

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

[[The material here is part of a beginning of a book that I am writing. Some the components are far enough along to be used as readings in a class I am teaching Spring Term, 2005. Thus, I am making this material available on the Web for use by these students.]]

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## About the Author

Probably you have accessed this book from the Web. You know that there are millions of Websites and that the quality of their content varies considerably. One way to help evaluate a Website is to look at the qualifications and the purpose of the author.

I am not a specialist in talented and gifted (TAG) education. However, I am a well-qualified educator and I care deeply about TAG education. Here are a few bits of information about me:

- Doctorate in mathematics from University of Wisconsin, Madison.
- Taught mathematics at Michigan State University and 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, which is this country's largest professional society for computers in education. Headed up this organization for 19 years.
- Author or co-author of about 40 books and several hundred articles.
- Served as a major professor for more than 50 doctoral students.

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

# Preface 1

## Preface for TAG Students

The goal of this book is to help improve the education of talented and gifted (TAG) students. When I began planning this book, I thought about writing for four main audiences:

- Talented and gifted students.
- Preservice and inservice teachers and other educators.
- Parents of talented and gifted students.
- Educational policy makers, School Boards, Legislators, etc.

It soon became apparent that I could not write simultaneously for four different audiences. So, I decided to write mainly for preservice and inservice teachers and their students. Teachers are the audience that I know best, and I have written many books for preservice and inservice teachers. I have written several books for upper elementary and middle school students.

At first glance, this looks like a book for teachers. However, this preface is mainly aimed at TAG students. At the end of each chapter there is a set of suggestions and activities for TAG students. The chapters themselves are mainly aimed at teachers. But, there is no reason why TAG students and their parents should not read them. Indeed, I encourage this.

### Computers

When I say the word *computer*, I actually mean Information and Communicating Technology (ICT). ICT includes computers, but it also includes communication technology such as email, the Web, cell telephones, and other wireless communication devices. ICT includes the input, storage, processing, and output of anything that can be digitized, such as still and motion pictures, and music. ICT includes the field of Computer and Information Science, and interesting topics such as Artificial Intelligence. ICT includes computer games, and a whole chapter is devoted to this topic.

Computers are now ubiquitous—they are a routine part of your life. Of course, you don't see most of these computers. They are built into cars, radios, games, television sets, music players, microwave ovens, telephones, wrist watches, and so on. In all of these examples, computers are an aid to solving problems and accomplishing tasks. From a user point of view, the focus is on solving problems and accomplishing tasks—it is not on computers. "Hmm," you might say." So, everybody is a frequent user of computers. I wonder what difference this makes in their lives and in my life? I wonder whether I should learn more about computers." This book will help you in making decisions in this area.

If you are a TAG student at the age of a typical 4<sup>th</sup> or 5<sup>th</sup> grader, the chances are that you can read and understand this book. This is because many TAG students who are 10 or 11 years old can read at a 9<sup>th</sup> or 10<sup>th</sup> grade level, or still more complex materials. However, there is a

difference between **reading** and **reading with understanding**. This book contains a number of intellectually challenging ideas. When you encounter an idea that both interests and challenges you, then is where the learning begins. I hope you will explore these ideas via the Web and other resources at an intellectual level appropriate to your current intellectual developmental level.

Here is an example of a challenging idea. I am writing this book using Microsoft Word. This piece of software can calculate the Flesch-Kincaid readability of a written document. This preface has about a ninth grade readability level. Perhaps some of the following questions have popped into your mind:

- What does it mean for a document to have a ninth grade readability level? It certainly does not mean that you need to be in the ninth grade, or the age of an average ninth grader, to read this book.
- How can a computer measure the reading level of text that it (the computer) does not understand? Or, does the computer make use of artificial intelligence in measuring readability level?
- How can you tell if you are reading with understanding?
- Can an artificially intelligent computer system read with understanding?
- Are computer intelligence and understanding the same as human intelligence and understanding?

If some of these questions interest you, then you may want to do some Web. You might want to check the readability level of your writing. You might want to do some research on readability measures. You might want to learn more about artificial intelligence, and the capabilities and limitations of computers. This book includes a chapter about human and computer intelligence.

Please do not hold your breath while waiting for your teacher and school curriculum to cover such topics. One of the advantages of being TAG and having access to the Internet (which includes the Web) is that you can learn whenever and whatever you want to learn. You can and should take major responsibility for your own learning.

## **Four Unifying Themes**

### **Learning Faster and Better**

As compared to “average” students, TAG students learn faster and better, and they are more effective users of their learning. For example, consider a typical group of students taking a course or unit of study in a particular discipline area. Compared to the average in this group, you might learn one-and-a half to two times as fast, demonstrate a much higher level of learning and understanding, and better transfer this learning to other areas. Speed and quality of learning, and making effective use of learning, constitutes one of the major unifying themes in this book.

