing the capabilities of the right hemisphere to deal with complex, challenging problems that one has not previously encountered.

In many areas, it can take years of study and practice to come close to achieving one's potential. For example, suppose one has the potential to become world class in an academic or athletic area. Then it typically takes 10 to 12 years (averaging perhaps a thousand hours or more per year) of very hard work to achieve this potential.

Of course, the amount of time varies with the area. If the accumulated knowledge and/or the skill levels in an area are very large, then it takes more time to become world class in the area. Science, math, and chess provide good examples of areas in which a combination of considerable natural ability and more than ten years of concerted effort are required to reach high levels of expertise.

As an alternative example, consider the situation faced by people when microcomputers were first being developed. In essence, the development of integrated circuits—for example, a single chip central processing unit—defined a new discipline. Steve Job and Steve Wozniak moved into this new discipline and quickly became world class—and started the Apple Corporation. A few years later Bill Gates quickly became world class in the more limited domain of operating systems for microcomputers. The result was Microsoft Corporation.

The previous paragraph is particularly relevant to TAG education. Because a TAG student learns much faster and better than average students, he or she has the time to develop relatively high levels of expertise in a variety of areas. Because ICT is a relatively new area and is a rapidly changing area, TAG students have the opportunity to “get ahead of the learning curve.” That is, they can relatively quickly learn enough about ICT so that they know far more than their fellow students and more than most of their teachers.

Metacognition

There are many different areas in which a student might work to increase his or her level of expertise. Some of these areas are interdisciplinary, cutting across many disciplines. Expertise in using a word processor or email provide good examples of this. Others are rather discipline

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specific. For example, a student might want to develop a high level of expertise in women's professional basketball.

In the process of living and growing up, all students learn about themselves. They learn about their strengths and weaknesses, and about their likes and dislikes. They learn some thinking about their thinking processes.

Metacognition (<http://www.gse.buffalo.edu/fas/shuell/cep564/Metacog.htm>) is knowledge about your own thought and thinking processes. Metacognition is thinking about one's thinking, and it is an important approach to improving one's cognitive processes. Through study and practice, one can increase their level of expertise in metacognition. This is useful in all areas of learning, problem solving, and other areas of higher-order thinking.

The next chapter of this book includes Howard Gardner's ideas about Multiple Intelligences. Intrapersonal intelligence is one of the eight intelligences proposed by Gardner. One makes use of this area of intelligence in doing metacognition.

Lower-order and Higher-order Knowledge and Skills

The above discussion about expertise can help us in the design of curriculum and can help individual students in making decisions as to how they want to expend their learning time and efforts. The diagram of Figure 1.3 is sort of like the diagram of Figure 1.2, but now the focus is on lower-order knowledge and skills, higher-order knowledge and skills, and moving up the expertise scale. From the point of view of a learner, lower-order tends to mean "stuff" that has already been mastered, while higher-order tends to mean new stuff that need to be learned. The idea is to have a learning environment that focuses most of its attention at a level a little above where the learner currently is—as illustrated by the large dot in the diagram.

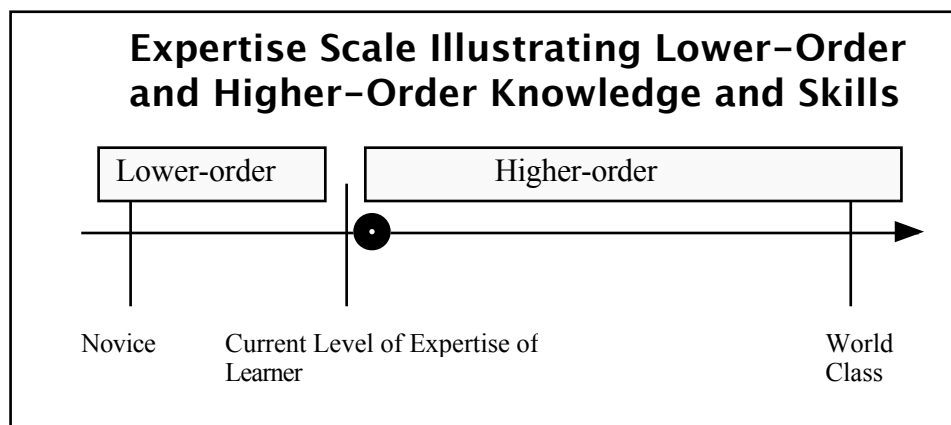


Figure 1.3. A student's view of lower-order and higher-order.

Figure 1.3 helps to explain why TAG students often find the curriculum and instruction in the regular classroom does not fit their needs. In subjects that interest them, they are apt to have a much higher level of expertise than the average for a class. Moreover, their rate of learning is apt to be considerable faster than average. Thus, they are sitting in a class where the instruction is both below their current expertise level and is proceeding at a painfully slow rate. They find this boring!

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At the same time, a number of the students in the class have a level of expertise that is lower than the class average. From their point of view, the curriculum and instruction covers higher-order knowledge and skills that is much too far above their current level of expertise. Our educational system puts a lot of money into attempting to individualize instruction to better meet the needs of these less cognitively able students.

ICT enters into this teaching and learning situation in two ways. First, computer-assisted learning and distance learning are powerful aids to individualization of instruction and learning. Second, ICT provides many tools that help a learner spend less time on lower-order knowledge and skills, and thus more time on higher-order knowledge and skills. For example, consider a child with a high level of verbal fluency who is just learning to write. It takes a lot of time and effort to learn to write legibly and to spell reasonably well. A word processor with a good spelling checker is a major help to writing legibly and decreasing the number of one's spelling errors.

Note that if a child is dyslexic and/or has certain types of motor control challenges, our educational system thinks it is perfectly acceptable for the child to use a word processor and spelling checker. You might want to spend some time thinking about arguments for and against providing this set of tools to all students (including TAG students) in the early grades.

Here is a somewhat similar example, but not nearly so controversial. Primary school students can learn to compose, edit, and perform electronic music. The learning curve to achieving an enjoyable level of expertise is much less steep than it is for learning to play an instrument such as a piano or a violin, and to compose and edit music for such instruments. This use of ICT adds a new dimension to music education. This new dimension can become an island of expertise for many students.

For still another example, think about digital still and video photography, and computer animation. With today's computer tools, students of all ages can achieve a level of photography and animation expertise that is much higher than that of most adults.

The last two examples are particularly important. In some areas, computer tools are so powerful that they empower their users to quickly learn to accomplish tasks that used to take years to learn. Think about what this can mean in the education of a child who happens to have significant artistic and musical ability. Also, think of the challenges the regular classroom teacher faces as students with such abilities, interests, and emerging talents seek to develop them through the regular school classroom and curriculum

Education for TAG Students

Many different approaches are taken in attempts to provide an appropriate educational environment for TAG students. If there were one "best" approach, then quite likely this approach would be well understood and widely implemented. However, it is clear that there is no one best approach.

The Carnegie Mellon Institute for Talented Elementary and Secondary Students was founded in 1992 and provides many services for academically TAG students in Pennsylvania. (C-MITES, n.d.) TAG students vary widely in their areas of ability, interests, and developed talents. The school environments and funding resources available to improve their education vary widely. The information quoted below comes from a C-MITES Website (Shoplik, 2004). It provides a

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quick summary of Anne Shoplik's ideas on various types of interventions applicable to students in a regular classroom.

1. Tutor Other Children This option is NOT recommended. Although it seems like a good idea to have bright students tutor others who are having difficulty, it is not a good use of their school time. ... Students should spend their classroom time learning new material.
2. Work Ahead in the Textbook at His or Her Own Pace, Usually Isolated in the Back of the Classroom This option is also NOT recommended
3. Work on an Independent Study Project This option is recommended as a supplement to the regular curriculum, but it is not meant to be a substitute for curriculum compacting and proper pacing.
4. Work on the Same Material as Other Students, Only in Greater Depth This approach avoids the problem of students being given more of the same work (also known as "busy work").
5. Explore Enrichment Topics in the Regular Classroom This option could be provided using [learning] centers.
6. Compact the Curriculum Compacting the regular curriculum opens up more time for gifted students to study enrichment topics.
7. Work on Assignments in Small Groups with Other Advanced Students This option, known as "homogeneous grouping" or "ability grouping" can occur when an entire classroom is composed of students of similar abilities, or when a classroom of students is divided into groups based on ability.

Homogeneous grouping is not popular in the United States today, mainly due to concerns about limiting opportunities for those not in the highest level groups. This problem can be avoided with proper planning, however, and research shows that ability grouping is one of the preferred options for academically talented students.

8. Move Up a Grade in One Subject This can be another good option for students who are particularly talented in one area. Whole-grade acceleration can also be considered if the child is talented in all subject areas.
9. Participate in Mentor-Paced Programs that Replace the Regular Curriculum [This option] is ideal for those students who are exceptionally talented and need much more challenge and acceleration than the regular curriculum offers.

Summary

TAG is complex and challenging to define. The percentages of students identified as TAG vary considerable among the states and among grade levels. TAG covers a huge range of children. An important distinguishing characteristic of TAG students is their ability to learn much faster and much better than average students.

Assistive technologies have long been routinely used in our society. ICT is making possible a wide range of cognitive-assistance devices, and many are widely used both by TAG students and other students. The growing availability and capability of such assistive devices is a challenge to our educational system and to students of all ages.

This book has a strong focus on ICT aspects of a TAG student's breadth and depth of expertise. For each area in which a TAG student is working to increase his or her expertise, ICT is potentially part of the content to be learned, an aid to learning the content, and an aid to solving the problems and accomplishing of the area. These topics will be explored more in later chapters.

Activities and Discussion Topics

Each chapter ends with some activities for the reader. If you are using this book in a formal class, some of these activities might be assigned as homework or used for inclass discussions. If you are using this book on your own, browse through the activities and spend a little time thinking about each one.

1. Reflect on your own cognitive talents and how they have developed in the past. What sorts of things could have happened in the past to better develop your cognitive talents?
2. Select several different teaching related areas that you consider important. For each, rate yourself on the scale given in Figure 1.4. They analyze and discuss the results.

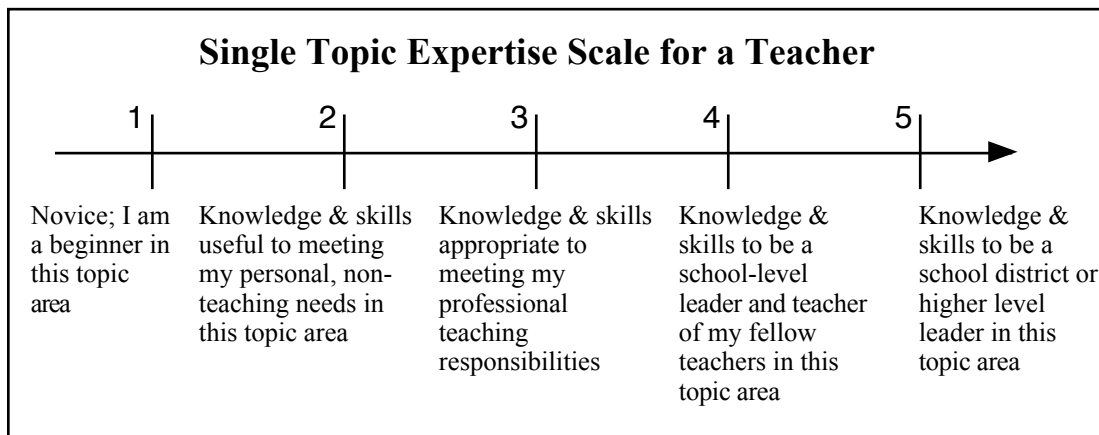


Figure 1.4. Single topic expertise scale for a teacher.

3. What are your personal thoughts about singling out children who are cognitively challenged and giving them special attention in school? Answer the same question for children who are cognitively gifted, and then compare and contrast your answers.
4. Many TAG students report that school is boring, and many TAG students drop out of school. Why do you think this is the case, and what do you think could or should be done about this situation?
5. If you are a teacher or preservice teacher, think about your current level of expertise as a teacher. How can you measure or determine this level of expertise? Give some specific examples of what you are currently doing to increase your level of expertise, and how well it is working.

Chapter 2

Human and Machine Intelligence

“When you spoke of a nature gifted or not gifted in any respect, did you mean to say that one man may acquire a thing easily, another with difficulty; a little learning will lead the one to discover a great deal; whereas the other, after much study and application, no sooner learns than he forgets...” (Plato, 4th century B.C.)

Your brain has tremendous capabilities, but it also has some severe limitations. The same statement holds true for the brain-like or intelligent-like capabilities and limitations of ICT systems. This chapter explores human and machine “intelligence” from a TAG education point of view. It is important that teachers understand some of the major differences between human intelligence and machine intelligence, and how a TAG student benefits by learning about both.

During the past two decades, study of the human brain has been greatly aided by progress in the development of computerized brain scanning systems. Progress in brain science is beginning to produce results that are useful to educators. A Google search conducted on 12/22/05 using the expression *brain science and education* produced more than 36 million hits. I believe you will enjoy looking at Nitin Gogtay et al. (2004). It contains some excellent brain scan pictures (<http://www.loni.ucla.edu/~thompson/DEVEL/PNASDevel04.pdf>) of human cortical development during ages 4-21.

Human Intelligence

This section explores a variety of topics related to human intelligence.

Intelligence Quotient (IQ)

Intelligence Quotient (IQ) is an important component of brain science. The study of intelligence has a long history (<http://www.testcafe.com/iqtest/history.html>) (History, n.d.). The Encarta article (Detterman, 2005) available at http://encarta.msn.com/text_761570026_24/Intelligence.html, provides a very nice overview of the field. Here is a short quote from this article that many people find quite interesting:

By analyzing the performance over the years of different normative samples on the same tests, researchers have concluded that performance on intelligence tests has risen significantly over time. This phenomenon, observed in industrialized countries around the world, is known as the *Flynn effect*, named after the researcher who discovered it, New Zealand philosopher James Flynn. Scores on some tests have increased dramatically. For example, scores on the Raven’s Progressive Matrices, a widely used intelligence test, increased 15 points in 50 years when scored by the same norms. In other words, a representative sample of the population that took the test in 1992 scored an average of 15 points higher on the test than a representative sample that took the test in 1942.

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It appears that people are getting smarter. However, only some tests show these changes. Tests of visual-spatial reasoning, like the Raven's test, show the largest changes, while vocabulary and verbal tests show almost no change. Some psychologists believe that people are not really getting smarter but are only becoming better test takers. Others believe the score gains reflect real increases in intelligence and speculate they may be due to improved nutrition, better schooling, or even the effects of television and video games on visual-spatial reasoning.

Likely, you have an intuitive understanding that a person with above average IQ tends to learn faster and better than a person with average or below average IQ. Suppose, for example, that we are looking at a student with an IQ of about 65-70 (about two standard deviations below average) and another student with an IQ of about 130-135 (about two standard deviations above average). Then research suggests (on average) that the IQ 65-70 student will learn at less than one-half the rate of an IQ 100 student, while the IQ 130-135 student will learn at more than twice the rate of the IQ 100 student. That is, the more intelligent student may well learn at four times the rate of the less intelligent student.

Such statements about learning speed are rather general and not very precise. For example, what does it mean for a person to learn twice as fast as another person? What does it mean for a person to learn better? In any event, a classroom teacher routinely faces students with a tremendous amount of variability in rate and quality of learning abilities. A later section in this chapter provides more detail about rate of learning.

The terms ability, aptitude, and intelligence are closely related. Intelligence and measures of intelligence have been extensively studied. Quoting from Gottfredson (1998):

The debate over intelligence and intelligence testing focuses on the question of whether it is useful or meaningful to evaluate people according to a single major dimension of cognitive competence. Is there indeed a general mental ability we commonly call "intelligence," and is it important in the practical affairs of life? The answer, based on decades of intelligence research, is an unequivocal yes. No matter their form or content, tests of mental skills invariably point to the existence of a global factor that permeates all aspects of cognition. And this factor seems to have considerable influence on a person's practical quality of life. Intelligence as measured by IQ tests is the single most effective predictor known of individual performance at school and on the job.

Results on an IQ test are often used as one component of a process to determine whether a student should be designated as TAG.

Figure 2.1 shows a normal curve with the shaded area representing the area between the mean and +1 standard deviation.

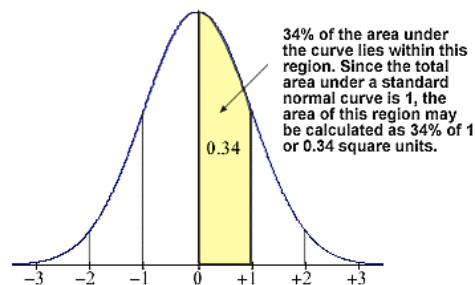


Figure 2.1. Normal distribution curve.

Figure 2.2 is a short table of data from a normal distribution. This table indicates that a total of 68.26% of the area under a normal curve lies between -1 and $+1$ standard deviations. From

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this table you can deduce that 2.28% of the area lies to the left of -2 standard deviations and 2.28% lies to the right of $+2$ standard deviations.

| Spread | Proportion of Cases |
|--------------------------------|---------------------|
| + or -1 standard deviation | 68.26% |
| + or - 1.5 standard deviations | 86.64% |
| + or -2 standard deviations | 95.44% |
| + or - 2.5 Standard deviation | 98.74 |
| + or -3 standard deviations | 99.74% |

Table 2.2. Normal curve data.

Some people think that TAG should be defined strictly in terms of IQ. Suppose, for example, that one defines TAG to mean an IQ greater than or equal to two standard deviations above the mean. The WAIS, Wechsler, and WISC IQ tests are normed with a standard deviation of 15. The Stanford-Binet, CTMM, and Otis-Lennon IQ tests are normed with a standard deviation of 16. Thus, the cutoff point for TAG in the first set of IQ tests would be an IQ of 130, while the cutoff point for TAG in the second set of IQ tests would be an IQ of 132. In either case, only about 2.28% of students would meet this criterion.

If the IQ criterion is set at 1.5 standard deviations—an IQ of 122.5 on the first set of tests; an IQ of 124 on the second set of tests—then about 6.68 percent of students would meet the criterion.

These IQ-based definitions of TAG are seriously flawed. One obvious flaw is that they do not consider what students with a certain IQ can do. A more appropriate approach is to use multiple criteria (including IQ) to identify students who display TAG-like characteristics.

Another obvious flaw with the IQ approach is that different IQ tests emphasize somewhat different components of IQ. From the work of Howard Gardner (discussed later in this chapter) and others, it is clear that a person might have substantial different intelligence scores in different areas of intelligence. Put another way, if two different IQ tests place different weights (for example, by using different numbers of questions) on various types of IQ, then a person might well score quite differently on the two tests.

Another major flaw with a strict IQ approach to identifying TAG students is that IQ tests do not measure persistence, drive, passion, intrinsic motivation, emotional intelligence, social intelligence, and other traits that make a huge difference in learning, problem solving, and other human activities. Some students make much more effective use of their intellectual gifts than do other students with similar IQs.

Intelligence and Problem Solving

Here is a definition of intelligence that I have developed through study of the literature, and that I find useful in my teaching and writing. Intelligence is a combination of the abilities to:

1. Learn. This includes all kinds of informal and formal learning via any combination of experience, education, training, introspection, learning on your own, and so on.
2. Pose problems. This includes recognizing problem situations and transforming them into more clearly defined problems.

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3. Solve problems. This includes solving problems, accomplishing tasks, and fashioning products, performances, and presentations.

Notice the emphasis on solving problems. In this book, I use the term **problem solving** to include all of the following activities:

- posing, clarifying, and answering questions
- posing, clarifying, and solving problems
- posing, clarifying, and accomplishing tasks
- posing, clarifying, and making decisions
- using higher-order, critical, and wise thinking to do all of the above
- using tools that aid and extend one's physical and mental capabilities to do all of the above.

Problem solving covers a very broad range of ideas and activities. These ideas and activities are an important aspect of every academic area. Some people are much better at problem solving than others. From this point of view, some people are more intelligent than others. However, it is evident that people vary considerably in their problem-solving capabilities in different areas or disciplines.

General Intelligence (g); Gf and Gc

IQ tests are designed to measure intelligence and such measurements are an important consideration in identifying TAG students. Sir Francis Galton (1822-1911) devoted much of his professional career to the development and use of tests and statistical analysis methods to study intelligence and other measurable aspects of people. During the latter half of the 19th century, it was generally believed that people could be divided into three categories: idiots, normal, and genius. It was believed that most people fell into the middle category and all people in this category had the same intellectual abilities. This was well before the development of IQ tests and ideas of multiple intelligences.

In 1904, psychologist Alfred Binet was commissioned by the French government to find a method to differentiate between children who were intellectually normal and those who were inferior (History of IQ, n.d.). The past 100 years have seen the development of many different forms of IQ tests, along with considerable use and misuse of the results of such tests.

Considerable research over the past century has supported the idea that IQ tests tend to measure a common factor called g, for general intelligence (Gottfredson, 1998). General intelligence (g) can be divided into two major components or factors: fluid intelligence (Gf) and crystallized intelligence (Gc).

The first common factor, **Gf**, represents a measurable outcome of the influence of biological factors on intellectual development (i.e., heredity, injury to the central nervous system), whereas the second common factor, **Gc**, is considered the main manifestation of influence from education, experience, and acculturation. (Healy & McNamara, 1996)

The research literature on IQ supports three important ideas relevant to this book:

1. A person's IQ comes from a combination of nature (biological factors) and nurture (education, experience, and other environmental factors).

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2. IQ can be decreased through lack of various vitamins and minerals, use of certain drugs, various poisons (such as lead and mercury), malnutrition, and injuries to the central nervous system.
3. IQ can be increased through informal and formal educational experiences, and through avoidance of or removal of factors such as listed in (2) above.

While a person's level of fluid intelligence tends to peak in the mid 20s, growth in crystallized intelligence may continue well into the 50s. Since the rate of decline in fluid intelligence over the years tends to be relatively slow, a person's total cognitive capabilities can remain high over a long lifetime. Current research strongly supports the idea of "use it or lose it" for the brain/mind, as well as the rest of one's body. (Goldberg, 2005; Memory Loss, 2004.)

Rate of Learning

Some students learn faster and better than others. A highly or profoundly gifted student may cover the grades 1-12 curriculum in six years and obtain nearly a straight "A" grade average. This student may have a rate of learning that is two to three times that of an average student. This student's quality of learning is much better than average.

In recent years, I have been particularly interested in finding literature on rate and quality of learning. Surprisingly, I have not found much literature on this topic. The literature that I have found tends to focus more on special education or learning disabled students than it does on TAG students. For example, here is a research-based statement about the rate and quality of math learning for students with mild disabilities (Cawley et al., 2001):

The background literature of special education has long shown that students with mild disabilities (a) demonstrate levels of achievement approximating 1 year of academic growth for every 2 or 3 years they are in school (Cawley & Miller, 1989); (b) exit school achieving approximately 5th- to 6th-grade levels (Warner, Alley, Schumaker, Deshler, & Clark, 1980); and (c) demonstrate that on tests of minimum competency at the secondary level, their performance is lower for mathematics than it is for other areas (Grise, 1980). Warner et al. showed that students with learning disabilities attained only one-grade equivalent level in mathematics from Grade 7 through Grade 12.

The data presented by Grise show that on a test of *minimum competency* for students in the 11th grade, 48% of students with learning disabilities passed the language/reading component, but only 16% of the students passed the mathematics component. Data from the State of New York (Mills, 2000) show that on performance on state administered mathematics assessments, 61% of 3rd-grade students with disabilities and 58% of Grade 6 students with disabilities in low socioeconomic districts met criterion whereas 90% of Grade 3 students with disabilities and 83% of Grade 6 students with disabilities in upper socioeconomic districts met criterion.

This information about math education provides strong evidence of the importance of social economic status (and its related aspects of home environment) in math education. It indicates that the rate and quality of math learning is substantially less for students with learning disabilities.

The following quoted material provide information about the rate of learning of slow versus fast learners (Gottfredson, 1998):

High-ability students also master material at many times the rate of their low-ability peers. Many investigations have helped quantify this discrepancy. For example, a 1969 study done for the U.S. Army by the Human Resources Research Office found that enlistees in the bottom fifth of the ability distribution required two to six times as many teaching trials and prompts as did their higher-ability peers to attain minimal proficiency in rifle assembly, monitoring signals, combat

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plotting and other basic military tasks. **Similarly, in school settings the ratio of learning rates between "fast" and "slow" students is typically five to one.** [Bold added for emphasis.]

...

Half a century of military and civilian research has converged to draw a portrait of occupational opportunity along the IQ continuum. **Individuals in the top 5 percent of the adult IQ distribution (above IQ 125) can essentially train themselves, and few occupations are beyond their reach mentally.** ... Serious problems in training low-IQ military recruits during World War II led Congress to ban enlistment from the lowest 10 percent (below 80) of the population, and no civilian occupation in modern economies routinely recruits its workers from that range. Current military enlistment standards exclude any individual whose IQ is below about 85. [Bold added for emphasis.]

Notice the bold parts of the above quote. The literature seems to suggest that students with IQs below 75 will learn two to three times or more slowly than average students, while students with IQs above 125 will learn two to three times as fast as average students. The higher IQ students are able to train themselves—to learn on their own. Obviously, there are exceptions to these general findings.

Reports such as the one listed above suggest TAG student should be strongly supported and encouraged to learn to learn on their own, and to take responsibility for their own learning. ICT—especially the Web and Distance Learning—can play a major role in the formal and continuing lifelong education of TAG students.

Multiple Intelligences: Howard Gardner

The study of general intelligence (g) has a long history and it still remains a key idea in the field. However, many researchers have argued that a human brain has many different kinds of intelligences. In the past 20-some years, Howard Gardner has been the most influential of these people. In 1983, he published his first book on Multiple Intelligences (http://www.pz.harvard.edu/PIs/HG_MI_after_20_years.pdf). He currently believes that a person has at least eight distinct areas of intelligence (Gardner, 2003):

- Linguistic intelligence ("word smart"):
- Logical-mathematical intelligence ("number/reasoning smart")
- Spatial intelligence ("picture smart")
- Bodily-Kinesthetic intelligence ("body smart")
- Musical intelligence ("music smart")
- Interpersonal intelligence ("people smart")
- Intrapersonal intelligence ("self smart")
- Naturalist intelligence ("nature smart")

Many educators have found this theory quite appealing. A variety of people have argued for possible additions to the list. For example, Michael Posner's research on attention provides strong evidence that attention is an aspect of intelligence and should be added to the list (Posner, n.d.). Research suggests that attention is something that can be improved by appropriate education/training. Teachers working with attention deficit students are apt to concur with Posner's suggestion.

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A number of schools have adopted Gardner's general ideas and attempt to provide a curriculum that meets the needs of students working to develop all of their areas of intelligence. This is in marked contrast to the current "traditional" elementary and middle school that places the majority of their emphasis on the areas of linguistic intelligence and logical-mathematical intelligence. Quoting from Gilman (2001):

Gardner describes his work with two distinct populations as the inspiration for his theory of Multiple Intelligences. Early in his career, he began studying stroke victims suffering from aphasia at the Boston University Aphasia Research Center and working with children at Harvard's Project Zero, a laboratory designed to study the cognitive development of children and its associated educational implications (Gardner, 1999a).

...

Gardner concluded from his work with these two populations that strength in one area of performance did not reliably predict comparable strength in another area. With this intuitive conclusion in mind, Gardner set about studying intelligence in a systematic, multi-disciplinary, and scientific manner, drawing from psychology, biology, neurology, sociology, anthropology, and the arts and humanities. This resulted in the emergence of his Theory of Multiple Intelligences (MI Theory) as presented in *Frames of Mind* (1983). [Bold added for emphasis.]

Notice that linguistic intelligence is one of the Multiple Intelligences in Gardner's list. Charles Stansfield (1989) is the author of an ERIC Clearinghouse on linguistics article, *What is foreign language aptitude?* The term aptitude tends to be used roughly in the same way as one uses the term fluid intelligence. Quoting from the article:

Aptitude for learning anything can be defined for operational purposes as "the amount of time it takes an individual to learn the task in question." Thus, individuals typically differ not in whether they can learn a task or not learn it, but rather in the length of time it takes them to learn it or to reach a given degree of competency. This is also true of foreign language aptitude.

Is foreign language aptitude actually different from general aptitude or intelligence? The answer, based on a number of studies... seems to be "Yes." Indeed, one index of the quality of a foreign language aptitude test is the degree to which it exceeds a general intelligence test in the prediction of success in learning a foreign language. A number of foreign language aptitude tests, although not all of those that have been developed, have demonstrated the ability to do so. [Bold added for emphasis.]

Research such as that cited above suggests that people vary in how fast they learn in various areas (such as the areas of intelligence identified by Howard Gardner).

Triarchic Model of Intelligence: Robert Sternberg

Robert Sternberg defines intelligence "mental activity directed toward purposive adaptation to, selection and shaping of, real-world environments relevant to one's life." (Triarchic Theory, n.d.) His triarchic model (http://en.wikipedia.org/wiki/Sternberg's_Triarchic_Theory_of_Intelligence) is a three-component, Multiple Intelligences, theory. The quoted material in the bulleted list given below is from Triarchic Theory (n.d.).

- experiential ability (creativity)

The experiential subtheory also correlates with another one of Sternberg's types of giftedness. Synthetic giftedness is seen in creativity, intuition, and a study of the arts. People with synthetic giftedness are not often seen with the highest IQ's because there are not currently any tests that can sufficiently measure these attributes, but **synthetic giftedness is especially useful in creating new ideas to create and solve new problems.** [Bold added for emphasis.]

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- practical ability (street smarts)
...practical or contextual [intelligence] “deals with the mental activity involved in attaining fit to context” (Sternberg, 1985, p.45). Through the three processes of adaptation, shaping, and selection, individuals create an ideal fit between themselves and their environment.
- analytic ability (academic smarts—sometimes called school smarts).
[Analytical giftedness] is one of three types of giftedness that Sternberg recognizes. Analytical giftedness is influential in being able to take apart problems and being able to see solutions not often seen. Unfortunately, individuals with only this type are not as adept at creating unique ideas of their own. This form of giftedness is the type that is tested most often.

I am a university professor—a category of people that are often called “egg heads.” The egg head label tends to suggest having a high level of analytic ability, but being somewhat lacking in practical ability. (I sometimes think that is the way my wife and children tend to view me.) Of course, many professors also have their share of practical ability.

We know that children vary considerably in preparation for school when they enter kindergarten or the first grade. Research data indicates that on average, children from low socioeconomic homes enter school about a year behind children from middle and upper socioeconomic home environments. My interpretation of this data is that children in low socioeconomic settings make use of their practical intelligence abilities to adjust to a low socioeconomic type of environment, and this adaptation is not well aligned with preparation to do well in school. Children in middle and higher socioeconomic settings tend to have a home environment that is much more supportive of preparing for formal schooling, and they use their practical intelligence ability to adapt to that setting.

The above ideas are strongly supported by the work of David C. Berliner. In his 2005 Presidential Invited Speech to the American Educational Research Association (<http://www.tcrecord.org/Content.asp?ContentID=12106>) he said:

... poverty restricts the expression of genetic talent at the lower end of the socioeconomic scale. Among the lowest social classes environmental factors, particularly family and neighborhood influences, not genetics, is strongly associated with academic performance. Among middle class students it is genetic factors, not family and neighborhood factors, that most influences academic performance.

The Average Brain has Tremendous Capability

As you are read and understand this book, you are displaying a very high level of *reading with understanding* intelligence and expertise. Now think about the level of intelligence required to gain oral fluency in a natural language. No computer system has yet achieved anywhere near your level of reading and oral language fluency. While many researchers in AI believe that these goals will eventually be achieved (perhaps 25 to 50 years from now), others argues that they will never be achieved.

Let’s continue this linguistic example. Linguistic intelligence is one of the eight Multiple Intelligences identified by Howard Gardner. The nature/nurture discussions in earlier parts of this book present a picture of a person being born with a wide range of potentials (nature) in these various areas of intelligence, and then developing their potentials (nurture) in these various areas.

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Consider an average child growing up in the country of Luxembourg. This is a small country in Europe. It is a trilingual country; French, German, and Luxemburgish are the official languages. Average children growing up in this trilingual environment become trilingual. Indeed, since many of the citizens of Luxembourg are fluent in at least one additional language, many children become fluent in a fourth language. For example, roughly 10% of the population is of Portuguese extraction and speaks Portuguese.

This situation provides us with good evidence of the natural linguistic ability or intelligence of average people. In a language-rich learning environment, ordinary people can develop oral fluency in three or four languages.

Now, consider the situation of people growing up in an environment that provides only one language. As adults, such people may want to learn a second language. Quite a bit is known about the adult learning of a second language. Quoting from Malone et al. (2005):

A learner at the *Superior* level can “communicate in the language with accuracy and fluency in order to participate fully and effectively in conversations on a variety of topics in formal and informal settings” (American Council on the Teaching of Foreign Languages, 1999), while a learner at the *Distinguished* level “begins to approach the level of an educated native speaker” (Leaver & Shekhtman, 2002). Speakers at these levels also possess the academic discourse skills that would be expected of any educated person in the target culture, such as the ability to hypothesize and persuade.

It can take up to 720 hours of instruction for a student to achieve proficiency at the ACTFL *Advanced* level (one level below *Superior*); for a native English speaker to acquire proficiency at the *Superior* level in a language such as Russian, the Foreign Service Institute estimates that a minimum of 1320 hours is required (Omaggio-Hadley, 2001). However, typical undergraduate language programs at U.S. colleges and universities offer only 3 contact hours per week, which, after 2 years, yields at most 180 hours of instruction.

The examples given in this section illustrate a number of things, such as:

- It is possible to specify and measure a particular level of second language oral fluency.
- It is possible to measure how many hours of instruction takes certain types of adults (for example, those who are admitted to and undertake a particular program of study) to achieve a particular level of second language oral expertise.
- It takes adults a great deal of time and effort for adults to achieve second language oral fluency that children can achieve just as a byproduct of growing up in a multi lingual environment.

Here is some additional information about rate of learning second language learning for two different age ranges of students, and for males versus females (Slavoff and Johnson, 1995).

The study was designed to test the role of age on the rate of acquiring English as a second language with different-aged children whose native language is typologically very different from English. Subjects were divided into two age groups: 7-9 year-olds and 10-12 year-olds arrivals. The subjects were all from a large urban school district, had participated in an ESL course at their school and received most of their English through immersion in school. Most of the subjects continued to use their native language at home.

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Rate of acquisition of English is not dependent on age, but instead is directly related to increased length of stay in the United States. It was further found that gender played an important role in language acquisition, with females outperforming males at all time intervals. Whatever learning difference might separate 7-9 and 10-12 year-old arrivals, it appears to affect only the learning of more difficult structures.

Learning to Use One's Other Intelligences

Research can be conducted in any discipline or area of human intelligence. The nature and extent of the research that has been conducted varies with the discipline or intelligence area. Second language learning “lends itself” to such research because of large number of students that are involved as well as the availability of good measures of levels of expertise.

As a preservice or inservice teacher, you have undoubtedly heard a number of people say “I can't do math.” Logical/mathematical intelligence is one of the eight Multiple Intelligences identified by Howard Gardner. I find it interesting to think about logical/mathematical versus linguistic. Do you suppose that children growing up in a bilingual or trilingual language environment say, “I can't do language?” Do you suppose that the 7-9 year old and 10-12 year old children mentioned above say “I can't do English?” What is there about the way we teach math that leads to so many students growing up with very weak math knowledge and skills, and the feeling that they can't do math?

Many leaders in math educators think of mathematics as a language and talk about a student gaining fluency in math. My math Website (Moursund, n.d.) contains a section on *Math as a Language*. All children have some natural ability to learn math, and babies only a few week old display some ability to count up to three and to differ among quantities of these sizes.

I grew up in an environment where both my father and mother taught in the Department of Mathematics at the university of Oregon. I believe that some of my mathematical talent came from growing up in that mathematically rich environment.

An average child will develop considerable ability to deal with mathematical aspects of life in our society, provided that the “nurture” aspects of this child's informal and formal education are appropriate. As might be expected, some students have a far greater amount of natural ability in math than other students. John Hopkins University is well known for its many years of successful work with students who are especially gifted in math (John Hopkins. n.d.).

To a large extent, our current elementary and middle school math curriculum does a disservice for students who are gifted in mathematics. Such students can easily learn math twice as fast as average students, and learn this math much better than average students. The majority of teachers at the elementary and middle school levels lack the math expertise and math pedagogical knowledge and skills to adequately serve the math education needs of students who are gifted in math.

ICT Developmental Scale

We know that the human brain grows quite rapidly during early years of life, and it continues fairly rapid change until a person is in their early 20s. Jean Piaget's work (<http://www.piaget.org/>) on cognitive developmental theory contributed greatly to our understanding of stages of human development. See Figure 2.3.

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| Approximate Age | Stage | Major Developments |
|---------------------|---------------------|---|
| Birth to 2 years | Sensorimotor | Infants use sensory and motor capabilities to explore and gain increasing understanding of their environments. If the environment (nurturing, food and vitamins, shelter, freedom from lead and other poisons, healthcare) is adequate beyond some modest threshold, then developmental progress is strongly dependent on genetic/biological factors. |
| 2 to 7 years | Preoperational | Children begin to use symbols, such as speech. They respond to objects and events according to how they appear to be. Children make rapid progress in receptive and generative oral language. There are large advantages of a “rich” cultural and socioeconomic environment (as contrasted with a “poor” environment). |
| 7 to 11 years | Concrete operations | Children begin to think logically. In this stage (characterized by 7 types of conservation: number, length, liquid, mass, weight, area, volume), intelligence is demonstrated through logical and systematic manipulation of symbols related to concrete objects. Operational thinking—including mental actions that are reversible mental testing of ideas—begins to develop. Schools and schooling play a significant role in helping to shape a child’s development during this stage. |
| 11 years and beyond | Formal operations | Thought begins to be systematic and abstract. In this stage, intelligence is demonstrated through the logical use of symbols related to abstract concepts. |

Figure 2.3: Piagetian cognitive development scale.

The rate of progress through the Piagetian developmental stages is dependent on both nature and nurture. Good home, neighborhood, and school environments make a huge difference (Piaget Society, n.d.).

The top end of the Piagetian developmental scale is called formal operations. An average student begins to move into this stage at age 11. In this stage, thought begins to be systematic and abstract, and intelligence is demonstrated through the logical use of symbols related to abstract concepts. It is essential to understand that there is a substantial difference between beginning to move into the state of formal operations, and actually achieving this level of development. Only about 35% of students in the United States achieve formal operations by the time they complete high school. Perhaps half of all adults never achieve this level of development (Moursund, 2005c, p45).

Research results such as those given in the previous paragraph help to emphasize the special needs of TAG students. Not only do they learn faster and better than average students, they tend to achieve formal operations at a younger age. They need an education that helps them to move up the Piagetian scale at a pace consistent with their abilities.

At the current time some high schools are moving toward making some of their Advanced Placement courses be required of all students. The typical AP courses assumes that students are well along toward achieving formal operations and is equivalent to a freshman course in a good university. Many TAG students thrive in this environment. Students who are not yet well along toward achieving formal operations will flounder in such a teaching and learning environment. Developmental theory provides a strong argument against requiring such courses for average students.

It is possible to consider Piagetian development in general, but it is also possible to consider it within a single discipline such as math or ICT.

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Figure 2.4 contains an ICT cognitive developmental scale based on the ISTE National Educational Technology Standards (NETS) for students. There is a strong parallel between this scale and the Piagetian cognitive development scale. I consider this scale to be a work in progress, and I will undoubtedly make changes to it in the future. However, I feel that in its current form it is already quite useful. With appropriate educational opportunities and encouragement, many TAG students can achieve formal operations in ICT by the time they finish high school.

| Stage "Title" | Age and/or Education Levels | Brief Discussion |
|-----------------------------------|---|---|
| Stage 1. Piagetian Sensorimotor. | Age birth to 2 years. Informal education provided by parents, and other caregivers. | <p>Infants use sensory and motor capabilities to explore and gain increasing understanding of their environments.</p> <p>ICT has brought us a wide range of sound and music-producing, talking, moving, walking, interactive, and developmentally appropriate toys for children in Stage 1. These contribute both to general progress in sensorimotor growth and also to becoming acquainted with an ICT environment.</p> |
| Stage 2. ICT Preoperational. | Age 2 to 7 years. Includes both informal education and increasingly formal education in preschool, kindergarten, and first grade. | <p>During the Piagetian Preoperational stage, children begin to use symbols, such as speech. They respond to objects and events according to how they appear to be. They accommodate to the language environments they spend a lot of time in.</p> <p>ICT provides a type of symbols and symbol sets that are different from the speech, gestures, and other symbol sets that have traditionally been available.</p> <p>TV and interactive ICT-based games and edutainment are a significant environmental component of many children during Stage 2. During this stage children can develop considerable speed and accuracy in using a mouse, touch pad, and touch screen to interact and problem solve in a 3-dimensional multimedia environment displayed on a 2-dimensional screen.</p> |
| Stage 3. ICT Concrete Operations. | Age 7 to 11 years. Includes informal education and steadily increasing importance of formal education at grades 2-5 in elementary school. | <p>During the Piagetian Concrete Operations stage, children begin to think logically. In this stage, intelligence is demonstrated through logical and systematic manipulation of symbols related to concrete objects.</p> <p>Operational thinking (mental actions that are reversible) develops.</p> <p>ISTE has established NETS-Student that includes a statement of what students should be able to do by the end of the fifth grade. During the ICT Concrete Operations stage children:</p> <ul style="list-style-type: none"> • Learn to use a variety of software tools such as those listed in the 5th grade ISTE NETS-Student, and begin to understand some of the capabilities and limitations of these tools. (They do logical and systematic manipulation of symbols in a computer environment.) • Learn to apply these software tools at a Piagetian Concrete Operations level as an aid to solving a wide range of general curriculum-appropriate problems and tasks. |
| Stage 4. ICT Formal Operations. | Age 11 and beyond. This is an open ended developmental stage, continuing well into adulthood. Requires ICT knowledge, skills, speed, and | <p>During the Piagetian Formal Operations stage, thought begins to be systematic and abstract. In this stage, intelligence is demonstrated through the logical use of symbols related to abstract concepts.</p> <p>Formal Operations in ICT includes functioning at a Piagetian Formal Operations level in specific activities such as:</p> <ol style="list-style-type: none"> 1. Communicate accurately, fluently, and with good understanding using the vocabulary, notation, and content of ISTE NETS-S for the 12th grade. 2. Given a piece of software and a computer, install and run the software, learn to use the software, explain and demonstrate some of the uses of |

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| | | |
|--|---|---|
| | understanding of topics in ISTE NETS for students finishing the 12 th grade. | the software, save a document you have created, and later return to make further use of your saved document. 3. Problem solve at the level of detecting and debugging hardware and software problems that occur in routine use of ICT hardware and software. 4. Convert (represent, model, pose) real world problems from non-ICT disciplines into ICT problems, and then solve these problems. 5. Routinely and comfortably use ICT in the other disciplines you have studied, at a level consistent with and supportive of your cognitive developmental level in these disciplines. 6. Have a conceptual understanding of similarities and differences, and capabilities and limitations, of human mind/brain versus ICT systems. Work comfortably and competently with ICT systems as auxiliary mind/brains. |
|--|---|---|

Figure 2.4. ICT cognitive developmental and expertise scale.

Notice the generality of this ICT cognitive developmental scale. It does not speak to specific brands of hardware and pieces of software. It is inherent to the scale that moving up the scale requires learning to learn ICT and to apply what one has learned. It requires gaining a broad range of skills and increasing confidence in handling the problems that are inherent in using “buggy” ICT hardware and software systems.

As a preservice or inservice teacher, there is a good chance that you have achieved formal operations on the general Piagetian scale. However, chances are that you are not at formal operations in ICT. This leaves you with the challenge of helping your students move up this scale—a challenge of helping many students who will eventually surpass you. Don’t panic! Good teachers are used to working with students who will eventually surpass them in a wide variety of knowledge and skill areas. Such teachers learn to be a “guide on the side”—to function in a coaching and facilitative manner.

Artificial Intelligence

This section contains a short introduction to Artificial Intelligence (AI). AI is sometimes called Machine Intelligence. My short book *Brief introduction to educational implications of Artificial Intelligence* (Moursund, 2005a) contains a more comprehensive coverage of this topic.

There is a huge amount of published research and popular literature in the field of AI and its roles in education. A Google search conducted 12/23/05 on the expression *Artificial Intelligence and education* produced over nine million hits.

AI is concerned with developing computer systems that can store knowledge and effectively use the knowledge to help solve problems and accomplish tasks. This brief statement sounds a lot like one of the commonly accepted goals in the education of humans. We want students to learn (gain knowledge) and to learn to use this knowledge to help solve problems and accomplish tasks.

Many people find it helpful to think about data, information, knowledge, and wisdom as being points on a scale such as the given in Figure 2.5.

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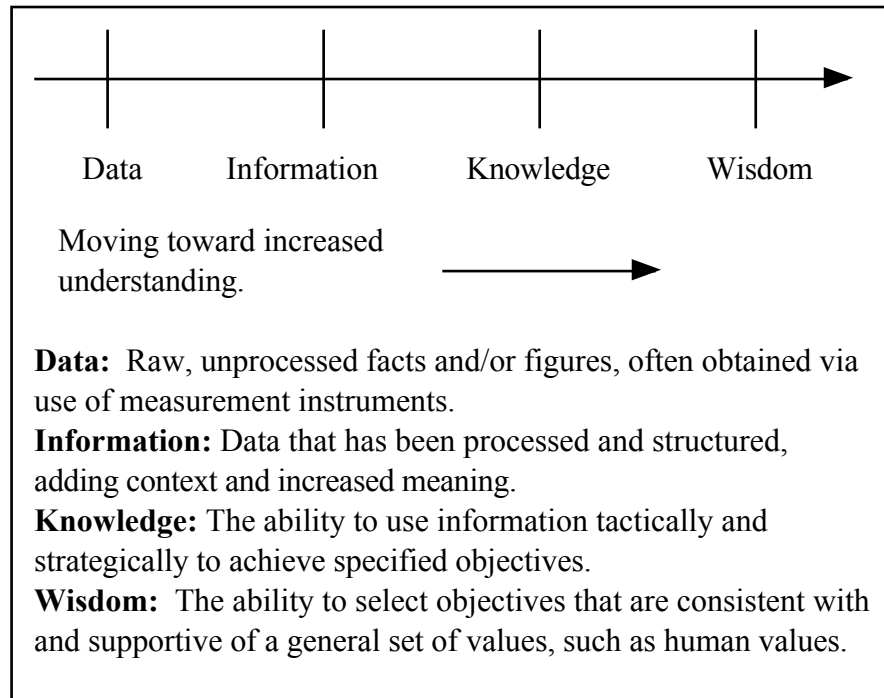


Figure 2.5. Data, information, knowledge, and wisdom.

While the terms Data, Information, Knowledge, and Wisdom are sometimes presented in the form of a scale, in no sense do these four terms define some sort of linear equal-interval scale. They do, however, help us to discuss the design of an educational system as well as current and potential uses of computers. For example, we all accept that computers can be used for the input, storage, processing, and output of data. However, there is considerable disagreement about whether a computer can have knowledge or be knowledgeable—or have wisdom and be wise.

In the good old days, in the early history of using computers to do business data processing, computers were data processing machines. There were lots of workshops and courses on data processing. "Raw data" was processed to produce reports that were then analyzed by management to make management decisions. Hourly time sheets of workers were processed to produce payroll checks and summary reports on employee costs.

Later came the idea of computers processing data to produce information. Payroll data can be put together with other cost data, sales data, and so on to produce information about which products are most profitable. The huge collection of raw data can be processed into reports that facilitate high-level management decisions.

Now, many large corporations include employees whose work is to use computers to transform data and information into knowledge, and this is a fruitful area of research (<http://www.acm.org/sigs/sigkdd/>) in the field of Computer and Information Science.

Typical definitions of AI do not talk about the computer's possible sources of knowledge. Two common sources of an AI system's knowledge are:

- Human knowledge that has been converted into a format suitable for use by an AI system.

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- Knowledge generated by an AI system, perhaps by gathering data and information, and by analyzing data, information, and knowledge at its disposal.

While most people seem to accept the first point as being rather obvious, many view the second point only as a product of science fiction. Many people find it scary to think of a machine that in some sense “thinks” and thereby gains increased knowledge and capabilities. However, this is an important aspect of AI.

The field of AI has come a long way since the development of the first electronic digital computers. However, competing with human intelligence has proven to be a formidable challenge. The next two subsections discuss two examples of such endeavors.

Alan Turing and the Turing Test

Alan Turing (1912-1954) (<http://www.turing.org.uk>) was a very good mathematician and a pioneer in the field of electronic digital computers. In 1936, he published a math paper that provides theoretical underpinnings for the capabilities and limitations of computers. During World War II, he helped develop computers in England that played a significant role in England’s war efforts. In 1950, Alan Turing published a paper discussing ideas of current and potential computer intelligence, and describing what is now known as the Turing Test for AI (Turing, 1950).

The Turing Test is an imitation game. Quoting from Turing’s 1950 paper:

The new form of the problem can be described in terms of a game which we call the 'imitation game.' It is played with three people, a man (A), a woman (B), and an interrogator (C) who may be of either sex. The interrogator stays in a room apart from the other two. The object of the game for the interrogator is to determine which of the other two is the man and which is the woman. He knows them by labels X and Y, and at the end of the game he says either "X is A and Y is B" or "X is B and Y is A." The interrogator is allowed to put questions to A and B thus:

C: Will X please tell me the length of his or her hair?

Now suppose X is actually A, then A must answer. It is A's object in the game to try and cause C to make the wrong identification. His answer might therefore be:

"My hair is shingled, and the longest strands are about nine inches long."

In order that tones of voice may not help the interrogator the answers should be written, or better still, typewritten. The ideal arrangement is to have a teleprinter communicating between the two rooms. Alternatively the question and answers can be repeated by an intermediary. The object of the game for the third player (B) is to help the interrogator. The best strategy for her is probably to give truthful answers. She can add such things as "I am the woman, don't listen to him!" to her answers, but it will avail nothing as the man can make similar remarks.

We now ask the question, "What will happen when a machine takes the part of A in this game?" Will the interrogator decide wrongly as often when the game is played like this as he does when the game is played between a man and a woman? These questions replace our original, "Can machines think?"

Turing’s 1950 paper predicted that by the year 2000 there would be computers that routinely fooled humans in this imitation game task. Interestingly, the field of AI has not yet passed Turing’s Test. A prize has been established and yearly contests are held to see if a computer program has been developed that can pass the test (Loebner Prize, n.d.). At the current time, humans are far better than computers at carrying on a written conversation. Moreover, humans are still better at carrying on an oral conversation, far exceeding computers in this task.

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Computer Chess

Here is a brief chronology of some early aspects of computer chess (Wall, 2004).

- In 1947, Alan Turing specified (in a conceptual manner) the first chess program for chess.
- In 1949 Claude Shannon described how to program a computer to play chess, and a Ferranti digital machine was programmed to solve mates in two moves. He proposed basic strategies for restricting the number of possibilities to be considered in a game of chess.
- In 1950, Alan Turing wrote the first computer chess program.
- By 1956, experiments on a MANIAC I computer (11,000 operations a second) at Los Alamos, using a 6x6 chessboard, was playing chess. This was the first documented account of a running chess program.
- In 1957 a chess program was written by Bernstein for an IBM 704. This was the first full-fledged game of chess by a computer.
- In 1958, a chess program beat a human player for the first time (a secretary who was taught how to play chess just before the game).

The last item on the list is particularly interesting. The secretary had received about one hour of instruction on how to play chess. The computer displayed a level of chess-playing expertise greater than a human could gain through one hour of individualized instruction. Thus, we have some of the first inklings of a tradeoff between human learning time and replacing this time and effort by an “intelligent” machine.

The early game-playing computer systems were of rather limited capability. In no sense were they able to challenge a human player with even moderate capability. However, over the years, computers that are more powerful were developed, and progress occurred in the underlying theory and practice of game-playing programs.

Slow but steady progress in computer chess playing has continued over the years. Tournaments were established so that computers could compete against other computers. Demonstrations were held, pitting human players against computers. Eventually computers were allowed to compete in some human chess tournaments.

Computer chess programs got better through a combination of greater computer speed and better programming. In May 1997, IBM's Deep Blue supercomputer played a fascinating match with the reigning World Chess Champion, Garry Kasparov. Although Kasparov was one of the strongest chess players of all time and the match was close, the computer won (Deep Blue, n.d.).

In early 2003 a six game match was played between Garry Kasparov and Deep Junior, the current reigning world computer chess champion. Deep Blue had long since “retired.” Deep Junior used a much slower computer than Deep Blue, but it employed much more sophisticated “intelligence” in its programming (Deep Junior, n.d.).

The computer that Deep Junior was running on was only 1/66 as fast as that used by Deep Blue. However, Kasparov was no longer the reigning human world chess champion. The six game match ended in a draw, with one victory for each player, and four tied games.

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Nowadays one can buy a variety of relatively good game-playing programs that run on a microcomputer. Quite likely, such programs can easily beat you at chess, checkers, backgammon, bridge, and a variety of other games.

The message is clear. In the narrow confines of games and relatively similar real-world problem solving, computers now have a relatively high level of expertise. In performance (being able to play certain games well), computer expertise now exceeds the highest level of human expertise.

Algorithmic and Heuristic Procedures

A procedure is a detailed step-by-step set of directions that can be interpreted and carried out by a specified agent. At some time in your life, you learned and/or memorized procedures for multi-digit multiplication and long division, looking up a word in a dictionary or a name in a telephone book, alphabetizing a list, and to accomplish many other routine tasks.

Here are two general categories of procedures relevant to both AI and human intelligence.

1. Algorithm. An algorithm is a procedure that **is guaranteed** to solve the problem or accomplish the task for which it is designed. You know a paper and pencil algorithm for multiplying multi-digit numbers. If you carry out the procedure (the algorithm) without error, you will solve the multiplication problem.
2. Heuristic. A heuristic is a procedure that is designed to solve a problem or accomplish a task, but that **is not guaranteed** to solve the problem or accomplish the task. A heuristic is often called a rule of thumb. You know and routinely use lots of heuristics. They work successfully often enough for you so that you continue to use them. For example, perhaps you have a heuristic that guides your actions as you try to avoid traffic jams or try to find a parking place. Perhaps you use heuristics to help prepare for a test or for making friends. Teachers make use of a variety of heuristics for classroom management.

Figure 2.6 is designed to suggest that there is an overlap between procedures that ICT systems can carry out and procedures that humans can carry out.

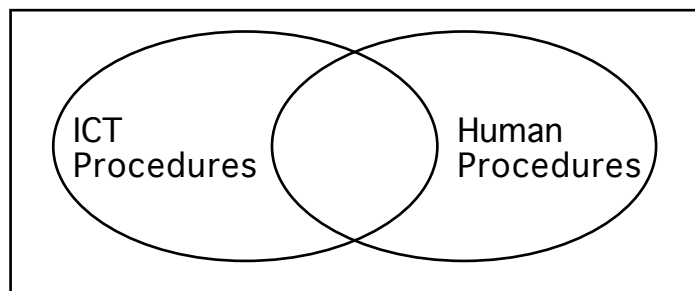


Figure 2.6. Procedures to be carried out by ICT systems and by humans.

The following quotation from Marvin Minsky (1960) indicates that early researchers in AI had a good understanding of the roles of heuristic programming in AI.

The problems of heuristic programming—of making computers solve really difficult problems—are divided into five main areas: Search, Pattern-Recognition, Learning, Planning, and Induction.

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The adjective "heuristic," as used here and widely in the literature, means related to improving problem-solving performance; as a noun it is also used in regard to any method or trick used to improve the efficiency of a problem-solving system. A "heuristic program," to be considered successful, must work well on a variety of problems, and may often be excused if it fails on some. We often find it worthwhile to introduce a heuristic method, which happens to cause occasional failures, if there is an over-all improvement in performance.

ICT systems are very fast and accurate at carrying out algorithms. A mid-priced microcomputer can carry out a billion arithmetic computations per second. This is done without errors, following algorithms built into its circuitry or stored in its memory. Computers can look up a word in a dictionary or alphabetize a list of names because programs have been written to carry out algorithms designed to accomplish these tasks.