When you read “and better transfer this learning to other areas,” what meaning did you assign to the phrase? Have you thought carefully about transfer of learning to areas that you have not yet thought about or studied? Are you especially good at making such connections? Are you familiar with various theories about transfer of learning, such as near/far transfer and high-road, low-road transfer? Aha—a research question that that you might want to explore!

## **Problem Solving and ICT as a Mind/Brain Tool**

ICT provides many aids to a person's mind and brain. The mind and brain tools provided by ICT are a powerful aid to solving complex problems, accomplishing challenging tasks, and answering hard questions. In this book, I combine problem solving, accomplishing tasks, answering questions, critical thinking, and other similarly activates under the label problem solving. Problem solving is the second unifying theme in the book.

## **Being Responsible for Your Own Education**

The third unifying theme is that you, personally (a TAG student) are mainly responsible for your own education. Our formal schools are often represented as a battleground, with students being coerced to learn what the teachers and the school district want them to learn. You are quite capable of learning on your own. You are quite capable of learning about the various things that you might be interested in learning. That is, you can (and should) take far more responsibility for your own education than does the average student.

As an example of the third theme, what do you know about brain science (neuroscience) and mind science (psychology)? I hope that these topics interest you, because I hope that you are interested in learning about your brain and mind. Cognitive neuroscience is a "hot" area of study and research nowadays. The chances are that the courses you are taking in school do not include much of a focus on cognitive neuroscience. This is an exciting area that is making amazing progress. It is a topic that is included in this book.

## **Expertise in Learning and Other Areas**

You know that you are better at some things than at other things. For example, you may be better at writing than at math. You may be better at playing a musical instrument than at singing. You may be better at chess than checkers. In anything that you do, you have a certain level of expertise. You can increase this expertise by study and practice.

What is your current level of expertise as a learner? This is a difficult question. How can you measure this? How can you compare this expertise with that of other people? How can you tell if you are better at learning some things than other things? What can you do to increase your level of expertise as a learner? These questions are important to all students. They are a unifying theme in this book.

## **Mission of This Book**

My hope is that you will read this book from a computer connected to the Web. (Reading a printed copy is an acceptable, but inferior alternative.) Your brain and mind are naturally inquisitive. As you read, you think about how the content relates to what you already know. Pose questions that you are interested in, and then seek answers. Introspect to learn more about yourself as a learner and as a problem solver. The Web provides an environment that facilitates this inquisitiveness, desire to learn, and desire to boldly go where you have not gone before.

For example, when you read the "boldly go" sentence, did it remind you of Star Trek? Or, is that science fiction so far past that you have never encountered the mission statement, "To boldly go where no one has gone before. To seek out new worlds ..." The Web can take you to this quote and related topics.

The mission of this book is to help you:

**To boldly go where your brain and mind have not gone before. To seek out new intellectual challenges. To develop your intellectual capabilities. ...**

Dave Moursund

April 2005

## Preface 2

### Preface for Teachers

The goal of this book is to help improve the education of talented and gifted (TAG) students. It is written mainly for preservice and inservice teachers and their students. Teachers are the audience that I know best, and I have written many books for preservice and inservice teachers. I have written several books for upper elementary and middle school students. (I hope that many parents and educational policy makers will also read this book.)

If you are a preservice or inservice “regular education” elementary or middle school teacher, you will find that this book is written specifically for you. Within the groups of students you teach, there will be a number of TAG students. The first chapter of this book discusses possible definitions of TAG. For now, it suffices to use estimates that about 10-percent of the students you teach are TAG.

The Preface for TAG Students and a set of questions and activities at the end of each chapter are written for students. The reading level for these sections is 8<sup>th</sup> to 9<sup>th</sup> grade. Certainly teachers and others will want to read these sections. Teachers will want to help their students to understand and act upon the content of the TAG students’ sections. Thus, if you skipped over the Preface for TAG Students, you should go back and read it.

You may wonder why I have attempted to include sections for students to read in a book written for preservice and inservice teachers. Of course, your TAG students may wonder why there are sections for teachers to read in a book written for TAG students. Why shouldn’t students read a book written for teachers? Do teachers have secret knowledge that must be kept away from their students?

### **Cognitively Challenged and Cognitively Gifted Students**

In a typical class of 25 to 30 students, a teacher may have one or two students who are cognitively challenged. One possible measure of being cognitively challenged is having a learning rate that is perhaps .5 to .75 times the rate of average students. You also may have one or two students who are cognitively gifted. One possible measure of being cognitively gifted is having a learning rate that is perhaps 1.5 to 2 or more times the rate of average students. This book focuses on education for students who are cognitively gifted. The goal is to help improve the quality of education that they are obtaining.