AI programs make use of both algorithmic and heuristic procedures. Many of the problems being addressed through the use of AI have the two characteristics:

1. The problems are very difficult from a human point of view, and a human world-class expert does not solve them perfectly. Indeed, many of the problems are beyond human (unaided by computers) capabilities.
2. The computer programs being written to address these problems make use of algorithms, heuristics, computer speed, computer storage capacity, and computer connectivity. This approach can produce ICT systems of increasing expertise within many different problem-solving areas of interest to people, but cannot guarantee success in solving all of the problems within each of these areas.

Think about the challenges of writing a computer program that can pass the Turing Test—that can carry on a good written conversation with a person. Many people have written computer programs that can carry on a written conversation via a computer terminal. Perhaps the most well known is a program named ELIZA written by Joseph Weizenbaum and published in 1966 (Weizenbaum, 1966). This heuristic program indeed carries on a written conversation. From time to time people using the program have actually believed they were conversing with another human being. However, the program is not nearly good enough to pass the Turing Test. The ELIZA program is available on the Web and many people find that it is fun to play with this program (ELIZA, n.d.). You and your students will likely enjoy conversing with a more modern version of such software, such as (ALICE, n.d.) and (Jabberwacky, n.d.).

Expert Systems

Expert Systems is an area of AI that explores how to computerize the expertise of a human expert. For example, is it possible to computerize the knowledge of a medical diagnostician, a computer repair person, or a teacher?

We are used to the idea that a large amount of the knowledge of an expert can be put into a book. The book may be designed to help a human learn some of the knowledge of its author. It may contain detailed step-by-step procedures which, if carefully followed, will solve certain problems or accomplish certain tasks that heretofore were done by a human expert. If you are a parent who has raised children, it is likely that you have made use of *Dr. Spock's Baby and Child Care* by Benjamin Spock. It is a great help to diagnosing certain types of child medical problems and what to do based on the diagnoses.

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Of course, the contents of any book can be stored on a computer. Moreover, a Website may well contain the equivalent of many books. Nowadays, a huge number of people make use of Websites such as WebMD (<http://www.webmd.com/>) as an aid to addressing medical problems.

However, an expert system is more than a computerized book. An expert system typically consists of four major components:

1. Knowledge Base. This is the knowledge in the expert system, coded in a form that the expert system can use. It is developed by some combination of humans (for example, a knowledge engineer) and an automated learning system (for example, one that can learn through the analysis of good examples of an expert's performance).
2. Problem Solver. This is a combination of algorithms and heuristics designed to use the Knowledge Base in an attempt to solve problems in a particular field.
3. Communicator. This is designed to facilitate appropriate interaction both with the developers of the expert system and the users of the expert system.
4. Explanation and Help. This is designed to provide help to the user and to provide detailed explanations of the "what and why" of the expert systems activities as it works to solve a problem.

Mycin (http://www.cee.hw.ac.uk/~alison/ai3notes/section2_5_5.html) was one of the first expert systems. Its job was to diagnose and recommend treatment for certain blood infections. It was developed at Stanford University in the 1970s.

One way to diagnose blood disorders is to grow cultures of the infecting organism. However, this takes approximately two days, and the patient may well die before then. Thus, it is important to make a relatively accurate preliminary diagnosis and to take actions based on the preliminary diagnosis. Some human doctors are very good at this, while many others are not.

Mycin represents its knowledge as a set of IF-THEN and "certainty" rules. Here is an example of one such rule (MYCIN, n.d.):

```
IF the infection is primary-bacteremia
AND the site of the culture is one of the sterile sites
AND the suspected portal of entry is the gastrointestinal tract
THEN there is suggestive evidence (0.7) that infection is bacteroid.
```

The 0.7 is roughly the certainty or probability that the conclusion based on the evidence will be correct.

Mycin was developed to help AI researchers learn to design and implement an expert system that could deal with a complex problem. The system was never actually used to diagnose patients. In research on the system, however, the system out performed staff members of the Stanford medical school. Work on Mycin has led to still better expert systems that are now used in a variety of areas of medicine and in many other fields.

It is very important to understand the narrow specialization of the typical expert system. An expert system designed to determine whether a person applying for a loan is a good loan risk cannot diagnose infectious diseases, and vice versa. An expert system designed to help a lawyer deal with case law cannot help a literature professor analyze poetry.

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Researchers in AI often base their work on a careful study of how humans solve problems and on human intelligence. In the process of attempting to develop effective AI systems, they learn about human capabilities and limitations. One of the interesting things to come out of work on expert systems is that within an area of narrow specialization, a human expert may be using only a few hundred to a few thousand rules.

Another finding is that typically takes a human many years of study and practice to learn such a set of rules and to use them well. The set of rules is a procedure that involves both algorithmic and heuristic components. In certain cases, the set of rules can be fully computerized or nearly fully computerized, and can produce results both very quickly and that may well be more accurate (on average) than highly qualified human experts.

Consider a medical diagnostic tool such as Mycin. It operates following a set of algorithmic and heuristic procedures. Of course, the computer system is not embodied in a robot that can draw blood samples and carry out medical tests. However, it might well be that a medical technician and the expert system working together can accomplish certain tasks better than a well trained medical doctor.

Moreover, it is very time consuming for a human doctor to memorize the steps of the procedures and to gain speed and accuracy in carrying them out. The point being made is that an expert system can be thought of as a tool that embodies or contains knowledge. The issue of educating people to work with or compete with such tools is a major challenge to our educational system.

Combining Human and Artificial Intelligence

We are all used to the idea of people working with machines that enhance and supplement their physical capabilities. The same thing has been going on for many years in terms of humans and AI machines working together. For example, while I was writing this book, I was seated at a computer, making use of a relatively sophisticated word processor. The spelling and grammar checker parts of this word processor make use of AI. From time to time, I did a Web search, using the Google search engine. This search engine makes use of AI. I like to play computer games. Many of the games that I play make use of AI in providing me with suitable opponents to play against, and in assisting me in my play.

Even a simple 6-function solar powered calculator can be thought of as having a certain amount or type of intelligence. For example, it “knows” more about calculating square roots than most people.

However, our educational system still has a strong resistance to allowing people and AI systems to work together in demonstrating their combined knowledge and skills. For example, very few teachers allow students to take “open ICT system” tests. This is in spite of the fact that many teachers understand and espouse authentic assessment.

Here is a somewhat different way to think about the situation described above. A library stores data and information. Depending on how you define the terms knowledge and wisdom, you can argue that a library also stores knowledge and wisdom. The computerization of a library certainly enhances storage, retrieval, and sharing data, information (and knowledge and wisdom). However, ICT facilitates much more than this. It facilitates the storage of algorithms and procedures that can act upon and make use of the contents of a library to automate some of the processes needed to make use of a library’s contents. The Web is a huge library that has a

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certain type of AI. This intelligence grows through the work of researchers, the addition of more content to the library, through the development of faster ICT systems, and so on.

Summary

Human intelligence and artificial intelligence have some things in common, but tend to provide quite different approaches to learning and problem solving. For example, a human has trouble memorizing a book, while a computer system can “memorize (that is, store) millions of books.

The data, information, knowledge, and wisdom scale given in Figure 2.5 can be used in discussing capabilities of computers versus capabilities of people. While knowledge engineering and data mining are now an important aspect of AI and many businesses, humans far exceed computers in their level of understanding of the data, information, knowledge, and wisdom they have acquired.

This book includes a focus on people and ICT systems learning to work together to solve problems. A deep or profound symbiosis of this sort is not easily achieved. It required education of the humans involved and development of software so that it interfaces appropriately with the humans.

In chess playing, this endeavor has been worked on since 1997, when Kasparov lost a chess match to Deep Blue (Advanced Chess, n.d.). At a more mundane level, such a symbiosis is occurring whenever you and a computer work together to solve a problem. For example, when I am writing, I am involved in such a symbiosis. However, I am still doing the great majority of the thinking—I am a far better writer than my computer system.

Activities and Discussion Topics

1. Make use of Howard Gardner’s list of eight intelligences to analyze your areas of greater and lesser intelligence. Then continue the analysis by attempting to determine, for each of the eight intelligence areas in Gardner’s list, the extent to which your intelligence is Gf and the extent to which it is Gc.
2. Consider your various uses of ICT. Select one in which it seems reasonable to you to analyze the symbiosis between you and the ICT system, and then do this analysis. Look for relative strengths and weaknesses of both you and the ICT system in this symbiosis. Look for what types of education and training might increase your contributions to the symbiosis, and what improvements in the ICT system might increase its contributions to the symbiosis.

Chapter 3

Joseph Renzulli

“After forty years of intensive research on school learning in the United States as well as abroad, my conclusion is: What any person in the world can learn, **almost** all persons can learn if provided with appropriate prior and current conditions of learning.”
(Benjamin Bloom, *Developing Talent in Young People*, 1985)

Joseph S. Renzulli (<http://www.gifted.uconn.edu/sem/expandgt.html>) is a national and world leader in TAG education. His work in TAG education led to the development of a *Schoolwide Enrichment Model* designed for schoolwide improvement. This model includes the development and use of individualized *Total Talent Portfolio* for each student. It also includes schoolwide use of project-based learning.

This chapter is based on ideas drawn from the work of Joseph Renzulli. I have interpreted and modified these ideas from an ICT point of view. The focus is on schoolwide changes that will help to improve the education of all students. According to Renzulli, this environment is very supportive of TAG education.

Introduction

Renzulli holds the position that there is much more to TAG than just a student's IQ. Figure 3.1 represents part of the thinking in a model he calls Operation Houndstooth (Renzulli, 2002). The six ideas illustrated in this diagram are all aspects of TAG. You probably have known many very smart people who do not seem to be achieving at a level consistent with their intellectual potentials. Perhaps it is because they are weak in some of the characteristics given in the diagram.

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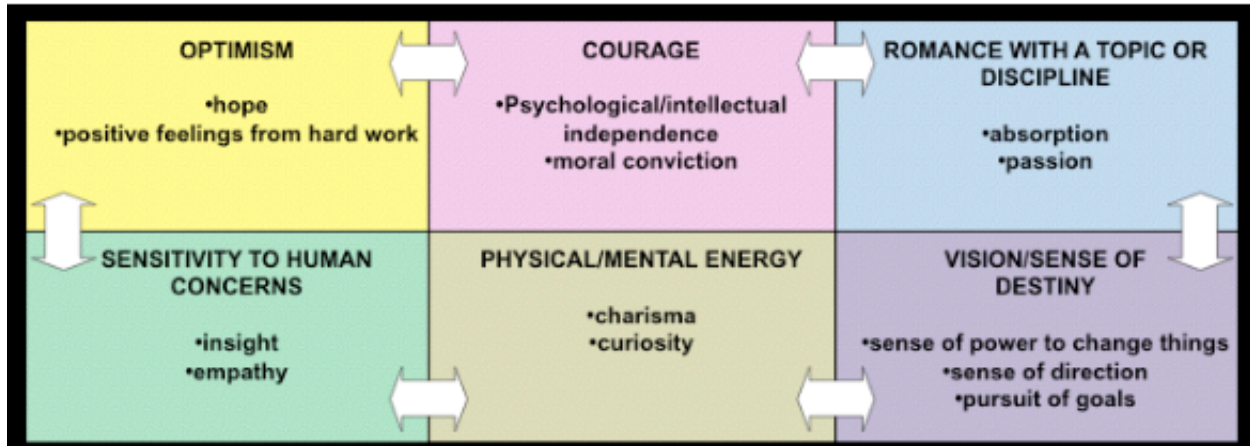


Figure 3.1. Some potential characteristics of a TAG person.

Chapter 1 contains a variety of ways to measure and think about giftedness. Joseph Renzulli of the University of Connecticut revolutionized the thinking about the concept of giftedness in 1978, with his argument that giftedness is defined by three factors. The three factors of his **three-ring model** are above average:

- ability
- task commitment
- creativity.

Renzulli recognized, in a manner consistent with the Multiple Intelligences ideas published by Howard Gardner in 1983, that a person can be gifted in some areas and not in others. He suggested it would be far better to label a child a "gifted writer" or "gifted mathematician" than a gifted child.

A 1998 interview of Renzulli by two math educators captures some of his thoughts on TAG education (Knobel and Shaughnessy, 1998). The following material is quoted from that interview.

What are you currently working on writing/researching?

As far as the National Research Center is concerned, we are looking at a number of different studies dealing with underachieving gifted students and ways to improve the school performance of at-risk student populations who have high potential. One of the biggest areas of frustration in the gifted field is bright kids who don't achieve, and so we are using different interventions or experimental treatments to see how we can turn around underachievement and low performance.

What do you see as your biggest contribution over the past 10, 20 years?

On the theoretical side, I would say it is the Three-Ring Conception of Giftedness, the Enrichment Triad Model, and the Multiple Menu Model for developing Differentiated Curriculum, which someone kindly referred to as the only curricular theory in the field.

How can we best train teachers to teach gifted children?

That's a difficult one to answer in a short period of time. But, I certainly believe that giving people that are interested in being teachers of the gifted more than just classroom courses! And now, of course, some people are getting most of their training on line.

How has the World Wide Web affected gifted children?

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I see a lot of much more advanced kinds of resources being brought to bear on kids' work as a result of the Web. Believe me I'm not one of these kinds of persons that think that computers and the Web will save us. However, the more that I get around to schools, and these are mostly schools where we're doing research, the more I see that kids need to have a facility to get information that is what I sometimes call "needed information". One of the problems with general education is that we teach everybody the same thing, at the same time, usually at the same pace. But, information on an "as needed basis" really makes for fairly outstanding and very authentic scientific work, literary work, artistic work, and creative productivity. And by being able to access this through the Web, young people are going beyond the traditional gatekeepers of knowledge—the teacher and textbook. This access literally opens up the floodgates to advanced knowledge and is already resulting in higher levels of student productivity.

How do gifted students learning styles differ from non-gifted students learning styles?

There has been a small amount of research on this topic—not as much as can or should be done, but the main findings have been that gifted students prefer less structured kinds of learning experiences—projects, independent investigations, simulations, and dramatizations.

What are your feelings about the current standardized I.Q. tests?

I've always said that IQ tests tell us something. But they don't begin to tell us everything, and in some cases they may not even be telling us what is most important about a young person's potential. The kinds of things that result in extremely high levels of creative productivity on the parts of young people and adults, come from combinations of characteristics which I've tried to summarize in the Three Ring Conception of Giftedness and others such as Howard Gardner have summarized in the Theory of Multiple Intelligences.

I hope you didn't just bleep over the above interview questions and answers. They provide an excellent summary of TAG education by one of the world's leading experts in the field. I am particularly impressed by his insights into access to information via the Web—how this empowers students and changes the teacher's role as gatekeeper. Our educational system continues to be quite resistant to possible changes in the role of teacher as gatekeeper, or the idea of empowering individual students to become increasingly responsible for their own education.

Learning Styles

Learning styles are approaches to learning or ways of learning. Through some combination of nature and nurture, students develop ways of learning that they find more useful than other ways of learning. These ways of learning may differ with the material to be learned. Thus, it behooves a student (perhaps with appropriate help from teachers) to learn how they best learn various disciplines or components of disciplines.

Renzulli's Total Talent Portfolio discussed later in this chapter includes a major emphasis on learning styles. There is an extensive literature on learning styles. A 12/23/05 Google search on this term produced about 25 million hits.

Visual, Auditory, Tactile/Kinesthetic

One of the simplest approaches to learning styles consists of just three components: visual, auditory, and tactile/kinesthetic. Quoting from LdPride.net (n.d.):

- Visual Learners learn through seeing.

These learners need to see the teacher's body language and facial expression to fully understand the content of a lesson. They tend to prefer sitting at the front of the classroom to avoid visual obstructions (e.g. people's heads). They may think in pictures and learn best from visual displays including: diagrams, illustrated textbooks, overhead transparencies, videos, flipcharts and hand-

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outs. During a lecture or classroom discussion, visual learners often prefer to take detailed notes to absorb the information.

- Auditory learners learn through listening.

They learn best through verbal lectures, discussions, talking things through, and listening to what others have to say. Auditory learners interpret the underlying meanings of speech through listening to tone of voice, pitch, speed, and other nuances. Written information may have little meaning until it is heard. These learners often benefit from reading text aloud and using a tape recorder.

- Tactile/Kinesthetic learners learn through moving, doing, and touching.

Tactile/Kinesthetic persons learn best through a hands-on approach, actively exploring the physical world around them. They may find it hard to sit still for long periods and may become distracted by their need for activity and exploration.

A number of Websites that discuss learning styles also discuss Howard Gardner's work on Multiple Intelligences. At the LdPride.net Website you can take free self-assessment tests to determine your Learning Style as well as your dominant Multiple Intelligence. A number of other Websites offer somewhat similar free assessment instruments.

The combination of three learning styles with eight Multiple Intelligences can be used to produce a table with 24 cells. To further add to the complexity, many academic disciplines cut across several of the Multiple Intelligence areas. Even this simple analysis suggests that a teacher cannot possibly take the responsibility of teaching each discipline in a manner that best meets each individual student's Multiple Intelligence strengths and preferred learning styles. Students need to learn about themselves as learners and how to make the best use of their intelligence and learning styles to effectively learn new material.

Walter McKenzie's Website provides an excellent overview of Gardner's work from an education point of view (McKenzie, n.d.). Many educators argue that a learner should understand both his or her preferred learning style and dominant intelligence. The learner then brings this information to bear in any learning task.

Even this somewhat simplistic 3-learning styles, 8-multiple intelligences approach to learning discussed in this subsection is rather complex. Consider math education at the elementary school level. The goal is for students to gain knowledge and skills in mathematics, regardless of their dominant Multiple Intelligence or their preferred learning style. Knowing this, many teachers now make use of math manipulatives. This may include both physical manipulatives and virtual (computer-based) manipulatives (Math Manipulatives, n.d.).

Using physical and virtual math manipulatives, a teacher can create a learning environment that is visual, auditory, and kinesthetic/tactile. Learners work to improve their math knowledge and skills—building upon their fluid mathematical intelligence, and adding to their crystallized mathematical intelligence. In this process, learners draw upon their total fluid (Gf) and crystallized (Gc) intelligence.

Constructivism adds to the complexity of this learning situation. Each learner constructs new knowledge by building on current knowledge. Since the current knowledge of each student in a class is different, a teacher cannot hope to individualize in a manner that optimizes the rate and quality of learning for each student. This is why it is very important for students to learning about their strengths and weaknesses as learners in varying disciplines, and to take responsibility for their own learning.

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A Broader View of Learning Styles

As indicated earlier in this chapter, there is an immense amount of literature on learning styles. Frank Coffield et al. (2004) is a free 84-page report that analyzes 13 different learning styles from a teaching and learning point of view. The focus in this report is on students in “post-16” education in England—that is, students in educational programs designed for students over 16 years of age. However, the document is also relevant to younger students, and many of the studies referred to in this report are applicable to precollege students.

One of the 13 learning styles highlighted in the 84-page report is the Dunn and Dunn learning style instrument. Later in this chapter you will see that Renzulli draws heavily on the Dunn and Dunn ideas. The following is quoted from Thompson and Mascazine (2003):

The model of learning styles created by Dunn, Dunn & Price (1979, 1980, 1990) comprises five major categories called stimuli. Within these five major categories are 21 different elements that influence our learning. Following are the five types of stimuli and the elements they comprise:

- * Environmental includes: light, sound, temperature, and room design.
- * Emotional includes: structured planning, persistence, motivation, and responsibility.
- * Sociological includes: pairs, peers, adults, self, group, and varied.
- * Physical includes: perceptual strengths, mobility, intake, and time of day.
- * Psychological includes: global/analytic, impulsive/ reflective, and right- or left-brain dominance.

Next, consider the following quote from the Thompson and Mascazine article:

But perhaps the greatest benefit from attending to learning styles in mathematics or science education is that of placing more responsibility for learning on the students themselves.

Students who discover and understand their personal learning styles can and often do apply such information with great success and enthusiasm. (Griggs, 1991) Thus, attending to learning styles can be an ongoing consideration and aid in attacking new or difficult learning situations and the processing of information.

As we learn more about the physiological and neurological functioning of the human brain, attending to learning styles becomes more credible and accepted. Mathematics and science educators can utilize such findings in small but significant ways. And while many elements of individual learning styles may be obvious to educators, students may not be aware or appreciative of them. **Thus it is important for educators to help individual students discover, utilize, and appreciate their own unique learning styles.** [Bold added for emphasis.]

Notice the focus on individual students learning more about themselves as learners and taking increased responsibility for their own learning. All students can and should do this, although it may well be that TAG students can do this better than students with lesser cognitive abilities.

Here are some words of warning from the 84-page report by Coffield et al.(2004):

This report and Coffield et al. (2004) examined in considerable detail 13 models of learning style and one of the most obvious conclusions is the marked variability in quality among them; they are not all alike nor of equal worth, and it matters fundamentally which instrument is chosen. The evaluation, which is reported at the end of Section 3, showed **that some of the best known and widely used instruments have such serious weaknesses (eg low reliability, poor validity and negligible impact on pedagogy) that we recommend that their use in research and in practice should be discontinued.** On the other hand, other approaches emerged from our rigorous evaluation with fewer defects and, with certain reservations detailed below, we suggest that they deserve to be researched further. [Page 61. Bold added for emphasis.]

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Finally, here is an important message for teachers from Coffield et al. (2004):

The more sophisticated learning style models appreciate that different disciplines require different teaching, learning and assessment methods. Entwistle, McCune and Walker (2001, 108), for example, are clear on this point: ‘The processes involved in a deep approach have to be refined within each discipline or professional area to ensure they include the learning processes necessary for conceptual understanding in that area of study’. **Alexander (2000, 561) knew he was adopting an unfashionable standpoint when he argued that it was a fact that different ways of knowing and understanding demand different ways of learning and teaching.** Mathematical, linguistic, literary, historical, scientific, artistic, technological, economic, religious and civic understanding are not all the same. Some demand much more than others by way of a grounding in skill and propositional knowledge, and all advance the faster on the basis of engagement with existing knowledge, understanding and insight. [Page 66-67. Bold added for emphasis.]

Schoolwide Enrichment Model

The heart of Joseph Renzulli’s Schoolwide Enrichment Model is a school decision to devote a half-day per week to project-based learning (PBL). During that time, all students in the school are engaged in PBL. A specific project may involve students from many different grade levels.

Chapter 5 of this book provides an overview of roles of ICT in PBL. For reading the remainder of this chapter, it suffices to know that:

- In PBL, students work individually or in teams, over an extended period, to produce a product, performance, or presentation.
- PBL is learner centered, with the teacher playing the role of a “guide on the side” rather than as a “sage on the stage.”
- A PBL unit of study typically has multiple goals and multiple methods of assessment. A relatively detailed rubric is often used both as an aid to assessment and as an aid to helping students to learn to self-assess and to provide formative assessment feedback to their peers.

Joseph Renzulli (1998) gives some of the philosophy and an overview of the Schoolwide Enrichment Model.

Every learner has strengths or potential strengths that can be used as a foundation for effective learning and creative productivity. The Schoolwide Enrichment Model capitalizes on these strengths by offering students options to realize their own potential. Through service delivery components like Curriculum Compacting and Enrichment Clusters, students are insured of being exposed to high level and challenging learning experiences. A third component, the Total Talent Portfolio (TTP) serves as the framework by which all the other elements of the model can be organized. [Note from Moursund: The TTP is covered in the next section of this chapter.]

Notice the emphasis on “every learner has strengths or potential strengths.” Suppose, for example, that for a particular set of projects, teams are selected to ensure cultural, ethnic, physical, and cognitive diversity. Then each member of a team will learn about these types of diversity and will contribute to team members learning about these types of diversities.

I believe that every student is both a learner and a teacher. Learning from others and helping others to learn (by example, covertly, and overtly) are routine aspects of life as a human being. A team-based PBL environment facilitates cooperative learning and learning cooperative problem solving.

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The Renzulli quote given above mentions “service delivery components.” What Renzulli mean is that the project-based learning should focus on real-world problems and tasks that have meaning and importance to students and the people in their community. This is a considerable narrowing of the broadest definitions of PBL. Here are a few examples of such projects:

1. Gathering and preserving oral and written histories of the community. These might be represented in writing, in multimedia, as a play, and so on.
2. Addressing the problems of poverty and homelessness in the community.
3. Addressing community environmental problems such as water pollution, lack of parks and play areas, crime, and safety.
4. Addressing problems of inappropriate behavior of students, such as bullying on the playground of disruptive or impolite behavior in the classroom.
5. Building on the cultural diversity in a school and community in order to increase student understanding of and appreciation for cultural diversity.

The Schoolwide Enrichment Model is based on the idea of a school as a unit of change. Substantial research by Michael Fullan (1991) and others stress that school reform is much more likely to succeed at a schoolwide or district wide level than at an individual teacher level, individual grade level, or individual discipline level. What is most needed is a strong commitment from a number of different levels.

For example, consider the idea of one 4th grade teacher in an elementary school decides to commit a half-day per week to ICT-assisted PBL. If appropriately implemented, this is apt to make a significant difference in the education of this teacher’s students. However, these students will be doing something different than what the students in the other 4th grades in the school are doing. Parents (of students both in and not in the PBL classroom) are apt to hear about this and perhaps complain to the principal. The widely used standardized tests do not assess many of the learning goals in ICT-Assisted PBL. Thus, even though the 4th graders are, in total, getting a better education, they may experience a decrease in test scores. Note also that as the students go on to the 5th grade, they create a dilemma for the 5th grade teachers. They have become used to a mode of teaching and learning that the 5th grade teacher might not be using.

As you can see, some of these problems go away if all 4th grade teachers in a school participate. Others go away if all teachers in the school participate. Still others go away if the projects that are addressed are important to the whole school and the whole community. Still others go away if students are assessed at a district or state level on some of the learning goals that are stressed in ICT-Based PBL.

Total Talent Portfolio

Joseph Renzulli strongly advocates the idea of each student having a Total Talent Portfolio (TTP):

A model for total talent development requires that we give equal attention to interests and learning styles as well as to the cognitive abilities that have been used traditionally for educational decision making. The Total Talent Portfolio is a vehicle for gathering and recording information systematically about students' abilities, interests, and learning styles. (Renzulli, 1998)

The basic idea is that each student is to have a personal TTP that is used to assist the student in learning, learning to learn, and learning about themselves as learners. For a very young

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student, the teacher develops an initial TTP for the student. This is done through an interactive discussion with the student as well as by drawing on the teacher's knowledge about the student. There are some similarities between this process and the development of an Individual Education Program (IEP). However, developing, making use of, maintaining, and revising a TTP can be a very informal process.

As students gain in maturity, they can assume more and more personal responsibility for their TTPs.

Students should achieve autonomy and ownership of the TTP by assuming major responsibility in the selection of items to be included, maintaining and regularly updating the portfolio, and setting personal goals by making decisions about items that they would like to include in the portfolio. Although the teacher should serve as a guide in the portfolio review process, the ultimate goal is to create autonomy in students by turning control for the management of the portfolio over to them. (Renzulli, 1998)

As a preservice or inservice teacher, it should be evident to you that some of the information in a student's TTP can help you to better meet the students instructional and learning needs. However, the teacher should hold in mind is that the most important goal is to help students make significant progress in learning to assume responsibility for their own learning.

I believe that one of the major weaknesses in our school system is that students are not learning to take a significant and steadily increasing level of responsibility for their own education, and their own mental and physical development.

Components of a TTP

There are many possible components of a TTP. For example, here are a few possible main headings and subheadings in a table-like approach to a representing a TTP:

1. Special strengths and abilities.
2. Weaknesses and challenges.
3. Interest areas.
4. Style preferences:
 - a. Instructional style preferences
 - b. Learning environment preferences.
 - c. Thinking style preferences.
 - c. Expression and performance style preferences.

Renzulli (1998) uses items 1, 3, and 4 from this list. His approach is to focus on the positive. I have included item 2 because I think it is important for a student to understand his or her areas of weaknesses and challenges. Others argue that it might be better to keep this knowledge from students. As a teacher, you will make a professional judgment as to what is most appropriate for each of your students. My opinion is that it is helpful to students to thoroughly understand areas of weaknesses and challenges. With this knowledge and understanding, a student (with help from teacher, parents, and so on) can develop ways to accommodate to and overcome the challenges. I have talked about this with a number of my students who have a variety of exceptionalities, and they all support this approach.

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Strengths/abilities and weaknesses/challenges have to do both with potential and realized potential. For example, a student may have very high potential in math (a very high math IQ) but not have learned much math. The student may have little or no interest in math, have had very poor instructors and other learning opportunities in math, or for other reasons not developed or used inherent math abilities.

Intelligence is discussed in more detail in the chapter on Human Intelligence and Brain Science. For the purposes of developing a TTP, it suffices to understand that measures of intelligence and aptitude can be an important component of a TTP.

Here are three approaches to identification of strengths/abilities and weaknesses/challenges.

1. Self-assessment. For me, personally, I “know” that my strengths and abilities in math far exceed my strengths and abilities in art or music. Indeed, I think my artwork is still at roughly a first grade level, and is far below my music strengths and abilities. My music ability is modest—my children indicate that I am “tune deaf.”
2. Comparison with classmates, with a group of friends or acquaintances, or a group that one plays computer games with on the Internet.
3. Comparison with other’s performance on tests and other assessments. These might be teacher-made tests, but they might be state and national tests, and so on. As an example, when I was in the sixth grade I took an Iowa Test of Basic Skills. The information I received about my test results gave me an increased understanding about myself.

The third topic on the list of possible TTP components interest areas. Interest areas can often be identified by determining which (if any) academic disciplines and courses one enjoys, one’s hobbies, one’s forms of entertainment, and other ways that one spends free time. As a personal example, I didn’t take any history or biology courses while I was in college. Those two areas did not interest me (then) relative to the other courses that were available. I used to be quite interested in stamp collecting, but I lost that interest many years ago. I am interested in computer games, and I spend a lot of time playing computer games. Over the years I have really enjoyed teaching and writing—I currently spend a lot of my leisure time writing books.

Style preference is the fourth topic on the list of possible TTP components Here is some information about each of the four ideas in this topic area:

- a. Instructional style preferences. This is a large and complex field of study and application. For example, it includes:
 - **Perceptual modalities.** Categorizing a person as an auditory learner, visual learner, or kinesthetic learner.
 - **Multiple Intelligences.** Categorizing a person on the basis of the eight different areas of intelligence identified by Howard Gardner.
 - **Mind styles.** Anthony Gregoric’s Mind Styles Model. Categorizing learners as Concrete Sequential (CS), Abstract Sequential (AS) Abstract Random (AR) and Concrete Random (CR).

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- **Learning styles.** David Kolb's Learning Style Model categories learners as: Type 1 (concrete, reflective) Type 2 (abstract, reflective); Type 3 (abstract, active); and Type 4 (concrete, active).
- **Myers-Briggs.** The Myers-Briggs Type Indicator, based on the work of Carl Jung identifies 16 personality styles based on: 1) How you relate to the world (Extravert or Introvert); 2) How you take in information (Sensing or Intuiting); 3) How you make decisions (Thinking or Feeling); and 4) How you manage your life (Judging or Perceiving).

The research supporting these and other measures of instructional styles is relatively weak. Instruments have been developed for each of these approaches to instructional style preference, and it is easy to locate self-assessment tests that can be used free of charge on the Web.

There are other ways to think about and explore learning style preferences. For example, look at the bulleted list given below. (You can easily expand the list.) When you have a choice, which of these instructional opportunities do you most and least prefer?

- Computer-assisted instruction.
- Demonstration.
- Drill and practice.
- Lab and/or other hands-on.
- Independent study.
- Individual PBL.
- Individual tutoring.
- Lecture.
- Small group discussion.
- Small group PBL.
- Student reports.
- Whole class discussion.

A list such as this can also be explored from the point of view of a particular discipline or topic to be learned. A student may have different learning style preferences for different topics.

- b. Learning environment preferences. This covers areas such as physical environments, people environments, time of day, food availability, and so on. For example, one student may prefer studying in a rather dimly lit room with music playing in the background, while another student prefers good lighting and quietness.
- c. Thinking style preferences. Based on the work of Robert Sternberg (<http://www.yale.edu:rjsternberg:#styles>) this might make use of the three categories: Analytic (school smarts); Creative/Inventive; and Practical (street smarts). Another approach, also drawing on the work of Sternberg, is to make use of the three

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categories: *Legislative* (creating, planning, imagining, and formulating); *Executive* (implementing and doing); and *Judicial* (judging, evaluating, and comparing).

- d. Expression or performance style preferences. How does the student like to display the results of his or her academic work? Examples of possible modes include written, oral, using manipulatives (such as math manipulatives), whole class or small group discussions, artwork, dramatization, graphic (such as video), service work, and work for pay.

Applications of TTP to ICT in Education

The ideas of TTP can be applied to the full range of areas appropriate to the age, education, life experiences, developmental level, and so on of students in a class. However, they can also be applied to a specific domain. This section explores applying TTP ideas to ICT for elementary and middle school students.

To begin, let's briefly review the idea of expertise in a domain. ICT is now a large and well-developed domain of study, research, and use. There have been Ph.D. programs in this field for more than 40 years. The first doctorates in the field of ICT in Education were awarded about 30 years ago. ICT is now well integrated throughout our society and is an important part of every academic discipline. Schools in the United States have an average of about one microcomputer per 4.5 students. More than 75% of students have access to a microcomputer at home.

Our educational system is now faced by the problem of deciding what levels of ICT expertise to help students achieve, and how to effectively help students to meet these expertise goals. This would not be too tough a problem if ICT were something simple, such as keyboarding. We could decide what level of keyboarding expertise we wanted students to achieve, we could implement keyboarding instruction at appropriate grade levels, and we could easily assess keyboarding skills.

However, keyboarding is a minor aspect of ICT. The absolute heart of ICT is in learning to make appropriate use of ICT as an aid to solving problems and accomplishing tasks. Many accomplished computer users who have very low keyboarding skills. That is not surprising. A similar situation exists in writing. Writing is a creative, high cognitive activity. Many accomplished writers have low keyboarding or typing skills.

Thus, our TTP in ICT needs to be based on topics that (in our current best judgment) are important to moving up an expertise scale that focuses on knowledge and skill in making effective use of ICT to solve problems and accomplish tasks.

A later chapter of this book is about computer games. We might decide that it is important for students to gain expertise in playing computer games. After all, in some sense a game involves solving problems and accomplishing tasks. Computer games are often designed so that one can easily measure increasing levels of expertise. In addition, there is a lot known about how to help a person gain an increased level of expertise in playing a particular game.

As with keyboarding, however, this is not a central aspect of ICT. It is true that many people enjoy playing computer games and gain self-satisfaction through their increasing level of expertise in playing one or a variety of games. In addition, some people make a living as game developers or game players. However, it is hard to argue that computer game playing should become part of the core curriculum at the elementary and middle school levels at the current time.

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TTP Areas 1 and 2: Strengths and Weaknesses

As indicated previously, ICT provides many powerful aids to problem solving and other higher-order cognitive activities. A high IQ indicates high cognitive aptitude—the ability to learn to solve complex problems, accomplish complex tasks, and to gain a high level of expertise in a number of different areas.

Of course, we know that it does not take a high IQ to learn to make use of ICT and to gain a personally useful of expertise over a broad range of ICT applications. Relatively young children learn to use a cell telephone, to play handheld computer games, and to use a keyboard in playing games or accomplishing other tasks on a microcomputer.

Thus, in the TTP areas of strength and weaknesses we are looking both for potential (aptitude, IQ) and for actual knowledge, skills, and usage. Some actual strengths of a student might be identified by the student, by teachers, parents, and others. Strengths might be demonstrated through products and performances, such as written products, oral presentations, works of art, musical performance, and so on. Both strengths and weaknesses can be measured compared to oneself as a whole, as compared to one's peers or some particular group, as compared to some set of norms or standards, and so on.

Here are a few starting points for gaining information about actual knowledge, skills, and usage:

1. Observe a student's ICT use fluency and frequency of use over a broad range of applications. For example, does the student frequently and readily use the Web to obtain information? Does the student compose at a computer keyboard, making appropriate use of the facilities provided by a word processor? Does the student often find appropriate uses of ICT as an aid to solving the types of problems being studied in class? Alternatively, is the student well behind the class average in ICT fluency, range of use areas, and frequency of usage?
2. Observe a student's ICT interactions with other students. Do other students (and the teacher, and other adults) frequently ask the student for ICT help? Does the student see where others are having ICT problems, easily identify the problems, and provide help in an appropriate manner? Alternatively, does the student need frequent help from fellow students, the teacher, and others to accomplish ICT tasks?
3. Does the student have an inquisitive mind in ICT? This might be demonstrated by the student often being in the process of exploring new pieces of software and hardware, and the capabilities and limitations of hardware and software. Alternatively, does the student have considerable difficulty in learning new hardware and software. Does the student relatively quickly lose ICT knowledge and skills that have previously been attained?
4. How is the student doing relative to the ISTE National Educational Technology Standards for Students of his or her age level?
5. Have the student do a self-assessment on his or her knowledge and skills in using ICT system as an aid to solving problems and accomplishing tasks. This approach should be broad-based. For example, it should include a focus on uses of computers to play games, use of the various capabilities of a cell telephone, and so on.

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TTP Area 3: Interest Areas

The focus here is on identifying a student's interest areas that currently involve significant use of ICT or that could potentially involve significant use of ICT. Because ICT is such a broadly applicable discipline, a good starting point in this component of the ICT-TTP is just the same as for a full fledged TTP. A student individually, or a student working with a teacher makes a list of areas that interest the student. Given a choice of topics to study, what does the student prefer? Given leisure time, what does the student do? What hobbies does the student pursue? Does the student have interests in music (such as listening, performing, historical), and what types of music? Does the student have interests in art?

After a general exploration, drill down into specific ICT-related interests. Is the student interested in computer games? If so, what kinds? Is the student interested in digital still and video photography? If so, what types of things is the student doing in these areas? Is the student interested in graphic arts and computer animation?

From a teacher perspective, what you are trying to do is to identify ICT-related areas that the student finds to be intrinsically motivating. Within such an area, with encouragement, instruction, and student effort, the student may well achieve the highest level of expertise in the whole class, or perhaps the whole school, or perhaps the whole school district, or so on. The student can develop self-confidence as a learner and a doer, and increased overall self-esteem.

TTP Area 4: Style Preferences

Earlier in this chapter, I listed four major components of Style Preferences:

- a. Instructional style preferences
- b. Learning environment preferences.
- c. Thinking style preferences.
- d. Expression and performance style preferences.

Each of these can be explored from an ICT point of view. ICT brings a number of new and/or improved dimensions to teaching and learning. Examples include computer-assisted instruction, highly interactive intelligent computer-assisted learning, distance learning, and just in time learning. ICT brings us the Internet, which includes email, and the Web.

As you and your students explore style preferences from an ICT point of view, keep in mind that the goal here is to help a student better understand his or her style preferences, and to then examine these style preferences from an ICT point of view. As an example, suppose that a student's preferred perceptual modality is visual. How can ICT help you to provide the student with appropriate instructional video materials? How can the student learn to find such materials on the Web?

Suppose that one of a student's preferred instructional styles is individual tutorial by an adult. Is highly interactive computer-assisted learning an appropriate alternative to this in some situations? Suppose a student is terrified in doing an oral presentation to the whole class. Is facilitating an online discussion group an appropriate alternative in some situations?

Suppose a student likes to demonstrate learning via oral presentations to the whole class. How can these presentations be improved by use of multimedia? Might this student want to learn to make use of digital video to develop video presentations?

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Suppose that a student's preferred thinking style is practical (street smarts). This student might like to be engaged in PBL activity that focuses on identifying and helping to solve some practical problem in the school or neighborhood. ICT provides a wide range of tools that can help in the analysis, representation, and solution of these types of problems.

Suppose that a student really likes to work with and learn from manipulatives. Then this student might like to work with and learn from virtual manipulatives (computer models of manipulatives). Computer modeling is a very powerful research and application tool in many different academic disciplines.

Why Not a Detailed List of ICT Competencies?

I expect that many readers of this chapter are wondering why it does not contain a list of possible ICT competency areas along with details on how to assess them. For example, email, word processor, and Web might be on such a list.

While many people find that this is a useful approach in designing and implementing ICT curriculum content, instructional processes, and assessment, it is a significantly different topic than what this chapter is about.

One way to explain this is to consider lower-order knowledge and skills versus higher-order knowledge and skills. I have written about this in a variety of articles, including Moursund (2002). Students can readily acquire a basic, lower-order, useful level of skills in using email, word processing, and the Web. Throughout this book, I am interested in higher-order knowledge and skills. I am interested in all students gaining increased expertise at solving complex, challenging problems and accomplishing complex, challenging tasks.

One approach to education is to expect students to master basic knowledge and skills before proceeding to higher-order cognitive activities. From my point of view, this is a terrible approach to education. A substantially different approach is to immerse students in an environment of challenging problem-solving and task-accomplishing situations that tweak their curiosity and that they find intrinsically motivating. This reminds me of a story that I like to share.

Many years ago, my wife and I were visiting a married couple who had been her friends for a long time. Both the husband and wife were "into" computers.

The couple shared with us a story about their oldest child, who was about six years old at the time. The child knew a lot about computers and liked to share this knowledge. The story related a recent situation in which the child was showing a sixth grader how to do various things on a microcomputer. The two were working together, with the six year old at the keyboard and taking a leadership role. The high point of this story was when the six-year-old child loudly asked, "How do you spell PRINT?" The child knew basic ideas of how to get the computer to print out documents, but had not yet learned to spell the word that was needed.

The point to the story is that the young child was very interested in computers and was certainly TAG within this specific area. I have no idea about this child's spelling, keyboarding, handwriting, or math skills, but the child's reading, oral communication, and problem-solving skills were certainly adequate to the situation.

Perhaps the child learned to spell PRINT during this "just in time" teachable moment. However, learning to spell the word is small potatoes compared to learning how to interact with a sixth grader in an intellectual and enjoyable manner, learning about how to help someone else learn, and dealing with other aspects of this cognitively rich, fun, intrinsically motivating situation.

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I believe the essence of the Renzulli ideas covered in this chapter is captured by the story. The goal is to provide all students with good opportunities to be immersed in challenging problem-solving environments that interest them—that they find intrinsically motivating, that peaks their curiosity, that leads them to explore, that leads them to do “just in time” learning.

Summary

Renzulli’s School Enrichment Model is based on a combination of involving all students in project-based learning, and helping all students to have and make use of a Total Talent Portfolio. This approach to education helps all students to spend some of their school week working on topics that interest them. It allows all students to work at a level that is appropriate to their abilities, and to their current knowledge and skills. It helps all students learn to take an increasing level of responsibility for their own learning.

ICT is now a routine tool in PBL. Thus, the School Enrichment Model facilitates students learning ICT and using ICT in a relatively authentic environment. Assessment in this environment **is not** via traditional teacher-made tests.

The open-endedness of this type of teaching and learning environment is very good for many TAG students. It encourages and facilitates them to take an increasing level of responsibility for their own learning. It provides opportunities in which they can take a leadership role.

Notice how this School Enrichment Model avoids the TAG education issue of enrichment versus acceleration. Also, notice how it allows students to focus some of their learning time in areas where they may have both considerable interest and talent. A student does not have to be identified as TAG to have this TAG-like learning opportunity.

Activities and Discussion Topics

1. What does it mean for an educational system to be student-centered? Isn't all teaching student centered? What evidence do we have that increasing the emphasis on a lesson being student centered leads to better quality education?
2. What are your personal thoughts about what a student should know about his or her capabilities and limitations as a learner? What evidence do you have support your position?
3. Discuss possible educational benefits and problems of every student having an IEP that takes into consideration the student’s TTP.

Chapter 4

Expertise in Problem Solving in

"In short, learning is the process by which novices become experts." (John T. Bruer. *Schools for Thought*, 1999, page 13.)

"An expert is a person who has made all the mistakes that can be made in a very narrow field." (Niels Bohr, 1885-1962)

Because TAG students learn faster and better than average students, they can achieve a higher level of expertise over a wider range of disciplines than average students. As noted in an earlier chapter, each discipline has its own ideas as to what constitutes a high level of expertise. However, if one uses a broad enough definition of problem and problem solving, then a key aspect of a person's level of expertise in a discipline is how well the person poses and solves problems within the discipline.

While there are many aspects of problem solving that are specific to a particular discipline, there are many other aspects that cut across a number of disciplines. Some of these general approaches to problem solving are appropriate to include in the curriculum of all students. Some other general approaches require special knowledge, such as knowledge of computer programming and computational modeling. Given appropriate educational opportunities, many TAG students can make substantial progress in these areas, gaining a level of expertise that most average students are unlikely to attain.

This chapter explores various aspects of problem solving, and it includes as emphasis on roles of ICT in problem solving. The key idea here is that in many problem-solving situations, people and machines (including ICT) can out perform people alone or machines alone.

Introduction

Problem solving is a routine part of your everyday life. At a conscious or subconscious level, you frequently encounter situations in which things are not as you would like them to be. At a conscious or subconscious level, your mind and body work to change the situation so that it better meets your needs and desires.

For example, suppose you are walking along a poorly lit street at night and you encounter a situation that seems like it might be dangerous to you. At a subconscious level, your body begins to prepare for fight or flight. At a conscious level, you analyze the situation, perhaps comparing it with other situations you have encountered in the past. You subconscious and conscious work together in an attempt to appropriately deal with the problem situation.

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Your mind is designed to make use of knowledge and skills learned in the past. Through informal and formal education and experiences, each of us builds a repertoire of problems that we have encountered in the past and know how to deal with.

Thus, for example, you have frequently encountered the problem of how to safely cross a busy street when you are walking. You have frequently encountered the types of problems that one encounters when shopping. Likely, you are relatively skilled in dealing with small amounts of money as you pay for purchases and receive change. Likely, you are skilled at telling time, by reading a clock or watch. Likely, you are skilled at solving the problem of determining the meaning of an unfamiliar word that you encounter while reading.

Bloom's Taxonomy

Benjamin Bloom's Taxonomy (<http://faculty.washington.edu/krumme/guides/bloom1.html>) is frequently used in talking about lower-order and higher-order knowledge and skills (Bloom's Taxonomy, n.d.). The six-level taxonomy uses the labels: knowledge, comprehension, application, analysis, synthesis, and evaluation. The ideas represented in this scale are complex, and it is not an equal interval scale. I find it useful to think about the end points of the scale.

1. **Knowledge:** arrange, define, describe, duplicate, label, list, memorize, name, order, recognize, relate, recall, repeat, reproduce, state, quote, and so on.
6. **Evaluation:** appraise, argue, assess, attach, choose, compare, conclude, defend, decide, estimate, explain, evaluate, judge, predict, rank, rate, select, support, and so on.

I further simplify this to a two-component approach to learning:

1. **Memorize with understanding:** Learn and understand some facts and procedures, and to use them in a manner that require little thinking.
2. **Think:** Learn to think creatively in addressing novel problems using one's memorized (and understood) facts and procedures.

As one's brain develops and matures, one's ability to function at the high end of Bloom's Taxonomy increases. However, this ability is not automatically translated into talent—actually performance at a higher-order level. It takes a substantial amount of informal and formal learning and hard work over a long period to develop higher-order levels of expertise. One gets better at problem solving through long and hard work while living and studying in a cognitively challenging environment.

Tools

You routinely make use of tools as an aid to solving the problems that you encounter. Figure 4.1 helps illustrate the idea of people and their tools—tools to aid their physical bodies and tools to aid their minds—working together to solve problems and accomplish tasks. Some examples of tools that aid your physical body include shoes and other clothing, the tools used in gardening and farming, the tools used in transportation, the tools used in constructing houses and buildings, telescopes and microscopes, and so on. Examples of mental tools include reading, writing, mathematics, books, and computers.

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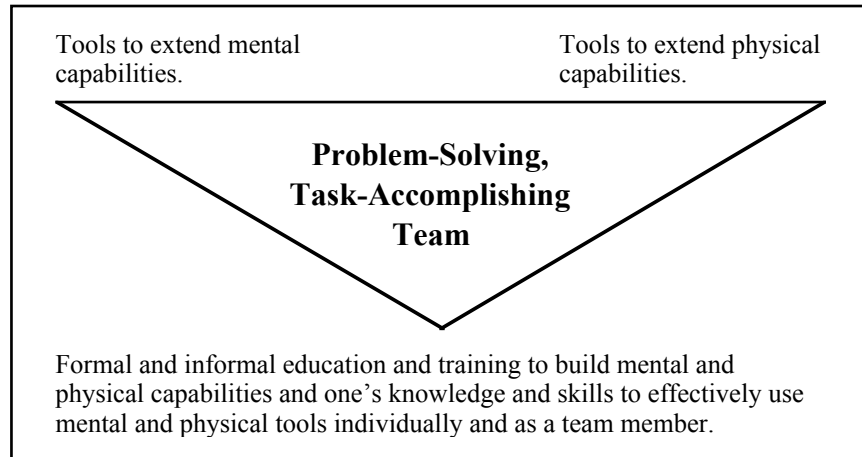


Figure 4.1. People and their tools.

Figure 4.1 can be used to help summarize the challenges faced by our formal educational system. What tools should we have students learn to understand and use? What level of knowledge and skill should we strive for with each of the tools that are studied in the curriculum? To what extent should all students be expected to study and learn the same curriculum, and to what extent should schools accommodate individual differences and interests?

Figure 4.2 is quite similar to Figure 4.1. It emphasizes the new dimension that ICT brings to education. ICT is both a large discipline in its own right and is a powerful aid to automating tools that extend mental and physical capabilities. As a simple example, consider the spelling checker and grammar checker in a word processor. As I write, my word processor functions at a "behind the scenes" level, checking the spelling of each word that I write and the grammar of what I write. Via this process, it helps me to identify keyboarding and spelling errors, and it also identifies some possible errors of grammar. When I request it to do so, the computer then provides suggestions to correct the errors that it thinks it has discovered.

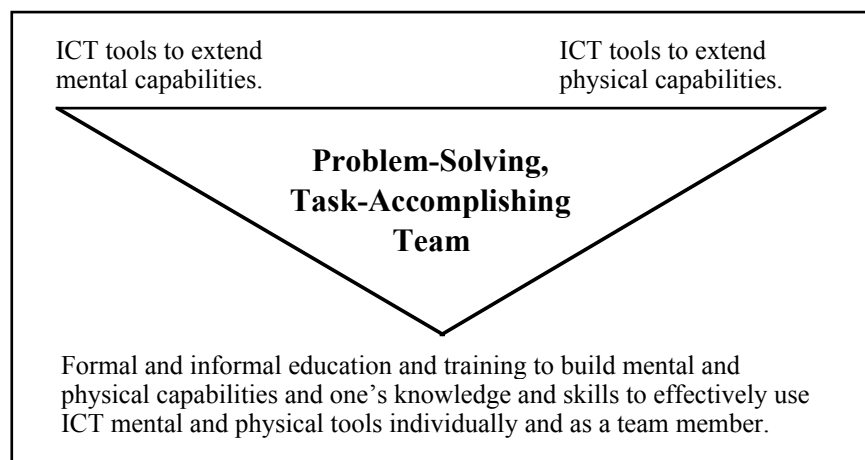


Figure 4.2. A team of people and their ICT aids.

Now, let's carry this example still further. When I have finished my writing activity, I may well direct the computer to print a hard copy of the document. My ICT system quickly accomplished this task, producing legible text far beyond what I can do by hand. Next, I decide to share the document with a number of other people. I might do this by adding it to one of my

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Websites, or I might do it by attaching it to an email message that I send to one of my distribution lists. In either case, my ICT system and I work together to quickly accomplish the information dissemination task.

Definition of the Terms “Discipline” and “Problem”

Here is a copy of a bulleted list given in Chapter 2. In general terms, each discipline can be defined by its unique combination of:

- The types of problems, tasks, and activities it addresses.
- Its tools, methodologies, and types of evidence and arguments used in solving problems, accomplishing tasks, and recording and sharing accumulated results.
- Its accumulated accomplishments such as results, achievements, products, performances, scope, power, uses, impact on the societies of the world, and so on.
- Its history, culture, language (including notation and special vocabulary), and methods of teaching, learning, and assessment.
- Its particular sense of beauty and wonder. A mathematician’s idea of a “beautiful proof” is quite a bit different than an artist’s idea of a beautiful painting or a musician’s idea of a beautiful piece of music.

The bulleted list is designed to emphasize problem solving. The terms problem and problem solving are used in a very broad sense, and include:

- Question situations: recognizing, posing, clarifying, and answering questions.
- Problem situations: recognizing, posing, clarifying, and solving problems.
- Task situations: recognizing, posing, clarifying, and accomplishing tasks.
- Decision situations: recognizing, posing, clarifying, and making decisions.
- Using higher-order, critical, creative, and wise thinking to do all of the above. Often the “results” are shared or demonstrated as a product, performance, or presentation.
- Using tools that aid and extend one’s physical and mental capabilities to do all of the above. (This book emphasizes ICT physical and mental tools.)

The two bulleted lists taken together emphasize that problem solving is part of every discipline. An increasing level of expertise in a discipline means an increasing level of knowledge and skill in recognizing, posing, and solving problems within the discipline. This idea is illustrated in Figure 4.3.

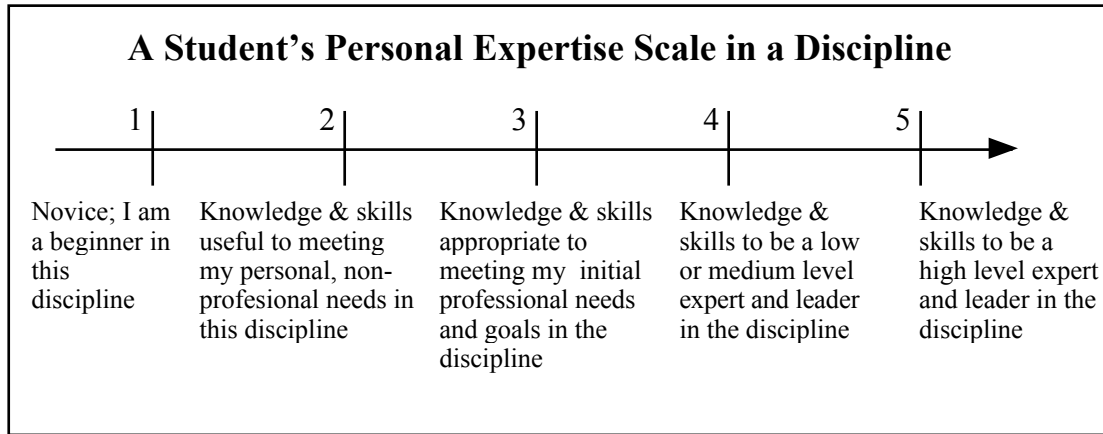


Figure 4.3. An expertise scale for a student in a discipline.

Critical Thinking

Problem solving and critical thinking are closely connected fields of study. Diane Halpern's area of specialization is critical thinking as a component of cognitive psychology. In her 2002 article *Why Wisdom? Educational Psychologist*. 36(4), 253-256, she says:

The term critical thinking is the use of those cognitive skills or strategies that increases the probability of a desirable outcome. It is purposeful, reasoned, and goal directed. It is the kind of thinking involved in solving problems, formulating inferences, calculating likelihood, and making decisions. Critical thinkers use these skills appropriately, without prompting, and usually with conscious intent, in a variety of settings. That is, they are predisposed to think critically. When we think critically, we are evaluating the outcomes of our thought processes—how good a decision is or how well a problem is solved. Critical thinking also involves evaluating the thinking processes—the reasoning that went into the conclusion we have arrived at or the kinds of factors considered in making a decision.

In summary, critical thinking is the ability of students to analyze information and ideas carefully and logically from multiple perspectives. This skill is demonstrated by the ability of students to:

- analyze complex issues and make informed decisions;
- synthesize information in order to arrive at reasoned conclusions;
- evaluate the logic, validity, and relevance of data;
- solve challenging problems, and;
- use knowledge and understanding in order to generate and explore new questions.

Notice that the first three bulleted items are the top end of Bloom's Taxonomy. It is evident that one can spend a lifetime improving their critical thinking skills in a specific discipline and/or across a variety of disciplines. Some aspects of critical thinking cut across many different disciplines. This is helpful as a person works to achieve a high level of expertise in a number of different disciplines.

Lower-Order and Higher-Order Thinking

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Bloom's Taxonomy is a way to categorize lower-order and higher-order cognitive activity. The work of Lauren Resnick is often quoted in discussing this issue (Resnick, 1987). She states that higher order thinking:

- Is nonalgorithmic—the path of action is not fully specified in advance;
- Is complex—with the total path not visible from any single vantage point;
- Often yields multiple solutions, each with costs and benefits;
- Involves nuanced judgment and interpretation;
- Involves the application of multiple criteria, which sometimes conflict with one another;
- Often involves uncertainty, because not everything that bears on the task is known;
- Involves self-regulation of the thinking process, rather than coaching at every step;
- Involves imposing meaning, finding structure in apparent disorder;
- Is effortful, with considerable mental work involved.

Our educational system attempts to differentiate between lower-order thinking skills and higher-order thinking skills. While there is no clear line of demarcation, in recent years our educational system has placed increased emphasis on the higher-order skills end of such a scale. In very brief summary, we want students to learn some facts (a lower-order skill), but we also want them to learn to think and solve problems using the facts (a higher-order skill).

For example, consider the teaching of writing. You may consider good penmanship and correct spelling to be important, but most people would consider these lower-order cognitive goals. Learning to write in a manner that communicates effectively is a higher-order goal. In some sense, each writing task is a challenging, new problem to be solved.

What is a Formal Problem?

Up to this point, I have not provided you with a formal definition of *problem*. Problem solving consists of moving from a given initial situation to a desired goal situation. That is, problem solving is the process of designing and carrying out a set of steps to reach a goal. Usually the term *problem* is used to refer to a situation where it is not immediately obvious how to reach the goal. The exact same situation can be a problem for one person and not a problem (perhaps just a simple activity or routine exercise) for another person.

Here is a formal definition of the term problem. You (personally) have a problem if the following four conditions are satisfied:

1. You have a clearly defined given initial situation.
2. You have a clearly defined goal (a desired end situation). Some writers talk about having multiple goals in a problem. However, such a multiple goal situation can be broken down into a number of single goal problems.
3. You have a clearly defined set of resources that may be applicable in helping you move from the given initial situation to the desired goal situation. There may be specified limitations on resources, such as rules, regulations, and guidelines for what you are allowed to do in attempting to solve a particular problem.
4. You have some ownership—you are committed to using some of your own resources, such as your knowledge, skills, and energies, to achieve the desired final goal.

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These four components of a well-defined (clearly-defined) problem are summarized by the four words: givens, goal, resources, and ownership. If one or more of these components are missing, you have an ill-defined problem situation rather than a well-defined problem. An important aspect of problem solving is realizing when you are dealing with an ill-defined problem situation and working to transform it into a well-defined problem.

There is nothing in the definition that suggests how difficult or challenging a particular problem might be for you. Perhaps you and a friend are faced by the same problem. The problem might be very easy for you to solve and very difficult for your friend to solve, or vice versa. Through education and experience, a problem that was difficult for you to solve may become quite easy for you to solve. Indeed, it may become so easy and routine that you no longer consider it a problem.

You may be confused by the resources (component 3) of the definition. Resources merely tell you what you are allowed to do and/or use in solving the problem. Indeed, often the specification of resources is implied rather than made explicit. Typically, you can draw on your full range of knowledge and skills while working to solve a problem. But, you are not allowed to cheat (for example, steal, copy other's work, plagiarize). Some tests are open book, and others are closed book. Thus, an open book is a resource in solving some test problems, but is cheating (not allowed, a limitation on resources) in others. In any event, resources do not tell you how to solve a problem.

For many types of problems, ICT is a powerful resource. Thus, people who have a broad range of ICT knowledge and skill, and access to ICT facilities, have a very useful and general-purpose resource. This creates the same type of situations as exists for open book versus closed book tests. Authentic assessment strives to have the assessment environment close to the performance environment that students will encounter in the "real world." Open book and open computers are standard resources when solving real-world problems. Often they are not allowed in tests in school setting.

Problems do not exist in the abstract. They exist only when there is ownership. The owner might be a person, a group of people such as the students in a class, or it might be an organization or a country. A person may have ownership "assigned" by his/her supervisor in a company. That is, the company or the supervisor has ownership, and assigns it to an employee or group of employees.

The idea of ownership can be confusing. In this document we are focusing on you, personally, having a problem—you, personally, have ownership. That is quite a bit different than saying that our educational system has a problem, our country has a problem, or each academic discipline addresses a certain category of problems that helps to define the discipline.

The idea of ownership is particularly important in teaching. If a student creates or helps create the problems to be solved, there is increased chance that the student will have ownership. Such ownership contributes to intrinsic motivation—a willingness to commit one's time and energies to solving the problem. All teachers know that intrinsic motivation is a powerful aid to student learning and success.

The type of ownership that comes from a student developing a problem that he/she really wants to solve is quite a bit different from the type of ownership that often occurs in school settings. When faced by a problem presented/assigned by the teacher or the textbook, a student

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may well translate this into, "My problem is to do the assignment and get a good grade. I have little interest in the problem presented by the teacher or the textbook." A skilled teacher will help students to develop projects that contain challenging problems that the students really care about.

Many teachers make use of Project-Based Learning within their repertoire of instructional techniques (Moursund PBL Website, n.d). Within PBL, students often have a choice on the project to be done (the problems to be addressed, the tasks to be accomplished), subject to general guidelines established by the teacher. Thus, students have the opportunity to have a significant level of ownership of the project they are working on. Research on PBL indicates that this ownership environment can increase the intrinsic motivation of students. A later chapter of this book discusses ICT-Assisted PBL in more detail.

Automaticity: A Key Problem-Solving Idea

Here is a simple idea. If you frequently encounter a particular problem, learn how to solve it, and then practice solving it until the process is so routine and thoroughly embedded in your mind and body so that you can quickly and easily solve the problem with little or no conscious thought. That is, achieve automaticity in solving the problem. For me, an example is tying my shoes. With some thought, I can dredge up hundreds of examples. I know the arithmetic multiplication facts through 12 by 12. I can spell many words with little or no effort. I automatically look both ways before crossing a street. I can pet one of my cats with either hand while I am reading a book. Sometimes, I can drive a car with little conscious thought. (Of course, occasionally this causes me start driving to a place different from where I intended to go. I am always somewhat embarrassed when this occurs.)

The type of automaticity discussed in the previous paragraph is very important. In all fields of endeavor one can talk about the "basics." In some sense these are "basic" building block types of problems that one can learn to solve in an automatic, non-thinking manner. The time and effort needed to gain and maintain such automaticity can be quite large. Thus, the learner faces a tradeoff between time spent developing a high level of automaticity in the basics versus time spent developing higher-order knowledge and skills that are critical to solving more complex problems and accomplishing more complex tasks.

Now, what happens as technology produces physical and mental tools that are a partial or complete replacement for by-hand methods for solving some important frequently occurring problems and accomplishing some important frequently occurring tasks? Producing light and heat by flipping on a light switch and turning up the thermostat are quite different than producing light and heat by starting a fire using a fire bow. Putting food on the table via shopping at a grocery store and cooking using modern kitchen appliances is quite different than doing so via hunting, gathering, and food preparation using hand tools that one has constructed.

The point to these examples is that technology can save a lot of learning time and decrease the amount of time and effort to solve many frequently occurring problems and to accomplish many frequently occurring tasks. However, many people are bothered by becoming so dependent on technology.

Learning handwriting and keyboarding provide an excellent example for discussion. It takes a long time for a child to learn to print and to learn cursive handwriting that produces legible text at a reasonable rate of speed. Technology first brought us the typewriter and more recently the computer. It takes a child quite a few hours of instruction and practice to learn to keyboard at a productive level. The meaning of "productive level" will vary from child to child. However,

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most children can gain a speed of keyboarding that is much faster (and much more legible) than their printing or cursive handwriting. This is an over simplification of the situation, since one makes typos in keyboarding much more frequently than one makes similar errors when handwriting.

At the current time in our current society, it is beneficial to a child to have both handwriting and keyboarding skills. However, the value of good cursive handwriting skills is declining versus the value of having good keyboarding skills. Thus, some elementary schools have begun to decrease the time spent on teaching cursive handwriting.

The issues of handwriting and keyboarding produce a number of interesting problems that are faced by teachers and by people who design the school curriculum. For example, suppose a student has developed considerable speed and accuracy in keyboarding. Should this student be allowed to use a word processor (complete with spelling checker and grammar checker) when taking tests? Indeed, is it fair to allow this student to do written assignments in this ICT environment?

Suppose that you decide that it is okay (indeed, even desirable) for a student to use a computer in the writing situations described above. Should the school be responsible for providing the student with appropriate access to a computer during testing and writing situations? To further complicate the situation, what about a student who has developed skill in using voice input to the word processing software? (Think about the logistics of a classroom full of students taking a test, with each student using voice input to a computer.)

ICT and the Basics in Education

For many years, leaders in the field of ICT in Education have argued that ICT is now one of the basics of education. While some progress has occurred in integrating ICT into the K-12 curriculum and everyday classroom activities, this progress has been slow. There are a variety of reasons for this. Some, examples include:

1. The ICT technology is relatively expensive and is not as readily available as other “traditional” technology such as paper, pencil, and books.
2. Most teachers have only a very modest level of ICT knowledge and skills, especially as ICT applies to solving complex problems and accomplishing complex tasks. Our preservice and inservice teacher education program has not succeeded very well in addressing this problem.
3. Time spent on learning ICT is time not available for to use on the traditional curriculum.
4. Through integration of ICT into curriculum content, instructional processes, and assessment would produce a major change in what constitutes a good education. Many parents, educators, and politicians resist this change, each for their own reasons.

My hope is that eventually this situation will change. During my long professional career, however, the rate of acceptance and appropriate integration of ICT into curriculum, instruction, and assessment has been very slow relative to the rate of improvement of ICT capabilities and availability. In some sense, our educational system has been falling further and further behind in its use of ICT.

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Humans and Robots

In Chapter 2, I presented information about human intelligence and machine intelligence (artificial intelligence). While the word “intelligence” is used in both cases, it is clear that human intelligence and machine intelligence are quite different.

Stretch your imagination a little bit, and suppose that some number of years in the future artificially intelligence robots have become commonplace in our world. These robots have mobility, dexterity, vision, and the type of intelligence and other capabilities of computers.

The intelligence of robots will vary, depending on the hardware and ICT power available to each robot. The intelligence of a robot is increased by providing the robot with better sensors, mobility, and other physical capabilities. It is also increased by providing it with better ICT hardware, software, and connectivity.

Bloom’s Taxonomy is based on human intelligence. Think about creating a taxonomy for AI-based robots. The lower end of this scale would be capabilities of inexpensive robots. The high end of the scale would describe capabilities of the “state of the art” robots. These robots would have considerable freedom for independent action to recognize, analyze, and solve certain types of problems. A still higher point on the scale would describe features that are being worked on by these future researchers—for example, perhaps it would be robots that have human-like intelligence at a higher level than most humans, as well as machine intelligence.

It is interesting to think about the lower end for the scale for robots. The robot can memorize the exact contents of many thousands of books. It can function in a stimulus/response mode to deal with thousands of frequently occurring problems and to answer a wide range of frequently occurring questions. If its own AI capabilities are not adequate to a particular situation, it can use its connectivity to quickly draw upon the greater intelligence of more powerful computer systems.

I hope you will see that some of these lower-order capabilities of a robot are somewhat like lower-order capabilities on Bloom’s Taxonomy for humans, but the robot easily exceeds humans in some of these capabilities. Hmmm. I wonder what the educational implications of this might be. I also wonder where this brief section might end up if I begin to consider the higher-order capabilities of current and future robots. I thoroughly enjoy reading science fiction stories that explore such issues. I don’t think I am likely to write a story that is nearly as good as the many stories I have read over the years.

You may find some of the futuristic science fiction ideas somewhat disconcerting or even frightening. So, let’s back off from a science fiction version of robots, and consider an ordinary human being (perhaps you) who carries an ultra modern cell telephone. Think of this cell telephone as being your personal robot. Your robot’s mobility and physical manipulators are provided by you, rather than built into the robot. Your personal robot has voice input and voice output capabilities. It can take pictures and can record sound. It can connect to the Internet, storing and retrieving information from the Web. It may have many other capabilities such as those currently in a palm-top computer, a GPS, and an iPod. Through its own built-in compute power and/or making use of computers accessible over the Internet, it has tremendous compute power and a high level of AI.

Bloom’s Taxonomy is not quite adequate to the situation I am discussing here. Humans are born with some potentials that are far beyond those of current AI systems or the AI we are apt to

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have in the next few decades. For example, a very young baby can recognize his or her mother by sight and smell. The development of highly accurate AI-based human recognition and identification systems is still a major problem, a long way from being successfully solved. An average child's ability to learn languages and to communicate with understanding via oral language far exceeds the capabilities of current AI systems. The emotional understanding and intelligence of an average person far exceeds the best of what is currently possible with AI systems. Humans readily learn the culture or cultures they grow up in, and they far exceed AI systems in knowing what it means to be human.

These types of abilities, and their development into powerful talents, are not part of Bloom's Taxonomy. What is important in this discussion is that humans and AI-based robots are substantially different. The AI-based robots (as well as other tools) have certain abilities and talents that far exceed those of humans, and vice versa.

My conclusion is that humans should learn to make effective use of the robot capabilities. Our current educational system is making a modest attempt to accomplish this educational task. However, it is doing a very poor job.

This creates opportunities for a substantial long-term improvement in our educational system. In addition, it creates immediate opportunities for TAG students. Because they can learn much faster and better than average students, they can be covering both the traditional curriculum and developing expertise in problem solving in an ICT environment.

Some Problem-Solving Strategies

A strategy can be thought of as a plan, a heuristic, a rule of thumb, a possible way to approach the solving of some type of problem. For example, perhaps one of the problems that you have to deal with is finding a parking place at work or at school. If so, probably you have developed a strategy—for example, a particular time of day when you look for a parking place or a particular search pattern. Your strategy may not always be successful, but you find it useful.

The research literature about problem solving indicates:

1. There are relatively few strategies that are powerful and applicable across all domains. Because each subject matter (each domain) has its own set of domain-specific problem-solving strategies, one needs to know a great deal about a particular domain and its problem-solving strategies to be good at solving problems within that domain.
2. The typical person has few explicit domain-specific strategies in any particular domain. This suggests that if we help a person gain a few more domain-specific strategies, it might make a significant difference in the person's overall problem-solving performance in that domain. It also suggests the value of helping students to learn strategies that cut across many different domains.

Remember, one of the most important ideas in problem solving is to effectively draw upon and make use of the accumulated knowledge of yourself and others. The Web is a global library that is steadily growing in size and that contains a large amount of accumulated information. A problem-solving strategy that cuts across all domains is to become skilled at information retrieval as an aid to solving problems. Research librarians are highly skilled in this type of

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information retrieval. However, all students can gain considerable facility for retrieving information from the Web and other sources.

The next few sections give examples of rather general-purpose strategies that cut across many domains. While a student may first encounter one of these strategies in a specific domain, each is amenable to teaching for high-road transfer. High-road transfer is the idea of learning a strategy in a manner that facilitates consciously and readily using it in a variety of settings.

To teach for high-road transfer:

1. Identify the generalizability strategy that is being illustrated and used in a particular problem-solving situation.
2. Give the strategy a name that is both descriptive and easily remembered.
3. Working with your students, identify a number of different examples in other disciplines and situations in which this named strategy is applicable.
4. Have students practice using the strategy in a variety areas in which it is useful, and where students have appropriate general and domain-specific knowledge.

Transfer of learning is discussed in more detail in Chapter 6. A teacher who is teaching a problem-solving strategy within a particular domain has a responsibility of teaching it for high-road transfer and helping students learn to use the strategy in a number of different domains.

Top-Down Strategy

The idea of breaking big problems into smaller problems is called the top-down strategy. The idea is that it may be far easier to deal with a number of small problems than it is to deal with one large problem. For example, the task of writing a long document may be approached by developing an outline, and then writing small pieces that fill in details on the outline.

It is useful to think of the “smaller problems” as building-block problems. You improve your ability to solve problems by a combination of increasing your repertoire of building-block problems (problems that you know how to solve easily and quickly) and getting better at using the top-down strategy.

Generally speaking, it takes quite a lot of time and effort to learn to solve a building-block problem to a relatively high level of speed and accuracy. Thus, our education system needs to decide how much effort to place on this endeavor when time is also needed to teach higher-order knowledge and skills, general strategies, and other components of high-road transfer.

ICT plays a major role in problem solving because it can automate a huge and growing number of building-block problems. As a simple example, consider “square root.” It doesn’t take very long to learn how to use a calculator to calculate the positive square root of a positive number. This allows our education system to clearly differentiate between the concept of square root and a process or procedure for calculating square root.

Building-block problems exist in every discipline. For example, you can think of the “problem” of spelling a word that you know how to use orally. A dictionary can help, as can a spelling checker on a computer.

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Or, consider the problem of cropping a photograph. This can be done with a pair of scissors. But, if the photograph is in a computer, the computer can be used both for cropping and for a range of other manipulations.

Don't Reinvent the Wheel (Ask an Expert) Strategy

Library research is a type of "ask an expert" strategy. A large library contains the accumulated expertise of thousands of experts. The Web is a rapidly expanding global library. It is not easy to become skilled at searching the Web. For example, are you skilled in using the Web to find information that will help you in dealing with language Arts problems, math problems, science problems, social science problems, personal problems, health problems, entertainment problems, shopping problems, and so on? Each domain presents its own information retrieval challenges.

Scientific Method Strategy

The various fields of science share a common strategy called Scientific Method. It consists of posing and testing hypotheses. This is a form of problem posing and problem solving. Scientists work to carefully define a problem or problem area that they are exploring. They want to be able to communicate the problem to others, both now and in the future. They want to do work that others can build upon. Well done scientific research (that is, well done problem solving in science) contributes to the accumulated knowledge in the field.

Trail and Error, Or Exhaustive Search Strategy

Trial and error (guess and check) is a widely used strategy. It is particularly useful when one obtains information by doing a trial that helps make a better guess for the next trial. For example, suppose you want to look in a dictionary to find the spelling of a word you believe begins with "tr." Perhaps you open the dictionary approximately in the middle. You note that the words you are looking at begin with "mo." A little thinking leads you to opening the right hand part of the dictionary about in the middle. You then see you have words beginning with "sh." This process continues until you are within a few pages of the "tr" words, and then you switch strategies to paging through the dictionary, one page at a time.

The "page through the dictionary one page at a time" is an exhaustive search strategy. You could have used it to begin with, starting at the first page of the dictionary. That is a very slow strategy to use for finding a word in a dictionary.

An ICT system might be a billion times as fast as a person at doing guess and check or exhaustive search in certain types of problems. Thus, guess and check, and exhaustive search, are both quite important strategies for the computer-aided solving of certain types of problems.

A General-Purpose 6-Step Strategy

This section contains a general six-step strategy that you can follow in attempting to solve almost any problem. This six-step strategy is a modification of ideas discussed in George Polya (<http://www-groups.dcs.st-and.ac.uk/~history/Mathematicians/Polya.html>) (1957) and can be called the Polya strategy or the six-step strategy. Polya was one of the greatest research mathematicians and math educators of the 20th century. Note that there is no guarantee that use of the six-step strategy will lead to success in solving a particular problem. You may lack the

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knowledge, skills, time, and other resources needed to solve a particular problem, or the problem might not be solvable.

1. Understand the problem. Among other things, this includes working toward having a well-defined (clearly defined) problem. You need an initial understanding of the Givens, Resources, and Goal. This requires knowledge of the domain(s) of the problem, which could well be interdisciplinary. You need to make a personal commitment to solving the problem.
2. Determine a plan of action. This is a thinking activity. What strategies will you apply? What resources will you use, how will you use them, in what order will you use them? Are the resources adequate to the task?
3. Think carefully about possible consequences of carrying out your plan of action. Place major emphasis on trying to anticipate undesirable outcomes. What new problems will be created? You may decide to stop working on the problem or return to step 1 as a consequence of this thinking.
4. Carry out your plan of action. Do so in a thoughtful manner. This thinking may lead you to the conclusion that you need to return to one of the earlier steps. Note that this reflective thinking leads to increased expertise.
5. Check to see if the desired goal has been achieved by carrying out your plan of action. Then do one of the following:
 - A. If the problem has been solved, go to step 6.
 - B. If the problem has not been solved and you are willing to devote more time and energy to it, make use of the knowledge and experience you have gained as you return to step 1 or step 2.
 - C. Make a decision to stop working on the problem. This might be a temporary or a permanent decision. Keep in mind that the problem you are working on may not be solvable, or it may be beyond your current capabilities and resources.
6. Do a careful analysis of the steps you have carried out and the results you have achieved to see if you have created new, additional problems that need to be addressed. Reflect on what you have learned by solving the problem. Think about how your increased knowledge and skills can be used in other problem-solving situations. (Work to increase your reflective intelligence!)

Many people have found that this six-step strategy for problem solving is worth memorizing. As a teacher, you might decide that one of your goals in teaching problem solving is to have all your students memorize this strategy and practice it so that it becomes second nature. Help your students to make this strategy part of their repertoire of high-road strategies. Students will need to practice it in many different domains in order to help increase transfer of learning. This will help to increase your students' expertise in solving problems.

Many of the steps in this six-step strategy require careful thinking. However, there are a steadily growing number of situations in which much of the work of step 4 can be carried out by a computer. A person who is skilled at using a computer for this purpose may gain a significant advantage in problem solving, as compared to a person who lacks computer knowledge and skill.

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Some Other Widely Used Strategies

Here are a few additional strategies that are applicable over a wide range of problem-solving domains. You and your students can benefit through a “bridging” form of instruction on these strategies that is designed to promote high-road transfer.

1. **Brainstorm.** Brainstorming can be done individually or within a group. The idea is to generate lots of ideas that may be relevant to clarifying a problem and developing possible solutions for further detailed analysis.
2. **Draw a Picture or Diagram.** This can range all the way from doodling (which might be considered a type of brainstorming) to a carefully directed effort to represent a problem situation through drawings, diagrams, and other graphical images.
3. **Sleep on It.** This strategy involves getting a problem clearly defined in your mind, and working to solve it. Then, go to sleep. Many people report that some of their best ideas for solving complex problems occur to them while they are asleep. An important variation on this is to get a problem firmly in mind, typically by working on the problem but failing to solve it. Then put the problem aside for a week or more. Researchers in problem solving have found that this often leads to the generation of new and important ideas on how to solve the problem.
4. **Explain It to a Colleague.** Many people find that carefully explaining a problem to a colleague often leads to an “Aha, now I see how to solve it.”

Getting Better at Learning

Consider the “problem” of learning. Each person is faced by this problem on a daily basis. The normal human brain is designed to be quite good at learning. However, evolution did not design our brains to be good at learning how to read, write, do arithmetic, use an ICT system, or learn the various other disciplines that are now taught in schools.

Over the thousands of years in which we have had formal education (schooling), people have learned a great deal about how people learn and how to facilitate learning. Each student gains knowledge and skills in how to learn. That is, because of formal education, each person gains an increasing level of expertise in attacking various learning problems/tasks.

Since each person is unique, each person is faced by the task of learning to learn in a manner that is appropriate to his or her capabilities, limitations, interests, current knowledge and skills, and so on. In some sense, we are talking about domain specificity, where a person is considered to be a domain.

From a teacher education point of view, we thus want to help each preservice and inservice teacher gain both domain specific approaches to attacking the problem of learning (approaches that are specific to a particular student) and domain independent approaches (approaches that cut across many students). We place upon ourselves a requirement to teach in a manner that fits various general learning styles. Thus, we may teach a particular topic in a manner that is consistent with visual, kinesthetic, and aural learning styles. By and large, however, we cannot provide each student with the one-on-one instruction that is specifically geared to the student’s combination of learning styles that is most appropriate to the specific that the student is expected to learn.

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Let's consider a specific example. One strategy for learning is to memorize in a stimulus-response manner, with little or no understanding. Another strategy for learning is to focus strongly on understanding, meaning, how the material ties in with one's previous knowledge (that is, following the ideas of constructivism), and so on. This leads a teacher to ask questions such as:

1. For a class as a whole and for a specific set of materials being taught, what do I want students to memorize and what do I want them to learning with understanding?
2. For a class as a whole, how do I appropriately assess student progress in these two aspects of learning the specific set of materials I want them to learn?
3. How do I appropriately take into consideration the individual differences among my students?
4. How do I take into consideration ICT both as an aid to each individual student's learning and as an aid to each individual student using his or her learning (to solve problems, accomplish tasks, etc.)?

Rote memorization is an important approach to learning. However, there is rote memorization without understanding, and there is rote memorization with understanding. ICT systems are very good at rote memorization without understanding. When coupled with a search engine, an ICT system has tremendous capabilities to store and retrieve information. This fact is one of the reasons that our education system is gradually placing increased emphasis on learning for understanding, and learning for problem solving, critical thinking, and other higher-order cognitive activities.

Ineffective and Effective Strategies

You and your students have lots of domain-specific strategies. Think about some of the strategies you have for making friends, for learning, for getting to work or school on time, for finding things that you have misplaced, and so on. Many of your strategies are so ingrained that you use them automatically—without conscious thought. You may even use them when they are ineffective.

The use of ineffective strategies is common. For example, how do you memorize a set of materials? Do you just read the materials over and over again? This is not a very effective strategy. There are many memorization strategies that are better. A useful and simple strategy is pausing to review. Other strategies include finding familiar chunks, identifying patterns, and building associations between what you are memorizing and things that are familiar to you.

What strategies do you use in budgeting your time? Do you frequently find yourself doing a lot of work at the last minute? Perhaps your time-budgeting strategy is not very effective.

Some learners are good at inventing strategies that are effective for them. However, most learners can benefit greatly from some help in identifying and learning appropriate strategies. In general, a person who is a good teacher in a particular domain is good at helping students recognize, learn, and fully internalize effective strategies in that domain. Often this requires that a student unlearn previously acquired strategies or habits.

Problem-solving strategies can be a lesson topic within any subject that you teach. Individually and collectively your students can develop and study the strategies that they and

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others use in learning the subject content area and learning to solve the problems in the subject area. A whole-class ICT-Assisted PBL project in a course might be to develop and desktop publish a book of strategies that will be useful to students who will take the course in the future.

Computer and Information Science

Computer and Information Science (CIS) is an important and foundational component of ICT. Here are two definitions from <http://www.nitrd.gov/pubs/bluebooks/1995/section.5.html>:

Computer Science: The systematic study of computing systems and computation. The body of knowledge resulting from this discipline contains theories for understanding computing systems and methods; design methodology, algorithms, and tools; methods for the testing of concepts; methods of analysis and verification; and knowledge representation and implementation.

Computational Science and Engineering: The systematic application of computing systems and computational solution techniques to mathematical models formulated to describe and simulate phenomena of scientific and engineering interest.

Computer and Information science is a large discipline. This section contains brief discussions of two important components of CIS.

Computer Programming

A computer is a machine that is designed for the input, storage, processing, and output of information by following a detailed step-by-step set of instructions called a computer program. A modern microcomputer can carry out (execute) several billion instructions per second. An instruction might be to add a pair of number, to compare two letters to see which comes earlier in the alphabet, or to compare two numbers to see which is the larger. A typical computer has a repertoire of perhaps 200 different instructions that it is “wired” to be able to carry out.

There are a huge and steadily increasing number of types of problems that computers can solve. The number is increasing because of:

1. Steady progress in the theory and practice of problem solving within each academic discipline.
2. Steady progress in developing more powerful computers (greater speed, larger memories).
3. A steady increase in the library of available programs.

There are many different computer-programming languages. Historically, FORTRAN was designed for writing programs to help solve science and engineering problems, COBOL was designed for writing programs to help solve business problems, BASIC was designed to be a tool for college students, and Logo was designed to be used by elementary school students.

In essence, computer programming is about problem solving. Thus, high IQ students have much greater potential to do well at computer programming than do low IQ students.

At one time, there was a considerable movement in schools in the United States to teach computer programming in BASIC or Logo to very large numbers of elementary school and middle school students. That movement has died out, although some schools and school districts are still quite successful in this endeavor. There are many good Logo resources (<http://el.media.mit.edu/logo-foundation/logo/programming.html>) designed to help educators

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who are interested in Logo. In addition, there are many free online tutorials (<http://www.programmingtutorials.com/>) on programming languages.

While it is quite helpful to have a good and knowledgeable teacher when learning computer programming, there are now some reasonably good computer-based tutorial programs. In addition, many TAG students have been very successful in learning programming on their own and/or from peers and acquaintances. The BASIC language and the Logo language are likely to be good starting points for elementary school students. A local computer club may well be able to provide a volunteer to help a TAG student who has interest in learning computer programming.

The Discipline of Computer and Information Science

The discipline of Computer and Information Science is far more than just computer programming. CIS is a discipline that explores the theory and practice of representing and solving problems in a computer environment. Much of the theory is rooted in mathematics, and most university degree programs in CIS require students to take a couple of years of math, including calculus and discrete mathematics.

CIS has a number of sub-disciplines. One of these is Artificial Intelligence, which has been mentioned repeatedly in this book. Another is software engineering, which can be thought of as the design and implementation of ICT systems to solve complex problems. Computer graphics is a component of CIS that has, in some sense “spun off” the field of multimedia. Information storage and retrieval has provided the foundations for the Web.

TAG students who have multiple areas on interest, including CIS, should think seriously about working for both a CIS degree and a degree in one or two other disciplines. Relatively few people are currently achieving this type of breadth and depth of knowledge—which is so important in working on the types of interdisciplinary problems that are so common in our world.

Summary

All students can increase their levels of expertise in a wide variety of disciplines. With appropriate curriculum, instruction, and assessment, most will learn much faster and better than they would if working just on their own.

However, TAG students are better than average at learning on their own. Moreover, because TAG students learn faster and better than average students, they have the wherewithal to develop broader and deeper areas of expertise.

ICT is a challenging discipline in its own right, and some TAG students will want to work toward a high level of expertise in this discipline. However, ICT is also a powerful aid to problem solving in most other disciplines. Thus, ICT can be a valuable area of study for students interested in the various non-ICT disciplines in the school curriculum. This situation provides one way to provide enrichment in Tag education. TAG students can simultaneously learn the traditional curriculum and can delve deeply into roles of ICT in knowing and “doing” the discipline.

Activities and Discussion Topics

1. Suppose that you are talking to a student who is at the grade level you are preparing to teach or currently teach. You know that this is a TAG student who can learn both much better than average students, and at least 1 ½ times as fast as average students.

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You have just finished studying this chapter on problem solving. What ideas would you share with this student, and why?

2. In talking to my professional colleagues, I find that they feel the ideas of lower-order cognitive skills and higher-order cognitive skills are not very well defined. This difficulty is further complicated because humans have a variety of intelligences as well as varying levels of giftedness and talent in areas that are closely related to these intelligences. Based on your insights into human lower-order and higher-order cognitive skills, discuss what might be meant by lower-order and higher-order for an artificially intelligent machine.
3. Give several examples of problems that you think:
 - a. Are readily solved by computers, but that are difficult or impossible for humans to solve.
 - b. Are readily solved by humans, but are not solvable by current computer systems.
 - c. Can be solved by a combination of humans and computers working together, but not by either alone.

Chapter 5

Project-Based Learning

"Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand."
(Confucius around 450 BC)

"You don't just learn knowledge; you have to create it. Get in the driver's seat, don't just be a passenger. You have to contribute to it or you don't understand it." (Dr. W. Edwards Deming; industrial quality control guru)

Project-based learning is an important component of this book for three reasons:

1. PBL lies at the heart of the Schoolwide Enrichment Model developed by Joseph Renzulli.
2. PBL creates a learning environment that can be effectively used in a variety of TAG education plans.
3. Information and Communication Technology Assisted PBL adds a new dimension to traditional PBL and helps to create a learning environment that can benefit both TAG and non-TAG students.

This chapter introduces PBL, with an emphasis on ICT-Assisted PBL. Ideas in this chapter are applicable to all students. However, ICT-Assisted PBL can help to provide an especially strong set of learning opportunities for TAG students. Many of the ideas from this chapter are drawn from my Website *ICT-Assisted Project-Based Learning* available at <http://darkwing.uoregon.edu/~moursund/PBL/>. That Website contains a detailed syllabus for a 1-credit course on ICT-Assisted PBL as well as an extensive annotated bibliography on the topic.

What is PBL?

PBL is a multi-goaled activity that goes on over a period of time, resulting in a product, presentation, or performance. Typically, PBL has milestones (intermediate goals), feedback from the teacher and one's fellow students, and other aspects of formative evaluation as the project proceeds. PBL can be done by individuals or teams. Teams may include classmates, but may well include students located throughout the world. This can provide TAG students with an opportunity to "meet" TAG students in other states and countries.

Project-based learning is learner centered. Students have a significant voice in selecting the content areas and nature of the projects that they do. There is considerable focus on students understanding what it is they are doing, why it is important, and how they will be assessed. Indeed, students may help to set some of the goals over which they will be assessed and how

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they will be assessed over these goals. All of these learner-centered characteristics of PBL contribute to learner motivation and active engagement. A high level of intrinsic motivation and active engagement are essential to the success of a PBL lesson.

From a student point of view, PBL:

- a. Is learner centered and intrinsically motivating.
- b. Encourages collaboration and cooperative learning.
- c. Requires students to produce a product, presentation, or performance.
- d. Allows students to make incremental and continual improvement in their product, presentation, or performance.
- e. Is designed so that students are actively engaged in "doing" things rather than in "learning about" something.
- f. Is challenging, focusing on higher-order knowledge and skills.

From a teacher point of view, PBL:

- a. Has authentic content and purpose.
- b. Uses authentic assessment.
- c. Is teacher facilitated—but the teacher is much more a "guide on the side" rather than a "sage on the stage."
- d. Has explicit educational goals.
- e. Is rooted in constructivism (a social learning theory) and gives careful consideration to situated learning theory.
- f. Is designed so that the teacher will be a learner, learning from and with the students.

ICT-Assisted PBL is merely PBL in which students are expected to routinely make appropriate use of ICT, and in which needed ICT facilities are readily available to students. In this setting, various aspects of learning and using ICT are part of the goals for the project.

Process writing as an Example of PBL

PBL shares much in common with Process Writing (<http://www.angelfire.com/wi/writingprocess/secwplinks.html>). The roots of Process Writing in the United States are often traced back to the Bay Area Writers Project circa 1975. A six-step version of Process Writing is:

1. Brainstorming ideas for the content, audience, and purpose of the document.
2. Organizing the brainstormed ideas; initial design work. Steps 1 and 2 often involve doing library research.
3. Developing a draft.
4. Obtaining feedback from self and others.
5. Revising, which may involve going back to earlier steps.
6. Publishing; finishing off the final document and polishing it for sharing and distribution.

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Most good writers give the advice "revise, revise, revise" to people seeking advice on how to become a good writer. Dean Koontz, a popular and prolific novelist, indicates that each part of his books gets revised about 70 times.

From the above point of view, doing writing is doing a project. Indeed, if the writer makes use of a word processor, uses the Web to search for information, uses email to communicate, etc. during the writing process, then this is a good example of ICT-Assisted PBL.

The idea of "revise, revise, revise" is applicable to doing any kind of an ICT-Assisted PBL project. Indeed, it is fundamental in solving problems and accomplishing tasks in every discipline. A PBL-based unit of study inherently includes problem solving and "revise, revise, revise." The revision process, striving toward a higher quality product, performance, or presentation, should be made explicit to students and should be stressed in any PBL lesson.

Goals in an ICT-Assisted PBL Lesson

An ICT-Assisted PBL unit of study will have a number of goals. While the major focus may well be learning some specific non-ICT content such as history or art, in many cases the other goals (in total) will be more important. This is illustrated in the general-purpose ICT-Assisted PBL planning table given in Figure 5.1.

| Goals: Students will learn: | Points |
|--|--|
| 1. The subject matter content of the project. Usually this will be subject matter supportive of a course you (the teacher) are teaching. | |
| 2. Some ICT content as an integral part of the subject matter content of the project. | |
| 3. Some general aspects of ICT, not specific just to the project or the course you are teaching. | |
| 4. How to budget resources (including time) in doing a project. | |
| 5. To work as a team member in doing a project. This includes providing constructive feedback (peer assessment) to one's team members. | |
| 6. To pose projects, and be problem solvers and creative, higher-order thinkers, working in a learner-centered environment. | |
| 7. To transfer their learning over time, distance, and environments. | |
| 8. To do self-assessment | |
| 9. Etc. (For example, incremental improvement through "revise, revise, revise.") | |
| | The total of the points must add up to → 100 |

Figure 5.1. ICT-Assisted PBL Planning Table

Here is some brief clarification of the goals:

1. If PBL is being use in a subject area such as history or health, you would certainly expect students to be learning some of the content of that subject area.
2. In many subject areas, there are some uses of ICT that are quite specific to the subject area. For example, composing, editing, and performing electronic music using a computer is part of the content of the discipline that we call music.
3. Some ICT tools cut across many, if not all, disciplines. A project may well include a goal that students practice using one or more of these general purpose ICT tools so as to increase their fluency in using the tools.
4. Young children do not automatically know how to do a project. Even college students are often quite poor at budgeting their time and other resources.

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5. It is not easy to learn to work in a team that is carrying out a project that is beyond the capabilities (in terms of time and other resources) of a single member of the team.
6. A good PBL lesson has a strong emphasis on students learning improving their higher-order knowledge and skills. Of course, while doing PBL students will also be making routine and interdisciplinary use of many of their lower-order skills.
7. Transfer of learning is one of the BIG IDEAS in education. (You DO routinely teach for high-road and low-road transfer, don't you?) Transfer of learning is an important learning goal in every type of instruction.
8. Self-assessment is one of the BIG IDEAS in education. Thus, it is an important learning goal in every type of instruction.
9. As students become accustomed to doing ICT-Assisted PBL, some goals that were made explicit in earlier projects begin to become implicit and need not be included in the list.

One of the most important aspects of PBL is the open endedness. Any project, performance, or presentation can be made better by expending more time, energy, thinking, practicing, polishing, and so on. This is an especially good learning environment for TAG students. In this environment, TAG students can learn to set their own goals and their own standards. They can aim high, and achieve far more than what is usually expected in school.

Differentiated Instruction

Differentiated instruction is an idea applicable to all students and one of the key ideas in PBL. It can play a significant role in the education of TAG students who are integrated into a regular, heterogeneous classroom. Quoting from ASCD (n.d.):

At its most basic level, differentiating instruction means "shaking up" what goes on in the classroom so that students have multiple options for taking in information, making sense of ideas, and expressing what they learn. In other words, a differentiated classroom provides different avenues to acquiring content, processing or making sense of ideas, and developing products.

- Specifically, differentiated instruction is:
- Proactive
- More qualitative than quantitative
- Aimed at offering multiple approaches to content, process, and product
- Student-centered
- A blend of whole-class, group, and individual instruction

Tracey Hall (n.d.) a Senior Research Scientist at the Center for Applied Special Technology says:

To differentiate instruction is to recognize students varying background knowledge, readiness, language, preferences in learning, interests, and to react responsively. Differentiated instruction is a process to approach teaching and learning for students of differing abilities in the same class. The intent of differentiating instruction is to maximize each student's growth and individual success by meeting each student where he or she is, and assisting in the learning process.

Hall then goes on to assert that differentiated instruction is an amalgamation of many different ideas from the theory and practice of education. Because of this, the literature supporting differentiated instruction consists much more of testimonials than it does of empirical research.

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There are many ways to provide differentiated instruction for TAG students working in an ICT-Assisted PBL environment. Here are a few examples:

- In a project that makes extensive use of published materials, strongly encourage or require TAG students to use primary resources, and strongly discourage their use of secondary sources. The TAG students should be faced by the challenging task both of understanding the primary resources and integrating them in a coherent manner.
- In a project that makes use of multimedia, strongly encourage or require TAG students to create their own multimedia, rather than just drawing from the libraries of “canned” materials. In this setting, TAG students might be expected to compose music, do drawings and paintings, take and edit still and video pictures, and carry on other activities that challenge and help to extend their levels of talent and giftedness.
- Give TAG students increased leeway to define their own project, with the stipulation that these projects be more challenging and comprehensive than the ones suggested to other students in the class. Place special emphasis on the projects requiring high-level use of creativity. Projects should stress quality over quantity, and use of higher-order knowledge and skills.
- Encourage TAG students to undertake projects that require empirical research. The first time you do this, you should expect your TAG students find and read some resources that discuss the meaning of empirical research (http://en.wikipedia.org/wiki/Empirical_research).
- Encourage or require TAG students to select a component of ICT (for example, a particular piece of tool software) that they are not well versed in using and that is relevant to doing their project, and learn to use the tool. That is, build into their projects a requirement to learn to use a new piece of software without the help of traditional teacher-led instruction.

The above discussion is oriented toward TAG versus non-TAG students. However, it is important to keep in mind that there are huge differences among TAG students. TAG education is definitely NOT a situation in which “one size fits all.” That is one reason why it is important for TAG students to learn to take a steadily increasing level of responsibility for their own education. They need to learn to set goals and standards that are appropriate to their own abilities, interests, and goals—and then take responsibility for accomplishing these goals.

Rubrics and Other Aids to Assessment

When I do talks and workshops on ICT-Assisted PBL, I get far more questions and comments on the topic of assessment than on any other topic. PBL poses some significant challenges in assessment.

Formal coursework on assessment is a common component of a teacher education program. Brookhart (1999) provides a short overview of assessment. An assessment process should be valid, reliable, and fair.

Assessment and evaluation are related, but they are not the same thing. *Assessment* refers to assignments, tasks, and tests that provide information, and *evaluation* refers to judgments based on that information. Developers of widely used, national-level tests such as the SAT or the GRE

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spend hundreds of thousands of dollars in an attempt to develop an instrument that is valid, reliable, and fair. They often come under heavy attack for failures in meeting these three criteria.

This strongly suggests that an individual teacher who spends a modest amount of time creating a test is unlikely to produce one that is valid, reliable, and fair. It also means that an individual teacher who is developing an assessment procedure for use in ICT-Assisted PBL should not expect perfection!

Assessment in PBL is rooted in the planning process, such as that illustrated in Table 5.1. You may well have “learning to assess self and others” as one of the goals in a PBL lesson. Students can learn to assess their own work (which is different than assigning a grade to their own work). A good assessment identifies strengths and weaknesses. It provides constructive feedback that can lead to revisions and improvement. Similarly, students can learn to provide constructive feedback to other students. Learning about and practicing self-assessment and peer-assessment can be integrated into any PBL lesson.

You might want to reflect a little more on the message in the previous paragraph. Part of the expertise of a leader is knowledge, skills, and experience in providing constructive feedback to oneself and others. This requires both content area knowledge and skills, and also interpersonal and intrapersonal knowledge and skills. (Remember, interpersonal and intrapersonal are two of the Multiple Intelligences in Howard Gardner’s list.)

Quite likely, you are familiar with the terms formative evaluation and summative evaluation (NWREL, n.d.). Formative evaluation provides feedback in a timely manner to allow mid course correction. In a project, assessment may be ongoing and produce formative evaluation feedback to the students in a timely manner. Formative evaluation may provide information used in summative evaluation. Summative evaluation of a project is a final evaluation after the project is completed. Students and teachers often think of a summative evaluation as a final grade. However, a letter or a number cannot adequately represent the time and effort that goes into doing a project, or the product, performance, or presentation resulting from a project. That is one of the reasons that portfolios and portfolio assessment have gained in acceptance and popularity.

During the past decade or so, authentic assessment has become an important idea in education. Grant Wiggins (1990) is one of the leaders in this field. Quoting Wiggins:

Assessment is authentic when we directly examine student performance on worthy intellectual tasks. Traditional assessment, by contrast, relies on indirect or proxy 'items'—efficient, simplistic substitutes from which we think valid inferences can be made about the student's performance at those valued challenges.

Although Wiggins was not writing specifically about PBL in his 1990 article, a number of his comments are directly applicable. For example, the following quote seems like Wiggins is explicitly talking about PBL.

Authentic assessments attend to whether the student can craft polished, thorough and justifiable answers, performances or products. Conventional tests typically only ask the student to select or write correct responses—irrespective of reasons. (There is rarely an adequate opportunity to plan, revise and substantiate responses on typical tests, even when there are open-ended questions).

One of the key ideas in authentic assessment is that students are to fully understand the assessment criteria. Indeed, it is often recommended that students be involved in developing the assessment criteria. This can be an explicit or implicit goal in any PBL lesson.

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The assessment criteria in PBL can be given in the form of one or more rubrics. These rubrics need to be clearly presented so that students can understand them, use them to self assess, and use them to assess their peers.

As a student is working on a project, we want the student to be thinking about questions such as:

- How can I tell if I have learned well enough to serve my current needs?
- How can I tell if I have learned well enough so that it will stay with me, for use in the future?
- How can I tell if I have learned well enough to transfer my new knowledge and skills to new (perhaps novel) situations where it is applicable
- How can I tell if I have learned well enough so that I can build on my new knowledge and skills in the future?
- How can I tell if I have learned well enough so I have some insight into what I don't know, why I might want to learn some of the things that I don't know but might want to know, and pathways to doing the learning?

If the content being covered is authentic and the assessment is authentic, then students should be able to answer the questions. All of these questions tie in closely with students learning to take an increasing level of responsibility for their own learning.

However, it takes considerable learning and experience for a student to become comfortable with such questions. Thus, learning to ask and answer such questions can be an explicit goal in PBL lessons until a student gains the maturity to deal with them as implicit goals in PBL and in all other learning situations.

I want to end this section with an example of what you SHOULD NOT be doing. Table 5.2 contains a general-purpose, 6-level rubric. While such a rubric may well be useful to a teacher, it is essentially useless to a student. The Brief Descriptions provide no information that a student can use to self assess or to do peer assessment. The Level assigned to a student does not provide useful information about possible revisions to produce a better product, performance, or presentation.

| Level | Brief Description |
|----------------|---|
| 1. Emergent | Student displays few, if any, of the rudimentary knowledge and skills that are expected. |
| 2. Limited | Student displays rudimentary knowledge and skills, but often requires substantial individual help and guidance. |
| 3. Developing | Student displays a minimally adequate level of the expected knowledge and skills. |
| 4. Capable | Student displays a functional, adequate level of the expected knowledge and skills. |
| 5. Strong | Student displays a high level of the expected knowledge and skills. |
| 6. Exceptional | Student displays an outstanding and creative/innovative level of the expected knowledge and skills. |

Figure 5.2. A terrible (useless to students) example of a rubric.

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Summary

ICT-Assisted PBL can be productively used with all students. However, it is a particularly powerful aid to providing differentiated instruction to TAG students.

A project involves a product, performance, or presentation (or more than one of these). In any of these situations a student or team of students works over a period of time, receives formative feedback from self and others, and does considerable revision work designed to improve the quality of the final results.

A typical PBL lesson has a number of goals. Assessment should cover these goals. The assessment should be authentic and transparent to students. Students should be able to understand the assessment criteria and process sufficiently well so they can do self-assessment and peer-assessment. It is a significant challenge to a teacher to develop rubrics (for use in PBL or in any other method of instruction) that students can fully understand and that students can use for self-assessment and peer-assessment.

One of the ongoing goals in PBL is for a student to become better at learning in a PBL environment. Various aspects of this goal should be made explicit until students reach a level of PBL knowledge, skills, and maturity so that such goals are implicit and need no longer be stated in the goal list.

Activities and Discussion Topics

1. Chapter 2 contains a 10-item list of recommendations about TAG education (Shoplik, 2004). Select one or more of the recommended approaches from this list, and analyze how well it agrees or disagrees with an ICT-Assisted PBL approach to instruction.
2. ICT-Assisted PBL emphasizes the role of a teacher as a “guide on the side” rather than as a “sage on the stage.” Analyze ICT-Assisted PBL from the point of view of it creating a classroom environment in which the teacher has the opportunity to do a lot of learning.
3. Many schools have students develop portfolios or electronic portfolios of their work. Discuss pros and cons of roles of ICT-Assisted PBL in the development of student portfolios.

Chapter 6

Computer Games

The game of life is not so much in holding a good hand as playing a poor hand well."

(H.T. Leslie)

All the world's a stage,
And all the men and women merely players:
They have their exits and their entrances;
And one man in his time plays many parts, ...
(William Shakespeare—As You Like It 2/7)

All the world's a game,
And all the men and women merely players:
They have their exits and their entrances;
And each person in their time plays many parts, ...
(Dave Moursund—Adapted from Shakespeare)

I have fond memories of playing all kinds of card games and board kids when I was a child, and then repeating this experience with my own children. I even tried —with modest success—to create several different games.

Games can be an important aid to social interaction. Games can be used to learn about oneself and about learning. Games represent the opportunity for a person to create Islands of Expertise.

In recent years, it has become clear that computer games have a number of characteristics that make them potentially quite valuable in education. This chapter explores roles of computer games in education, with a special emphasis on roles of computer games in the education of TAG students.

While this chapter focuses on games that can be played using a computer, the general ideas apply to both computer-based and non computer-based games. Learn more about educational uses of games by visiting my Games Website at <http://darkwing.uoregon.edu/%7emoursund/Books/Games/games.html>.

Introduction

For many people, computer games are attention grabbing and attention holding. Indeed, games sometimes have an addictive-like quality. When playing a game, a person's brain/mind may be fully engaged—in a state that Mihaly Csikszentmihalyi (<http://www.unrealities.com/essays/flow.htm>) calls *flow*.

A key concept that frequently emerges in the literature is that of 'flow', first discussed by Csikszentmihalyi (1990). This is summarized by several researchers as **“the state in which we are so involved in something that nothing else matters”, which has clear relevance to research into games and play.** Debate on the issue of 'flow' centres around how the 'state' can be created in an individual, and measuring how it might make a person more receptive to

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receiving, comprehending and using educational-based content and skills (Kirriemuir and McFarlane 2004). [Bold added for emphasis.]

Many people view computer games as an opportunity to help improve our educational system. James Paul Gee is a professor of reading at the University of Wisconsin-Madison and a leader in educational uses of computer games. He notes that computer games are often quite complex and present a serious learning challenge. Quoting from (Gee, n.d.):

So the question is: How do good game designers manage to get new players to learn long, complex, and difficult games? The answer, I believe, is this: the designers of many good games have hit on profoundly good methods of getting people to learn and to enjoy learning. They have had to, since games that were bad at getting themselves learned didn't get played and the companies that made them lost money. Furthermore, it turns out that these learning methods are similar in many respects to cutting-edge principles being discovered in research on human learning (for details).

Educational use of computer games received increased legitimacy in October of 2003 when the Massachusetts Institute of Technology announced an initiative to study educational roles of computer games (Education Arcade, n.d.).

There are now a number of colleges and universities that offer the bachelors degree with a major or substantial emphasis in computer games. In some universities, it is possible to get a doctorate that includes substantial coursework and a research dissertation in computer games.

Think about your current knowledge about the discipline of computer games. Perhaps you have a high level of expertise in some aspects of the discipline. For example, you may be thoroughly immersed in the culture of multiplayer online computer games, or you may know a great deal about the history of computer games. You may enjoy playing a variety of games on the small, battery-powered handheld games that are so widely available. In addition, probably you have played a variety of card games and board games that do not require use of a computer.

Here is a copy of a bulleted list that also appears in chapters 1 and 4. In general terms, each discipline can be defined by its unique combination of:

- The types of problems, tasks, and activities it addresses.
- Its tools, methodologies, and types of evidence and arguments used in solving problems, accomplishing tasks, and recording and sharing accumulated results.
- Its accumulated accomplishments such as results, achievements, products, performances, scope, power, uses, impact on the societies of the world, and so on.
- Its history, culture, language (including notation and special vocabulary), and methods of teaching, learning, and assessment.
- Its particular sense of beauty and wonder. A mathematician's idea of a "beautiful proof" is quite a bit different than an artist's idea of a beautiful

Spend a minute or so thinking about computer game aspects of each of the five bulleted items from what you know about the discipline of games. For example, when I think about the first bulleted item, I think about both the types of problems that games help to solve (they help to solve an entertainment problem, and they may help a person's social life) and the problems created by computer games (they lead to people "wasting" a lot of time, and they are addictive

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for some people). I think about the problems of creating games, since I have a daughter and a son-in-law who are sometimes involved in such tasks. I think of how the problems in the discipline of computer games are similar to and different from the problems in other disciplines such as education or mathematics.

As I think about the first bulleted item, I also think about my own thinking. That is, I do metacognition. I am aware that this thinking activity helps me to construct and better understand my own knowledge. I am aware of the importance of constructivism in learning—that each person builds on their own knowledge to construct new knowledge and understanding, I am aware that I have drifted far away from computer games—but that I have drifted into some of the most fundamental ideas of teaching and learning.

Games are a broad and deep discipline with many thousands of years of history. Many games require only a little bit of learning to get started, but depth that is challenging to the most talented and gifted. That is part of the appeal of many games—easy entry, no ceiling. It is also part of the reason for including a chapter on games in this book about TAG education. A TAG student who is interested in a particular game or category of games has the opportunity to gain a level of expertise that exceeds that of his or her peers. This level of expertise may well exceed that of many or most adults.

What is a Game?

In 2004, the British government funded a review of the literature on learning and educational values of computer game (Mitchell and Savill-Smith, 2004). The following quote from the 93-page report helps to define the words *play* and *game*.

First, **play**: something one chooses to do as a source of pleasure, which is intensely and utterly absorbing and promotes the formation of social groupings (Prensky 2001, page 112). Fun, in the sense of enjoyment and pleasure, puts us in a relaxed receptive frame of mind for learning. Play, in addition to providing pleasure, increases our involvement, which also helps us learn (Prensky 2001, page 117). Play has been further defined as: ...an intellectual activity engaged in for its own sake, with neither clearly recognizable functionalities nor immediate biological effects ... and related to exploratory processes that follow the exposure of the player to novel stimuli. (Fabricatore 2000, page 2)

Second, a **game**: seen as a subset of both play and fun (Prensky 2001, page 118). A game is recognised as organised play that gives us enjoyment and pleasure (Prensky 2001). Dempsey et al. (1996, page 2) define a game as: ...a set of activities involving one or more players. It has goals, constraints, payoffs and consequences. A game is rule-guided and *artificial in some respects*. *Finally, a game involves some aspect of competition, even if that competition is with oneself*. A game can be informed by concepts of ‘as if’, where the user suspends belief because they are immersed in the imaginary world of the game (Fabricatore 2000). Competitive games may involve undertaking chances in an imaginary setting. They motivate via challenge, fantasy and curiosity (Randel et al. 1992).

Notice the emphasis on learning and intellectual activity in the first paragraph. As I think about this, I am reminded of a statement I have heard many times—that the “job” of young children is to play.

Here is some more generally accepted information about computer games (Asgari & Kaufman, 2004).

Computer games can be categorized as adventure games, simulation games, competition games, cooperation games, programming games, puzzle games, and business management games (Hogle, 1996, citing from Dempsey et al., 1993; Jacobs & Dempsey, 1993). During the past 40 years,

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computer games have been played from a floppy disk, CD-ROM, with the use of email, or online through the Internet. Computer games can be played individually, against the computer, or against other people face-to-face or on-line.

For some reason unknown to me, Asgari and Kaufman's list of categories does not include "educational." However, educational computer simulations and other educational computer games are one of the reasons why computer games are of growing importance in education. For example, consider a computerized airplane pilot simulator. Inexpensive versions of such simulators run on a microcomputer and have been popular forms of entertainment for many years. For many years, more expensive versions of flight trainers have been routinely used in the training of both civilian and military pilots.

Declarative and Procedural Knowledge

In simple terms, declarative knowledge consists of descriptions or listings of facts, objects, events, rules—that is, data and information. Procedural knowledge is reflected in making use of motor or manual skills, and cognitive or mental skills, to do something. Declarative knowledge is "knowing about" while procedural knowledge is "knowing how."

Each discipline contains both declarative and procedural knowledge. Here is an example from language learning (Keatley and Kennedy, n.d.):

Language teachers and language learners are often frustrated by the disconnect between knowing the rules of grammar and being able to apply those rules automatically in listening, speaking, reading, and writing. This disconnect reflects a separation between declarative knowledge and procedural knowledge.

- Declarative knowledge is knowledge *about* something. Declarative knowledge enables a student to describe a rule of grammar and apply it in pattern practice drills.
- Procedural knowledge is knowledge of how to do something. Procedural knowledge enables a student to apply a rule of grammar in communication.

The literature on declarative and procedural knowledge makes clear the value of a student gaining both within a particular discipline. However, it is less clear what an appropriate balance between the two might be, as one strives to have a particular level of expertise in a discipline. For example, a mathematician has a great deal of mathematical declarative knowledge, but also knows how to *do* math. Doing math is a lot different than doing history or doing various other disciplines.

In a game-playing situation, *doing* is stressed. People often talk about expertise in a game in terms of how well a person can play the game. A game can provide a learning environment in which a learner can self-assess and can see progress toward attaining an increased level of game playing expertise. For many people, getting better at doing something (such as getting better at playing a game) provides a feeling of achievement, and it may increase self-esteem and intrinsic motivation.

As TAG other students work toward achieving a higher level of expertise in various domains, they need to understand what constitutes a higher level of expertise. Our educational system often does a poor job of this. As an example, think about what experts do in diverse disciplines such as geography, health, history, language arts, math, and science. You have some declarative knowledge in each discipline. You also have some procedural knowledge—what it means to use the declarative knowledge to actually *do* something. Now, think about the balance you have

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between declarative and procedural knowledge in these disciplines, versus the balance that experts in these disciplines have.

Finally, think about the declarative knowledge and procedural knowledge capabilities of ICT systems. An ICT system can store a huge amount of declarative knowledge—about which it has little or no understanding. It can store and carry out many different procedures represented as computer programs—again, with little or no understanding of when to do this or what is being accomplished. A key difference between people and ICT systems is in the understanding of declarative and procedural knowledge. That is why our educational system is gradually placing increased emphasis on understanding and then using this understanding to represent and solve problems. The representing and solving problems is *doing*, drawing upon one's knowledge, physical capabilities, mental capabilities, and creativity.

Situated Learning and Transfer of Learning

Situated learning is the study of how learning is influenced by the situation in which the learning occurs. Transfer of learning is the study of transfer of one's learning to other situations and over time. If the situation of the learning is a game environment, the one wants, a reasonable question to ask is the nature and extent of the transfer of this learning to other situations (OTECb, n.d.)

A theory of situated learning has been developed over the past 20 years or so. The general idea is that the learning that occurs in a particular situation is highly dependent on the nature of the learning activity, the context of the learning situation, the culture of the people involved in the learning situation, and so on. By and large, this theory is ignored by our educational system. Our educational system tends to provide knowledge in an abstract and out of context teaching environment. In an elementary school, for example a field trip is a “big deal” and a student may have this experience only a couple of times a year. The field trip may well be designed to provide a learning opportunity in a “real world” learning environment, quite similar to the one in which the learning might eventually be used.

Suppose, as an example, that students are gaining declarative and procedural knowledge about history in a classroom environment that stresses memorization and quick recall of facts such as names and dates. The environment is competitive, with the “rewards” going to students who raise their hands quickly, and perhaps enthusiastically shout out answers. The great majority of students are not called upon to provide responses—perhaps they sort of fade into the woodwork.

Besides the obvious flaws, this learning environment almost completely misses the fundamental ideas of what history is and what people who have a reasonable level of expertise in history do. History is a study of cause and effect. It is a study of complex interactions. It is a generation and testing of theories. It is striving to understand people and their cultures. It is an attempt to learn from the past. Contrast the memorization of names and dates with the learning that occurs on a field trip to a carefully reenacted historical site, where students can be immersed in the physical and cultural settings of an important period of time.

Alternatively, contrast this with good multimedia (for example, a video) or interactive multimedia (for example, via the Web) environment depicting a historical situation. The idea of [virtual field trips](#) is now becoming common in schools. A 12/26/05 Google search of *virtual field trip* produced about 4,600,000 hits.

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Situated learning is closely tied to the various theories of transfer of learning. Transfer of learning is one of the most important ideas in education. We want and expect that what students learn at a particular time and in a particular situation at school will transfer to other setting and into the future. The reality is that often this does not occur. Research into transfer of learning and other topics such as “forgetting” provide information that helps teachers get better at teaching for transfer and helps students get better at learning for transfer.

Transfer of learning is commonplace and often done without conscious thought. For example, suppose that when you were a child and learning to tie your shoes, all of your shoes had brown, cotton shoelaces. You mastered tying brown, cotton shoelaces. Then you got new shoes. The new shoes were a little bigger, and they had white, nylon shoe laces. The chances are that you had no trouble in transferring your shoe-tying skills to the new larger shoes with the different shoelaces.

This example gives us some insight into one type of transfer of learning. Transfer occurs at a subconscious level if one has achieved automaticity of that which is to be transferred, and if one is transferring this learning to a problem that is sufficiently similar to the original situation so that differences are handled at a subconscious level, perhaps aided by a little conscious thought.

However, many transfer of learning situations that are far more difficult than shoe tying. For example, a secondary school math class might teach the metric system of units. From the math class, students go to a science class. Frequently the science teacher reports that the students claim a complete lack of knowledge about the metric system. Essentially no transfer of learning has occurred from the math class to the science class.

On a more general note, employers often complain that their newly hired employees have totally inadequate educations. Part of their complaint is that the employees cannot perform tasks on the job that they "should have" learned to do while in school. Schools respond by saying that the students have been taught to accomplish the tasks. Clearly, this is a transfer of learning problem that is owned jointly by schools, employees, and employers.

The goal of gaining general skills in the transfer of your learning is easier said than done. Researchers have worked to develop a general theory of transfer of learning—a theory that could help students get better at transfer. This has proven to be a difficult research challenge.

At one time, it was common to talk about transfer of learning in terms of near and far transfer. This "near and far" theory of transfer suggested that some problems and tasks are so nearly alike that transfer of learning occurs easily and naturally. A particular problem or task is studied and practiced to a high level of automaticity. When a nearly similar problem or task is encountered, it is automatically solved with little or no conscious thought. This is called near transfer. The shoe-tying example given above illustrates near transfer.

The decoding component of reading provides another example. A major goal in learning to read is to develop a high level of decoding automaticity. Then your conscious mind can pay attention to the meaning and implications of the material you are reading.

Many potential transfer of learning situations do not lend themselves to the automaticity approach. There are many problems that are somewhat related, but that in some sense are relatively far removed from each other. A person attempting to make the transfer of learning between two such problems does not automatically "see" or sense the connections between the two problems. Far transfer often requires careful analysis and deep thinking.

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The theory of near and far transfer does not help us much in our teaching. We know that near and far transfer occur. We know that some students readily accomplish far transfer tasks, while others do not. We know that far transfer does not readily occur for most students. The difficulty with this theory of near and far transfer is that it does not provide a foundation or a plan for helping a person to get better at far transfer and dealing with novel and complex problems. It does not tell us how to teach to increase far transfer.

In recent years, the low-road/high-road theory on transfer of learning, developed Perkins and Salomon (1992), has proven to be a more fruitful theory. Low-road transfer refers to developing some knowledge/skill to a high level of automaticity. It usually requires a great deal of practice in varying settings. Shoe tying, keyboarding, steering a car, and single-digit arithmetic facts are examples of areas in which such automaticity can be achieved and is quite useful.

High-road transfer involves: cognitive understanding; purposeful and conscious analysis; mindfulness; and application of strategies that cut across disciplines. In high-road transfer, there is deliberate mindful abstraction of an idea that can transfer, and then conscious and deliberate application of the idea when faced by a problem where the idea may be useful.

For example, consider the idea of “look ahead” while playing a game. Consider a possible move, and then possible responses by your opponent. Consider what you might do in responses to your opponent’s possible responses, and so on. More generally, consider the consequences of your possible actions. This heuristic is useful in all kinds of problem-solving and decision-making situations.

Many computer games include a “redo” or “take back” provision. Thus, they allow a player to make a move and then take it back. Contrast this with carrying on a conversation and saying something that you really didn’t want to or mean to say. Once said, it is difficult or impossible to take it back. The take back feature in games that contain this provision provides a good opportunity to practice look ahead.

Here is another example. In many computer games, players move about in a simulated world (city, castle, multi level cave, forest). Some players find it is helpful to draw a map so they know where they have been and how to get back to particular places. Draw a map is a valuable heuristic in many different problem-solving situations. It is an excellent heuristic to have in one’s repertoire of high-road transfer heuristics.

Learning in a Game-learning Environment

Figure 5.1 in the chapter on Project-Based Learning is a table illustrating many possible goals in an ICT-Assisted PBL lesson. The table in Figure 6.1 given below is patterned along the same line of thought. It lists some of the possible learning goals that might be applicable to a student engaging in playing a game.

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| Goals: Students will learn: | Points |
|--|--------|
| 1. Declarative knowledge about the game—rules, vocabulary, objectives. | |
| 2. Procedural knowledge about the game—fluency in making appropriate, good “moves.” | |
| 3. How to learn a game, How expertise increases through gaining improved declarative and procedural knowledge, and through practice. | |
| 4. How to obtain and use feedback from oneself, the computer (if playing in a computer environment), and one’s fellow players (if playing with and/or against others). | |
| 5. To practice the high-road transfer of learning heuristics of developing an overall long-range strategy and making use of look ahead. | |
| 6. How to appropriately interact with fellow players and opponents (learning the culture and social skills of game playing in general, as well as for the particular game being played.) | |
| 7. The thrill of victory, the agony of defeat (if it is a competitive game). | |
| 8. How to help others learn to play the game; how to be a teach/mentor in a game learning and game playing environment. | |
| 9. Etc. | |
| The total of the points must add up to → | 100 |

Figure 6.1. Goals in a Game-playing “Lesson”

You may think it was rather silly of me to provide a column for points. However, I am suggesting that learning to play a game and actually playing the game is an educational experience. In the context of formal schooling, it might well be worthwhile to think about having explicit learning goals and assigning points to the goals. In an informal gaming setting, this is indeed silly.

It is useful to analyze some of the possible goals and to think about the nature of learning that might occur in a gaming environment.

- 1 and 2. As noted earlier in this chapter, a gaming environment tends to have less clutter and complexity than the school environment typically available as one studies a traditional school discipline. Thus, a gaming environment may be well suited to helping a student learn about declarative and procedural knowledge. This can be the basis of an important high-road transfer of learning heuristic that is often useful in attacking a learning problem. The heuristic is: Divide the learning task into declarative and procedural components.
3. If you are a person who is apt to be learning many different games during a lifetime, it is beneficial to learn to learn games. In addition, many non-game problems have much in common with game problems. Thus, there can be considerable transfer of learning from the process of learning a game to the process of dealing with such real world problems.
4. Feedback is important in any learning and problem-solving situation. Part of the learning process is to develop skill in obtaining and using feedback from self, others, the problem-solving situation, and so on. This is the basis for an important high-road transfer of learning heuristic. When attempting to solve a problem, make a list of possible sources of feedback that can provide information on the progress you are making in solving the problem.
5. Game playing often ends itself to developing and using a long-range strategy. Long-range strategic planning is such a widely useful heuristic that it should be part of the

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problem-solving repertoire of all students. A similar statement holds for the look ahead strategy. Such strategies can be learned in a widely applicable manner through appropriate teaching for high-road transfer. (Note also that a person can learn to recognize opportunities for high-road transfer and then do the steps needed to help increase high-road transfer—a teacher may be helpful, but certainly is not a necessary requirement. TAG students tend to be good at this.)

- 6 There are many different learning theories. Lev Vygotsky's learning theory (<http://chd.gse.gmu.edu/immersion/knowledgebase/theorists/constructivism/vygotsky.htm>) is called social constructivism. It is a social development theory, quite a bit different than Piaget's cognitive development theory. A key aspect of this theory is the social aspects of a learning situation. Many people play games because they enjoy being in the social setting that the environment provides. In an educational setting, metacognition might help game players learn some things about their social skills, likes, and dislikes.
7. Some games are competitive, some are collaborative, some are both (a team working together, competing with another team), and so on. Many games provide an opportunity to experience the thrill of victory and the agony of defeat—and to learn about how one responds to such occurrences.
8. I believe that all people are “naturally” both learners and teachers. Through informal and formal education, we all get better at learning and teaching. Game-playing environments tend to provide a good opportunity to help others learn. For example, a game player might be engaged in both teaching and learning why asking another player a question such as, “Can you explain to me what you had in mind when you ... (question asker describes a particular move or action by the other player)?

Research

The types of learning goals listed in the previous section are not automatically achieved by students who play games. Quoting from Conati and Klawe (2000):

These results indicate that, although educational computer games can highly engage students in activities involving the targeted educational skills, such engagement, by itself, is often not enough to fulfill the learning and instructional needs of students. This could be due to several reasons.

One reason could be that even the most carefully designed game fails to make students reflect on the underlying domain knowledge and constructively react to the learning stimuli provided by the game. Insightful learning requires meta-cognitive skills that foster conscious reflection upon one's problem solving and performance [2, 4, 24], but reflective cognition is hard work.

The Conati and Klawe research helps to make clear important roles of teachers when teaching in a computer game environment. With the aid of teachers, students can learn to be more reflective in such learning environments, and learning goals can be made more explicit.

Many of today's popular computer games are multiplayer, first person shooter (FPS) games. In such games, a game player controls a “person” or avatar who is a member of a team, playing against the computer and/or against other teams (Wright et al., 2002). The referenced article includes an emphasis on the social interaction that goes on in such a game. Quoting from this research article:

Play is not just "playing the game," but "playing with the rules of the game" and is best shown in the diversity of talk, the creative uses of such talk and player behavior within the game, plus the

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modifications of game technical features. Of course, the playing of the game also produces changes in one's own subjectivity making it a pleasurable experience if one is accomplished (Myers 1992). In essence, the game is a platform for showing off human performances in a mock combat setting. But, all is not combat or simply shooting a virtual enemy. And, as in any human performance, creativity of execution is the norm.

From our text files we identified 39 possible coded talk categories which fit into the following five general categories: 1) creative game talk, 2) game conflict talk, 3) insult/distancing talk, 4), performance talk and 5) game technical/external talk. These were the categories that appeared to exhibit the greatest frequency of use among players. They give a direct insight into the types of social interactions and the "policing" of such interactions in these types of action games

A number of people and groups are now engaged in research and development of educational computer games. Kurt Squire at the University of Wisconsin-Madison is a leading researcher in this field. Quoting from Massachusetts Institute of Technologies' *Games-to Teach* Website (Squires, n.d.)

The most under-examined potential of games may be their impact as an educational medium. Playing games, I can relive historical eras (as in Pirates!), investigate complex systems like the Earth's chemical & life cycles (SimEarth), govern island nations (Tropico), manage complex industrial empires (Railroad Tycoon), or, indeed, run an entire civilization (Civilization series). Did I forget to mention travel in time to Ancient Greece (Caesar I,II, & III), Rome (Age of Empires I, and II), relive European colonization of the Americas (Colonization), or manage an ant colony, farm, hospital, skyscraper, theme park, zoo, airport, or fast food chain? As my opening anecdote suggests, the impact of games on millions of gamers who grew up playing best-selling games such as SimCity, Pirates!, or Civilization is starting to be felt. Perhaps there are important cultural questions beyond "Do games cause violence?" that academics could begin exploring.

Squire's paper contains an extensive bibliography and provides good evidence of the growing research literature in this discipline.

The following definition of *serious games* is quoted from Katrin Becker (n.d.):

Serious Games: The use of computer and video games for non-entertainment purposes (i.e., public policy, education, corporate management, healthcare, military).

The use of computer and video games for learning is an emerging area of research, and interest is growing rapidly. As a sub-field of Serious Games, digital game-based learning poses some unique problems and challenges. As more and more young people grow up with digital games as one of their primary forms of entertainment, it behooves us to become familiar with this genre, how it affects people, and how we might use it for educational goals. Computer technology has advanced to the point where it is feasible (we now have the horse-power to accomplish this) to use games in a classroom setting. "Computer pioneer Alan Kay (DARPA in the '60s, PARC in the '70s, now HP Labs) declares 'The sad truth is that 20 years or so of commercialization have almost completely missed the point of what personal computing is about.' He believes that PCs should be tools for creativity and learning, and they are falling short."

If you are interested in some of the current Serious Games ideas and research, you might enjoy reading the notes published by an attendee at the two-day Serious Games Summit held October 31 and November 1, 2005. The notes are available at (Accessed 12/21/05): <http://www.mcmains.net/ruminations/2005/11/01>.

Competition, Independence, Cooperation

Games can be divided into three overlapping categories by their nature of the competition, independence, and cooperation. Let's use a crossword puzzle from the morning newspaper as an example. Suppose I work alone (independently) doing a crossword puzzle. I am not competing "head-to-head" with anybody, and I am not cooperating with anybody.

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Of course, later I might talk to a friend who also does the crossword puzzle from the same morning newspaper. We might talk about how hard or easy the puzzle seemed to be. We might talk about how long it took us to complete the puzzle, or how many clues we were unable to decipher. We might even discuss a particular clue, in a cooperative effort to figure it out.

Thus, we see how the independence of puzzle solving can be modified to being somewhat competitive and/or somewhat cooperative. Moreover, a social interaction can be added to the overall activity. Often such social interaction can be considered as being cooperative/collaborative in nature.

Some games have a strong social interaction characteristic. This can be seen in many board games that children play—especially when they are first learning to play. Many people play bridge or poker mainly for the social interaction. However, bridge and poker can also be played as highly competitive games. Thus, one might analyze a social bridge-playing or poker-playing event both in terms of its cooperation (for social purposes) and its competition (who wins; who loses).

The idea of independence is worthy of further exploration. Suppose I am a recreational bowler. I bowl alone, but I keep a careful record of my scores. Thus, I can tell if I am doing better, about the same as, or worse than I have in the past. This can be thought of as me competing with myself. However, in my opinion that is a poor use of the idea of competition. Competition is a win-lose situation.

This is a very important idea in education. Suppose education is considered as a type of game that is designed for independence, rather than for competition or cooperation. My goals as a learner are to learn, to get better at learning, to learn to use my learning, and so on. I take satisfaction in the process of learning, in having learned, and in using what I have learned. Moreover, keep in mind that each person is different, and that there are quite large differences in abilities, interests, drive, and so on. I may well want to have some information about what others are doing and able to do, but my focus is upon myself as a learner. In some sense, I want to “be all I can be.”

As an example, consider learning to keyboard. Personally, I can keyboard much faster than I can handwrite or print, and my keyboarded materials are far more legible than my handwriting or printing. Moreover, keyboarding in a word processing environment is a great aid to my writing, as the spell checker and grammar checker find many of my errors, and the word processor aids me in my revision efforts. From time to time, I feel a certain amount of envy of people who can keyboard faster and more accurately than me, or who are better at spelling. In essence, however, keyboarding for me is neither competitive nor cooperative. My (independent) expertise in keyboarding is at a sufficient level to be a great aid to achieving my writing goals.

Contrast independence this with a competitive model of education. The competition can be with other students, or it can be with “norms” that have been established for various state and national tests. The learner’s goal becomes one of winning

- “I got the top score in our class on this test!”
- “I am the best speller in my school!”
- “I am the fastest keyboarder at my grade level in our school!”

Another type of competition is scoring high enough to meet some specified requirements

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- “I have passed both the reading and math tests required for graduation!”
- “I scored high enough on my SATs to get into an Ivy League school!”

Still another way to look at competition-independence-cooperation is to consider competition versus cooperation. Competitiveness is a genetic characteristic, and all people are competitive. However, people vary considerably in the nature of their competitiveness, and competitiveness is strongly influenced by one’s home and community environment, and one’s culture.

Moreover, research suggests that males (on average) are more competitive than females. Put another way, the research suggest that on average, females are more cooperative/collaborative than males. Moreover, research in education supports the cooperative/collaborative approach over the competitive approach. That is, research indicates that designing schooling along cooperative/collaborative approaches is more effective than designing them along competitive lines.

Here is a brief summary of this section:

1. With a little effort, a person can find games that meet his or her interests in or orientation toward competition, independence, and cooperation. There are lots of games in each category, and many games have overlapping characteristics.
2. If we think about our overall educational system as a game, we can see competitive, independence, and collaborative aspects of this game. In many cases, we can see a mismatch between the characteristics that an individual student desires and the characteristics that our educational system forces on the student.
3. The field of Games-in-Education can contribute to creating a school environment that better fits the individual competition-independence-collaboration needs of students.

Student Creation of Games

As you watch small children at play, you see that they are adept at creating games they find entertaining and attention holding. Many students enjoy creating games for themselves and others. This can be a valuable educational experience. Quoting from Yasmin Kafai (2001):

We have only begun to build a body of experience that will make us believe in the value of game activities for learning. Obviously, the image of children building their own games is as much a "knee-jerk reflex" for constructionists as making instructional games is for instructionists. In the case of instructional games, a great deal of thought is spent by educational designers on content matters, graphical representations, and instructional venues. **The greatest learning benefit remains reserved for those engaged in the design process, the game designers, and not those at the receiving end, the game players.** [Bold added for emphasis.]

The last sentence in the quote applies to most project-oriented educational activities. It provides a good summary of the case for integrating project-based learning as a routine component of instruction in schools.

It is possible to create an interactive computer game in any general-purpose computer programming language designed to facilitate interactivity. BASIC and Logo are programming languages that millions of students have learned and that are quite suitable for game development. Both commercial and free versions of each of these programming languages are available. The Website (accessed 12/21/05)

<http://www.thefreecountry.com/compilers/miscellaneous.shtml> is a useful starting point for finding free versions of these and other programming languages.

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Squeak is a more recently developed computer programming language that is designed for students. It provides an excellent environment for creating games. It is available free (<http://www.squeak.org/Features/>) for both Mac and Windows platforms.

An alternative approach is to make use of software that has been specifically designed for game development. Game Maker is available free on the Web and provides a good example of such software (Overmars, n.d.). Quoting from Mark Overmars' Website:

Did you always want to design computer games? But you don't want to spend a lot of time learning how to become a programmer? Then you came to the right place. *Game Maker* is a program that allows you to make exciting computer games without the need to write a single line of code. Making games with *Game Maker* is great fun. Using easy to learn drag-and-drop actions you can create professional looking games in little time. You can make games with backgrounds, animated graphics, music and sound effects. And once you get more experienced there is a built-in programming language that gives you full flexibility. What is best, *Game Maker* can be used free of charge. And you can use the games you produced in any way you like. You can even sell them!

On 12/21/05, a Google search on the expression *free game creation software* produced over 93 million hits. The first of these hits (Accessed 12/21/05) was <http://www.ambrosine.com/resource.html>. The Website provides many examples of free software available for creating computer games.

Summary

For thousands of years, games have been an important component of human cultures throughout the world. Computer games are now an important component of the lives of many children and adults.

In many ways, computer games are having a negative impact on education because they compete for student attention and time. However, there is a growing body of research and practitioner literature on educational values of computer games. Moreover, the development and use of computer games specifically for use in education is now a growing business.

With appropriate mentoring from teachers and others, computer games can be used to create learning environments that are quite useful in helping students make progress toward achieving a number of generally accepted educational goals.

In addition, TAG and other students may enjoy developing their own games. A wide variety of free computer resources are now available to students who have such interests.

Activities and Discussion Topics

1. For you, personally, what makes a game fun? Give some examples of games that you have played that you considered fun. Then give some examples of learning that occurred for you as you learned and played these games.
2. One can now purchase computerized sporting event games, such as basketball, baseball, golf, football, pool, and so on. Compare and contrast the nature of the enjoyment of playing such computer games versus playing the "real" games.
3. This chapter contains a number of examples of things that a person might learn through playing a game. Select two of these examples. Then do a compare/contrast between achieving these learning goals in a computer game environment versus achieving them through the traditional curriculum. Your discussion can include the differing roles of a teacher in these situations.

Appendix 1. Projects for TAG Students

The capacity to know oneself and to know others is an inalienable part of the human condition as is the capacity to know objects or sounds, and it deserves to be investigated no less than these other "less charged" forms. (Howard Gardner, 1983, p. 243, *Frames of Mind*)

This Appendix contains a number of examples and topics of projects that might be of interest to TAG (and other) students. In developing this Appendix, I was torn between writing specifically for TAG students and writing for their teachers. I finally decided to write for preservice and inservice teachers. This is because it will often be necessary for teachers to help their TAG students to shape the ideas given in the Appendix into projects suited to the interests, needs, and developmental levels of particular students.

Moreover, as discussed in the chapter on ICT-Assisted PBL, a PBL project can have many different learning goals. When working with a TAG student, it is highly desirable for the teacher and student to carry on a discussion about the learning goals that seem suitable from the teacher's and the student's points of view, as well as how assessment and evaluation will be done.

Please think back to the ideas of the Total Talent Portfolio presented in Chapter 3. As you work with TAG students, help each student to develop a TTP. Repeatedly emphasize the idea of the student taking responsibility for selecting and developing Islands of Expertise. Help the student to gain increased understanding of his or her relative strengths and relative weaknesses, and provide guidance in helping the student to address these strengths and weaknesses.

Many TAG students will be able to read this Appendix; those who have a sufficient level of reading skill should be encouraged to do so. However, a teacher has a responsibility of helping to guide TAG students in the choice of suitable PBL activities, and to monitor their progress while working on such projects.

This appendix provides examples of projects that have a low level of entry and are open ended. Thus, a relatively young student can explore these problem areas and make progress in the areas. However, the problems and tasks are challenging at the highest research levels.

A project leads to a product, presentation, or performance. However, much of the value of doing a project is inherent to the actual "doing process" and to learning about oneself while doing the project. Each project should include a strong emphasis on metacognition—learning more about oneself as a learner and doer. One way to encourage such an endeavor is to encourage each student to keep a personal Learning Reflections Journal.

A PBL project often has many of the characteristics of a research project. The first of the projects given below contains a somewhat general outline for conducting research. Ideas from this project are applicable in many PBL projects.

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Learning and Forgetting

Throughout your lifetime, your brain is both learning and forgetting. There has been considerable research on learning and on forgetting, and how the two interact. The literature provides general theories, and it suggests that individual people differ considerably in their rates and quality of learning, and in their rates of forgetting. It also suggests that learning and forgetting of factual knowledge is different than learning and forgetting of skills.

On 12/26/05 when I did a Google search on the expression *learning and forgetting* (that is, I was looking for Websites that contain both the term *learning* and the term *forgetting*) I got about 2,580,000 hits. Here are a few references that you may find useful in starting your studies in this area:

Gordon, John L. (1999). Cognition, learning, and forgetting. *Applied Knowledge Research and Innovation*.

Accessed 12/26/05: <http://www.akri.org/cognition/learfor.htm>. This Website provides a quick overview and some useful definitions of terms.

Starmer, C. Frank (n.d.). About education: Fundamental concepts of forgetting and learning. Medical University of South Carolina. Accessed 12/26/05: <http://monitor.admin.musc.edu/~cfs/forgetting/>. The first part of this Website contains some self-analysis done by the author as well as a philosophy of doing less rote memorization and more use of the Web.

Yue, Hong (2005). Worker flexibility in dual resource constrained (DRC) shops. Appendix: Literature review on learning and forgetting Accessed 11/3/05:

<http://dissertations.ub.rug.nl/FILES/faculties/management/2005/h.yue/appendix.pdf>. This is an English translation of part of a doctorate dissertation written in Dutch. The dissertation focuses on learning and forgetting in certain types of work situations. One reason for including this reference is to emphasize that good research is being carried out throughout the world.

Specific PBL Activity. A good Learning and Forgetting project might include:

1. A careful statement of the problem you are addressing, along with some arguments why this is a good and important problem or set of problems. A clear statement of your research question or questions. A research question is sometimes stated as a hypothesis or a theory. For example, you might be interested in testing a theory that TAG students don't forget as fast as non-TAG students.

It is important to narrow your study and be precise in stating your research questions. You might be doing research on learning and forgetting within a particular discipline, job, or other setting. Your research might be a self-study, but it might be a study of yourself and some of your peers. The research might be about learning and forgetting over a relatively short period of time, such as a few weeks; however, it might be over a period of months or years. Your study might compare and contrast learning and forgetting of two relatively different disciplines, such as math and history. Your study might focus on people of certain ages, or people having certain levels of education.

2. Attempt to answer your research question or questions by doing a survey and analysis of the published research literature. More than likely, you will still have some unanswered questions after analyzing the research literature. Also, you may think of new questions, which will lead you back to step 1.
3. Develop a design for your research study. What data will you gather, how will you gather it, and how will you analyze it? Include a careful discussion of how this set of activities will help answer your research questions.

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4. Gathering and analyzing data, and then using the results to help answer your research questions.
5. Conclusions. What did you learn, what remains to be learned (which questions or parts of questions are not yet answered), and what new research questions are suggested by your study?

Developing Scenarios of Possible Futures

A 10/03/05 search of Google on the expression *future studies* produced about 217 million hits. This suggests that a lot of people are interested in the possibilities of predicting (forecasting) the future, as well as methods for doing so. The term *futures studies* is also frequently used. A 11/03/05 Google search using this expression produced about 8,560,000 hits. An overview of the field is available in Wikipedia (n.d.).

All of us are futurists to one extent or another. For example, we think about possible outcomes of an action before we take the action. We often consider the possible outcome of an action, and then don't take the action because we believe we would not be happy with the future that might be created if we take the action. Alternatively, we consider a number of possible actions and their possible consequences, and then we take one of them that we believe will be appropriate to our needs and interests (or, to others needs and interests).

Most of us make considerable use of futurists. For example, most of us make use of weather forecasts. Perhaps you make use of forecasts for the time of sunrise or sunset, or forecasts of when the ocean's high tide or low tide will be. Note that the forecasters in these situations are likely to be ICT systems, or ICT systems and humans working together.

I have long been interested in the future of ICT in education. Over the years, I have written a number of articles and a couple of books in this area. *Planning, Forecasting, and Inventing Your Computers-in-Education Future* was written specifically for teachers, and it contains a chapter analyzing a variety of forecasting methods (Moursund, 2005, Chapter 5). The title of the book is based on the following quote from Alan Kay, a person who has made many major contributions to the field of ICT and to ICT in Education.

Don't worry about what anybody else is going to do. ... The best way to predict the future is to invent it. (Alan Kay)

In the fall of 2004, I was asked to write a futuristic scenario that would serve to promote discussion at a meeting of the Blue Ribbon Panel of the North Central Regional Educational Laboratory. I am interested in the future of education, and I have fun creating scenarios that depict possible futures. I created a scenario of a high school girl who was enrolled in a course titled *Me: A Course of Study* (Moursund, 2005, Appendix A). One of the PBL activities given in the Appendix you are now reading is based upon *Me: A Course of Study*. For another of my futuristic educational scenarios, see Moursund (November, 1999).

Many futurists develop scenarios of what they think the future will be like. When such scenarios are written by people who have a high level of expertise in the field of their predictions and who have good knowledge and skill in forecasting techniques, the results often prove useful. For example, an urban planner might develop some possible scenarios of the future growth and livability of a city. This may be detailed enough and convincing enough so that city leaders use the scenario to plan some changes within the city.

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Specific PBL Activity. This is an activity suitable for all students, not just TAG students. It can be done by individuals or by teams. The assignment is to select a “futures” topic for which forecasting using scenarios combined with other forecasting methodologies is an appropriate approach. Develop a set of conditions and assumed activities that are occurring or could be made to occur, that will affect the futures topic you want to study. For example, if you are forecasting the air quality environment in your city 15 years from now, one set of conditions might be no growth in population or number of hydrocarbon-burning vehicles. A different set of conditions might be two-percent yearly growth in population and three-percent yearly growth in vehicles, but also new tax laws that provides a significant decrease in taxes for people who buy vehicles that produce less pollution.

After a suitable topic is selected, the task is to write one or more scenarios (such as worst case, middle level case, best case) for one or more sets of conditions and assumptions.

Me: A Course of Study

Me: A Course of Study is a project to be carried out by an individual student over an extended period of time. Alternatively, it could be used as a whole-class project. The unifying theme is that of students learning more about themselves—both in general, and as learners.

The title for this project comes from a curriculum *Man—a Course of Study* (MACOS, 1962-75). These curriculum materials were developed by Educational Development Center Inc. (EDC) using funding from the National Science Foundation and the Ford Foundation. They were designed for middle school and upper elementary grades, and they stressed a cross-cultural view of human behavior. MACOS focused on cultural diversity, principally from an anthropological viewpoint.

MACOS was developed under the intellectual leadership of Jerome Bruner. In his 1966 book *Toward a Theory of Instruction* Bruner says:

The single most characteristic thing about human beings is that they learn. Learning is so deeply ingrained in man that it is almost involuntary, and thoughtful students of human behavior have even speculated that our specialization as a species is a specialization for learning.

Specific PBL Activity. There are a number of possible directions in which a project *Me: A Course of Study* might go. One way to learn more about yourself is to do a combination of things such as:

1. Directly studying yourself. Do introspection, metacognition, journal writing, data gatherings, self-analysis, and so on. Develop a Total Talent Portfolio. Work to determine your strengths and weaknesses, your likes and dislikes, your goals and how well you are progressing toward these goals, and so on.
2. Study people in general, and then do a compare and contrast between yourself and the people you have been studying.
3. Enlist the help of others. For example, talk to your parents, grandparents, siblings, other relatives, friends, and so on. Use these resources to learn about your past, how these people have interacted with and influenced you, what you have learned from these people, and so on.

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4. Draw upon family photograph albums, videos, scrapbooks, old toys, and other memorabilia that can help you learn about your past and the environment you have grown up in.
5. Study the history and culture of the communities in which you have lived.
6. Study current research on brain science and learning theory. Analyze these results from a personal point of view and from a point of view of the teaching and learning environments currently available to you and your fellow students.

The sixth topic listed above might be particularly suitable for a TAG student or a team of TAG students. In my opinion, there is a considerable gap between the theory of teaching and learning, and the practice of teaching and learning. Our educational system has considerable difficulty in translating theory into practice. From a TAG student point of view, one solution of to this problem is to shift the responsibility from “they” (the school system) to “me” (a TAG student). A TAG student can easily gain theoretical knowledge about teaching and learning that is at the frontiers, and that is not being incorporated into the typical school setting. A TAG student can incorporate some of this theory into his or her own learning efforts. A TAG student can also work to have these ideas incorporated into the educational system that is available to all students.

However, here is a word of warning to TAG students, and teachers of such TAG students. Many adults do not like to be told that they are not doing their jobs well. Many adults are resistant to change. Jerome Bruner and the MACOS project encountered this situation in the MACOS project. Quoting Richard Atkinson, President of the University of California:

One of the films produced for the course told the story of an Eskimo village above the Arctic Circle. Among the Eskimo practices depicted in the film was the custom of borrowing someone else's wife to keep you warm on a long journey across the ice if your own wife was not well enough to accompany you. Another was the practice of abandoning grandparents on an ice floe when they became too old to contribute. MACOS succeeded brilliantly in demonstrating cultural differences; it was equally effective in arousing public outrage. There were protest rallies, public meetings at schools that adopted MACOS, and vitriolic editorials—Jim Kilpatrick wrote extensively on the damage MACOS was inflicting by undermining the moral character of America's young people. (Atkinson, 1997)

Studying and Writing About TAG-ness

A 12/26/05 search using the expression *talented and gifted* produced about 4,800,000 hits. A search using the expression *talented gifted Blog* produced more than a quarter-million hits. I wonder how many of these various TAG hits are Websites, Blogs, or articles developed and written by TAG students, for TAG students? Perhaps this is a question you would like to do some research on?

Some TAG students will likely find this question defines an opportunity to develop and share ideas that they feel are particularly important. Here are some examples of TAG-related topics in which TAG students might enjoy developing an increased level of expertise and sharing with others. The results of this work might be shared on a Website or Blog.

1. Prodigies. You are probably aware of prodigies who accomplished truly amazing things when they were relatively young. For example, Wolfgang Mozart is frequently cited as being a prodigy in musical composition and performance. Here is a way to think about prodigies:

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- a. The work is truly outstanding compared to what others of this age are able to do at the same age. The comparison may be worldwide, and over time. Thus, perhaps few people in the world have done what Mozart did at age eight. But his compositions and performances were not nearly as good as he did later as he got older, or as older people were doing at the time Mozart was eight. Mozart “grew up” to be an adult who was a great composer and performer; however, there are other people who (as adults) were or are great composers and performers.
- b. The work might be truly outstanding compared to people of all ages throughout the world at the current time. For example, a sixteen year old may win the World Figure Skating Championship. This provides an example of a person being best in the world at a relatively young age.

There is a lot of literature on prodigies. For example, see:

Schaffhausen, Joanna (n.d.). *Child prodigies*. Brain Connection, Scientific Learning Corporation. Accessed 12/27/05: <http://www.brainconnection.com/topics/?main=fa/child-prodigies>.

2. Measuring intelligence. The science of measuring intelligence is now well over a hundred years old. Recent research in brain science is beginning to provide some insights in how the brains of highly intelligent people differ from those who are less intelligent. Research into Alzheimer’s disease and into other types of dementia is beginning to produce intelligence-enhancing drugs. Some useful background information is available at:

Gabriel, Gerald (n.d.). Measuring the mind. Accessed 12/27/05: <http://www.brainconnection.com/topics/?main=fa/measure-mind>.

3. Expertise. What is expertise, and how long does it take to acquire a high level of expertise within a particular domain?

There has been a lot of research on world-class expertise and how long it takes for a gifted person to achieve world-class status. In brief summary, a person working within a relatively narrow discipline, can come close to reaching his or her potential by about 10 years of very hard work. Often this work is carried out with the aid of good teachers and coaches. If the person is sufficiently gifted in the discipline, the person may become world class.

However, much depends on the breadth or narrowness of the discipline. Suppose, for example that your spatial intelligence is very good and that you have a special interest in puzzles such as Rubik’s Cube. With a modest amount of study and practice, you may become the best person in your school in completing Rubik’s Cube tasks. Because there are a variety of Rubik’s Cube contests, this is an area where you might have the opportunity to show that you are the best in your city, state, or country. See:

Rubik (n.d.). Rubik’s cube website. Accessed 12/27/05: <http://www.rubiks.com/>.

Contrast this with the discipline of mathematics. Math is a large and deep field. It is a discipline in which there has been a huge accumulation of knowledge over thousands of years. It is a field in which there is student completion at the state, national, and international levels. (For more information, do a Web search of *Math Olympiads*.) Thus, a student who is highly gifted in math and who works very hard for many years can

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demonstrate that he or she is very good at solving math problems relative to his or her peers in this country or throughout the world.

Secondary school students who place high in the International Mathematics Olympiad are exceedingly good at solving math problems. However, few have done high-level original math research as teenagers. That is, they are world class relative to their peers, but they are not yet world class relative to research mathematicians in general.

4. Multiple intelligences. From quite early on, researchers into intelligence have argued about a single measure of intelligence (the “g” factor) versus multiple factors or multiple intelligences. Howard Gardner (2003) published his first book on Multiple Intelligences in 1983, and his ideas have gained wide acceptance. A TAG student may have considerably different levels of linguistic intelligence, logical/mathematical intelligence/ musical intelligence, and spatial intelligence.

For example, I personally have a much higher level of logical/mathematical intelligence than I do of musical intelligence or linguistic intelligence. Thus, I had little trouble getting a doctorate in mathematics from a good research university. However, my spatial sense is terrible—according to a test that I took near the end of my high school days, my IQ in that area is well below 100.

Linguistic intelligence is an interesting area to examine. Clearly, some people are much better than others at learning a second, third, and subsequent languages. However, almost all people have a high level of linguistic intelligence. For example, people growing up in Luxembourg become trilingual or 4-lingual. This is no big deal—it comes with growing up in that environment.

The linguistic example extends to many other areas. Developing a high level of expertise in an area depends both on nature and nurture. I often wonder to what extent my success in mathematics came from nature and to what extent it came from nurture. Both of my parents were quite good at math, and I grew up in a home environment that valued and frequently used mathematics.

5. Islands of Expertise. Crowley and Jacobs (2002) discuss the idea of Islands of Expertise. In brief summary, the main idea is that a student can develop an area of expertise in which he or she has a much higher level of expertise than his or her peers. Many TAG students have islands of expertise that they like to display and that they like to share with others. It is fun to find and communicate with “email pals” who share similar interests.

For example, a TAG student might be quite interested in building and programming robots. Many people share this hobby. Because of this, there are contests at state and national levels in which students or teams of students can compete. See, for example:

NASA (n.d.). *Robotics education project*. Accessed 12/27/05:
<http://robotics.nasa.gov/first/2005/kickoff.htm>

6. TAG and Our Schools. Schools vary widely in the special services that they provide for TAG students. A project on this topic might study TAG in one’s own school and school district versus TAG in other schools and school districts in one’s own state, in other states, and in the world. See:

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Colangelo, Nicholas, Susan G. Assouline and Miraca U. M. Gross (2004). A nation deceived: How schools hold back America's brightest students. *The Templeton National Report on Acceleration*. Accessed 12/27/05: <http://nationdeceived.org/download.html>.

7. Brain Science. This is a rapidly growing field. Because our K-12 schools mostly ignore the field, it is a field in which TAG students can easily become more knowledgeable than their fellow students. Indeed, it is a field in which TAG students can often become more knowledgeable than their teachers and most other adults. Young TAG students may find that the following reference is a good starting point.

Chudler, Eric H. (n.d.). Neuroscience for kids. Accessed 12/27/05: <http://faculty.washington.edu/chudler/neurok.html>.

There are many possible directions for projects on brain science. For example:

- a. Write a paper and develop a presentation for your fellow students about some of the latest progress in this field. Among other things, this paper might explain various approaches to brain imaging and the types of information that can be garnered via brain imaging.
- b. Select a topic in brain science and study it from a personal point of view. How is research on this topic helping you to better understand yourself?
- c. Many people think that IQ is fixed at birth, and does not change. Others argue that IQ can and does change. Write a paper and develop a presentation for your fellow students about this topic. See:

Sternberg, Robert J. (Summer 1997). Technology changes intelligence: Societal implications and soaring IQs. *Technos Quarterly*. Accessed 12/23/05: http://www.technos.net/tq_06/2sternberg.htm.

- d. Significant progress is occurring in the area of developing connectivity between brain waves and computers located outside one's brain. Related topics include cochlear implants and retinal implants. See:

National Association of the Deaf (October 6, 2000). *Position Statement on Cochlear Implants*. Accessed 12/28/05: <http://www.nad.org/site/pp.asp?c=foINKQMBF&b=138140>.

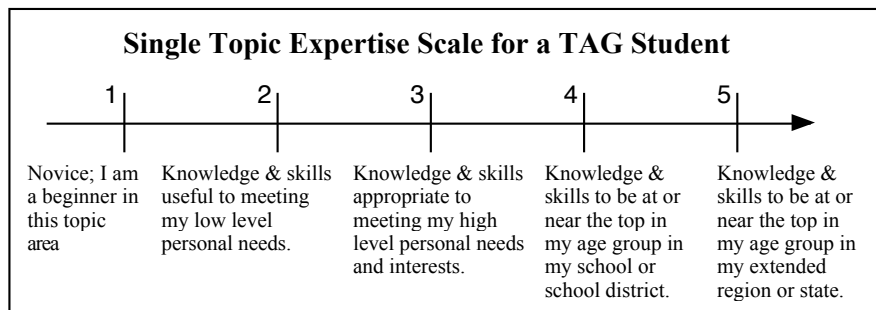
8. Total Talent Portfolio. Chapter 3 of this book focuses on the work of Joseph Renzulli, a long time world leader in TAG education (Renzulli, 1994, 1998).

The chapter explores the idea that all students have strengths and weaknesses. When a strength or weakness is large relative to average students, it is called an exceptionality. Many students have more than one exceptionality. For example, a student may be a very talented writer and a terrible speller. A student may be both dyslexic and brilliant.

The word *metacognition* refers to thinking about your own thinking. Probably you do this quite often. This is a good way to learn about yourself and to learn new things. Many people find that it is even more useful to write some of their metacognitive results in a personal journal. The following activities are designed to help you learn more about yourself. They activities can be done in your head. However, you will likely benefit much more from them if you write your responses in a personal journal. In addition, if you have some TAG friends, talk about these questions and ideas with them.

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- a. Here are some things to think about, and perhaps to write about in a journal. When and how did you first learn that you are TAG? What evidence do you have that you are TAG, and how good is the evidence? What have you done that makes good use of your special gifts? Who is helping you to learn to make effective use of your talents and gifts? How could they better help you?
- b. Do an inventory of your greatest strengths and your greatest weaknesses. Think about what you are doing to increase and make good use of your strengths. Think about what you are doing to overcome or get around your weaknesses.
- c. Analyze some of your areas of greatest expertise using the diagram given below. You might want to begin by developing a set of labels for the scale in the diagram that are more appropriate to you.



Single topic expertise scale.

9. Other types of intelligences. Traditional IQ tests are designed to measure cognitive intelligence. They are not designed to measure emotional intelligence, social intelligence, or other intelligence-like characteristics of a person. Each of these other types of intelligence can be the basis of a project. Within such a project, you might want to explore your social or emotional intelligence and compare it with your cognitive intelligence. You might want to compare and contrast how ICT helps one's uses of various types of intelligences. Here are a few references that may be useful starting points.

Hein, Steve (n.d.). Emotional intelligence home page. Accessed 12/27/05: <http://eqi.org/history.htm>.

Mendiratta, Nitin (n.d.). Emotional Machines. Accessed 11/27/05: <http://ai-depot.com/Articles/50/Emotional.html>. An exploration of emotional intelligence from an artificial intelligence point of view.

Kihlstrom, John and Nancy Cantor (2000). Social intelligence. Accessed 12/27/05: http://ist-socrates.berkeley.edu/~kihlstrm/social_intelligence.htm.

10. Cognitive learning styles. What are your (preferred) cognitive learning styles, and how are these affected by ICT? Quoting from *Cognitive/Learning Styles* (n.d.) Accessed 12/25/05: <http://tip.psychology.org/styles.html>:

Cognitive styles refer to the preferred way an individual processes information. Unlike individual differences in abilities (e.g., [Gardner](#), [Guilford](#), [Sternberg](#)) which describe peak performance, styles describe a person's typical mode of thinking, remembering or problem solving. Furthermore, styles are usually considered to be bipolar dimensions whereas abilities are unipolar (ranging from zero to a maximum value). Having more of an ability is usually

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considered beneficial while having a particular cognitive style simply denotes a tendency to behave in a certain manner. Cognitive style is usually described as a personality dimension which influences attitudes, values, and social interaction.

There are a number of Websites that offer free self-assessment instruments that can be used to help determine your learning style according to a variety of theories about learning styles. You can easily find some of these by doing a Web search.

Problems You Feel Need Solutions

One way to look at the world is to believe that current and past adults having identified and solve all of the problems that any precollege student might possibly solve. A different way to think about the world is that it is literally full of problems that have not been solved and that a TAG student might well solve.

There is ample evidence to support the latter point of view. Many of the examples that help make up this evidence come from situations in which there has been and continues to be a rapid change in technology and in the accumulation of knowledge within a particular area. The new technology and new knowledge can be the foundation for many new problems and questions. Alternatively, the new technology and knowledge can be the tools that help to solve problems that have previously proved to be intractable.

The following material gives a few examples of what is possible. Quoting from:

Jewell, Mark (11/06/05). Fab. labs unshackle imaginations. *The Miami Herald*. Accessed 12/27/05: <http://www.miami.com/mld/miamiherald/business/national/13098459.htm>.

BOSTON - When Makeda Stephenson compared flight simulator games sold in computer stores and didn't find anything she liked, she didn't stop there.

The 13-year-old used a set of computer-controlled manufacturing tools at a community center to make her own simulator—one that lets her "fly" an airplane of her design over an alien planet born of her imagination.

In a room filled with computers and tabletop-sized manufacturing equipment, Stephenson created a pilot's control yoke with motion sensors she fashioned from a mélange of old electronic toys and parts.

A computer program Stephenson wrote with help from a Massachusetts Institute of Technology students guides the plane's movements on her computer screen.

She did it all through a teen learning program at one of seven so-called Fabrication Labs that MIT has established in places as distant as Norway and Ghana. Each lab has tool sets that, costing about \$25,000, would be out of the reach of most fledgling inventors.

The Fabrication Lab program is part of the MIT Center for Bits and Atoms. You can learn more about this Center and access a number of related articles at:

Fab Lab (n.d.). Accessed 12/27/05: <http://cba.mit.edu/projects/fablab/>.

Many TAG and other students participate in Science Fairs. A 11/07/05 Google search using the expression *science fair* produced nearly 88 million hits. There are large numbers of samples of projects that people have carried out in the past.

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Your Reading Skills

How well can you read? At first blush, this might seem like a simple question. A simple answer might be, "I am a good reader, and I read a lot. I think I am a better reader than most of my peers." Now, think a little deeper. Ask yourself:

1. How fast do I read? Can training and practice help me to be a much faster reader?
2. How well do I understand when I read? Can training and practice help me to read with considerably better understanding?
3. At what grade level do I read most comfortably? (There are many measures of readability, and some report their results as school grade levels.)
4. Am I good at reading interactive multimedia, such as interactive Web documents?
5. Am I an equally good reader in a variety of different disciplines, such as science, math, social studies? Is reading math different than reading history, and how do I get to be a better reader in specific disciplines?
6. What are good ways to help others get better at reading?

Some of these questions are easy to answer, while others have challenged researchers for many years.

Let me give you an example of a research question that has not been addressed very well. There are lots of measures of the readability of a written document. A couple of these are available in the Microsoft Word, a widely used word processor. Question: How do you measure the readability level of a highly interactive multimedia document that contains lots of links, pictures, graphics, and so on? A useful starting point might be to browse:

Nielsen, Jacob (n.d.): useit.com: Jakob Nielsen's Website. Accessed 12/27/05: <http://www.useit.com/>. Note that readability of written material and usability of a Website are somewhat similar ideas.

Nielsen Norman Group (n.d.). *Intranet Usability Reports*. Accessed 12/27/05: <http://www.nngroup.com/reports/intranet/>.

Readability Formulas (n.d.). Accessed 12/27/05: <http://csep.psyc.memphis.edu/cohmetrix/readabilityresearch.htm>.

Miscellaneous Other Topics

The following are topics and/or resources that might suggest projects to be carried out by TAG and other students.

1. The future of learning. See:

MIT Media Laboratory. Future of Learning Group. Accessed 12/27/05: <http://learning.media.mit.edu/> and <http://learning.media.mit.edu/projects.html>.

Quoting from the first of the two Websites:

The Future of Learning Group explores how new technologies can enable new ways of thinking, learning, and designing. The group creates new "tools to think with" and explores how these tools can help bring about change in real-world settings, such as schools, museums, and under-served communities.

2. Mirror neurons. See:

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Ramachandran, V.S. (1995). The third culture. Accessed 12/27/05:
http://www.edge.org/3rd_culture/ramachandran/ramachandran_p1.html. Quoting from the article:

The discovery of mirror neurons in the frontal lobes of monkeys, and their potential relevance to human brain evolution—which I speculate on in this essay—is the single most important "unreported" (or at least, unpublicized) story of the decade. I predict that mirror neurons will do for psychology what DNA did for biology: they will provide a unifying framework and help explain a host of mental abilities that have hitherto remained mysterious and inaccessible to experiments.

...

The hominid brain reached almost its present size—and perhaps even its present intellectual capacity—about 250,000 years ago. Yet many of the attributes we regard as uniquely human appeared only much later. Why? What was the brain doing during the long "incubation" period? Why did it have all this latent potential for tool use, fire, art, music and perhaps even language—that blossomed only considerably later? How did these latent abilities emerge, given that natural selection can only select expressed abilities, not latent ones?

Watch a short video on this remarkable discovery in brain science. See:

Mirror Neurons PBS 25 January 2005 About 14 minutes. Accessed 12/27/05:
<http://www.pbs.org/wgbh/nova/sciencenow/archive/q050125.html>.

3. Female and male brains. See:

Cahill, Larry (April 25, 2005). His brain, her brain. *Scientific American*. Accessed 12/27/05:
http://www.sciam.com/print_version.cfm?articleID=000363E3-1806-1264-980683414B7F0000.
Quoting from the article:

Not so long ago neuroscientists believed that sex differences in the brain were limited mainly to those regions responsible for mating behavior. In a 1966 *Scientific American* article entitled "Sex Differences in the Brain," Seymour Levine of Stanford University described how sex hormones help to direct divergent reproductive behaviors in rats—with males engaging in mounting and females arching their backs and raising their rumps to attract suitors. Levine mentioned only one brain region in his review: the hypothalamus, a small structure at the base of the brain that is involved in regulating hormone production and controlling basic behaviors such as eating, drinking and sex. A generation of neuroscientists came to maturity believing that "sex differences in the brain" referred primarily to mating behaviors, sex hormones and the hypothalamus.

That view, however, has now been knocked aside by a surge of findings that highlight the influence of sex on many areas of cognition and behavior, including memory, emotion, vision, hearing, the processing of faces and the brain's response to stress hormones. This progress has been accelerated in the past five to 10 years by the growing use of sophisticated noninvasive imaging techniques such as positron-emission tomography (PET) and functional magnetic resonance imaging (fMRI), which can peer into the brains of living subjects.

4. TAG throughout the world. Select a country and do research on the nature and extent of TAG education in the country. For example, see the UK Website:

Gifted and Talented (n.d.). Accessed 12/27/05:
<http://www.standards.dfes.gov.uk/giftedandtalented/>.

5. Person plus machine. This topic focuses on people and machines working together to do better than either can do alone. Chess playing provides an interesting environment in which to study this topic. See the two articles on Advanced Chess:

Dvorsky, George (12/27/2005) Cozying up with Deep Blue. Accessed 3/10/05:
http://www.betterhumans.com/Features/Columns/Transitory_Human/column.aspx?articleID=2005-03-02-2.

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Advanced Chess (n.d.). Wikipedia. Accessed 12/27/05; http://en.wikipedia.org/wiki/Advanced_Chess.

This is a nice article about symbiosis of human and computer in chess playing. The idea also applies in other problem-solving situations. It seems obvious to me that this idea is a key aspect of the future of computers in education.

6. American Memory (The US Library of Congress). See:

American Memory (n.d.). American Memory, the Library of Congress. Accessed 12/27/05: <http://memory.loc.gov/ammem/>.

This is a large and continuing project. It can serve as a basis for many different history-oriented projects to be carried out by TAG and other students. As an example, select one of the thematic collections and become the most knowledgeable person in your class, school, etc. on that topic. Develop a document and presentation that facilitates sharing your new knowledge.

Quoting from the American Memory Website:

American Memory is a gateway to the Library of Congress's vast resources of digitized American historical materials. Comprising more than 9 million items that document U.S. history and culture, American Memory is organized into more than 100 thematic collections based on their original format, their subject matter, or who first created, assembled, or donated them to the Library.

The original formats include manuscripts, prints, photographs, posters, maps, sound recordings, motion pictures, books, pamphlets, and sheet music. Each online collection is accompanied by a set of explanatory features designed to make the materials easy to find, use, and understand. Collections may be browsed individually, searched individually (including full-text searching for many written items), or searched across multiple collections.

7. The Turing Test (named after Alan Turing) is a test of the human-like intelligence of a computer system. This is an "fun" area to study as well as a continuing challenge in the field of Artificial Intelligence. The first three references given below give you access to three programs that can carry on written conversations.

ALICE (n.d.). Artificial Intelligence Foundation. Accessed 12/23/05: <http://www.pandorabots.com/pandora/talk?botid=f5d922d97e345aa1>.

ELIZA. *ELIZA—a friend you could never have before*. Accessed 12/23/05: <http://www-ai.ijs.si/eliza/eliza.html>.

Jabberwacky (n.d.). Accessed 12/23/05: <http://www.jabberwacky.com/>.

Turing, A.M. (1950). Computing machinery and intelligence. *Mind*, 59, 433-460. Accessed 12/23/05: <http://www.loebner.net/Prizef/TuringArticle.html>.

8. What is computer science? Computer science is now affecting every academic discipline. Thus, no matter what academic disciplines you are interested in, it is helpful to know about the contributions that computer science is now making to these disciplines. This idea opens up a large number of projects. Select a discipline of study. Explain what this discipline is, and explore contributions that computer science is making to the domain. (Make use of the definition and discussion of discipline given in Chapter 4.) See:

Denning, Peter J. (2005). Is computer science science? *Communications of the ACM*. Accessed 3/30/06: <http://cs.gmu.edu/cne/pjd/PUBS/CACMcols/caemApr05.pdf>.

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

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