There are many different definitions of what constitutes being cognitively gifted. For example, consider a “learning disabled” student who can read, write, speak, and listen, but who is several years below grade level in subjects such as reading and math. Other than humans, no other creatures on earth match or exceed this student’s cognitive capabilities. From that point of view, this student is cognitively gifted in areas such as learning to communicate in a human natural language and learning a human culture. Such a point of view suggests that every student should be treated as being gifted.

However, TAG education is most often focused on students who are exceptionally cognitively talented relative to average students. Interestingly, one of the leading TAG educators in the United States has taken a very broad perspective of which students should be given TAG-like opportunities in school. In essence, Joseph S. Renzulli feels that such 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 2

For example, TAG students are often given considerable freedom in deciding what they will study and how they demonstrate their learning progress. Perhaps you wonder why this is not also true for all students? As educators, we talk about student-centered education—but often this does not provide nearly as much individual choice as it might. We can do much better in helping students learn about their strengths and weaknesses, interests and disinterests, levels of intrinsic motivation and personal drive, and so on in various cognitive areas.

## **Brains and Computers**

There are lots of things that a human brain can do better than the very best of current multimillion dollar supercomputers. On the other hand, there are lots of things an inexpensive computer can do 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.

Over the past 60 years, the cost effectiveness of electronic computers has improved by more than a factor of 10 million. Computers have become much faster, have larger primary and secondary storage devices (memory), and have much improved software. Human-machine interfaces have been substantially improved. This rapid pace of improvement in computer 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. Our educational system has not done very well in preparing students to work in an environment in which steadily more powerful auxiliary brains are becoming more and more available. This book contains a number of ways to address this issue in TAG education.

**[[This Preface, as well as the rest of the material in this draft, remains to be completed.]]**

Dave Moursund

April 2005

# Chapter 1

## Introduction

One of the major goals of education is to help students increase their level of expertise in the various subject areas covered in the curriculum. Thus, for example, we expect that students will increase their levels of expertise in reading, writing, math, art, music, science, social science, and perhaps many other areas. We know that the results will vary from student to student, reflecting their specific interests, abilities, academic work ethic, and so on.

Students vary considerably in their physical and cognitive capabilities and limitations. Some of these differences can be traced to genetics (nature), and some can be traced to environment beginning from the time of conception (nurture). Nurture includes drugs, diseases, nutrition, injuries (or, the lack of such damage), informal education, and formal education. Each of us is a product of nature and nurture.

The main focus in this book is on roles of computers in the informal and formal education of cognitively talented and gifted (TAG) students. This chapter provides some general background.

### Expertise

This section introduces the idea of a student gaining increasing expertise in a performance or problem-solving area. You can think about your current level of expertise in art, dance, math, reading, science, social science, or other academic areas. In addition, you can select much smaller areas, such as mental arithmetic, drawing, or playing a specific musical instrument. Within any area you currently have a certain level of expertise. Through study and practice you can increase this level of expertise. Figure 1.1 illustrates this idea.

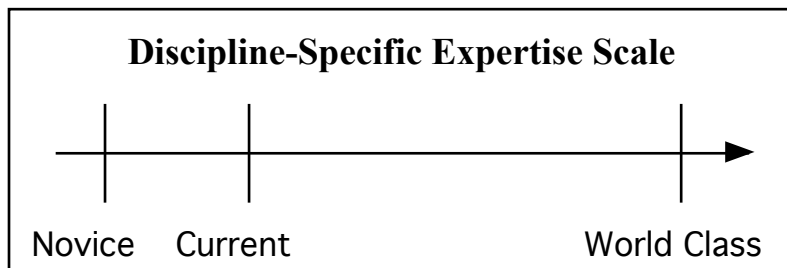


Figure 1.1. Expertise scale.

Over time, “world class” moves to the right in the diagram. In essence, this is because of building on the previous work of others. The output of many researchers working over a period of many years is made available to a student just beginning to study a particular area. Educators and other scholars have organized the collected results in a manner as to help the student learn. With appropriate books, teachers, and other aids to learning, the student makes much more rapid progress than did the individuals contributing to the collected knowledge base.

Increasing expertise in an area means an increasing level of performance. One becomes better at solving the problems and accomplishing the tasks. Progress in brain science is helping us to understand what happens. When presented with a novel, challenging problem, both the right hemisphere and the left hemisphere of a person's brain examines the situation and begins to work on the problem. One hemisphere (the left, for most people) stores patterns of previously encountered problems that have been encountered, along with actions takes to solve the problems. The other hemisphere (the right, for most people) is designed to deal with novel situations.

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 left 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.

Research indicates that it takes many years of concerted effort to become world class in a particular area. Of course, the amount of time varies with the area. If the accumulated knowledge in an area is 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 talent 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.

This type of analysis of 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 1.2 is sort of like the diagram of figure 1.1, 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 things 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.

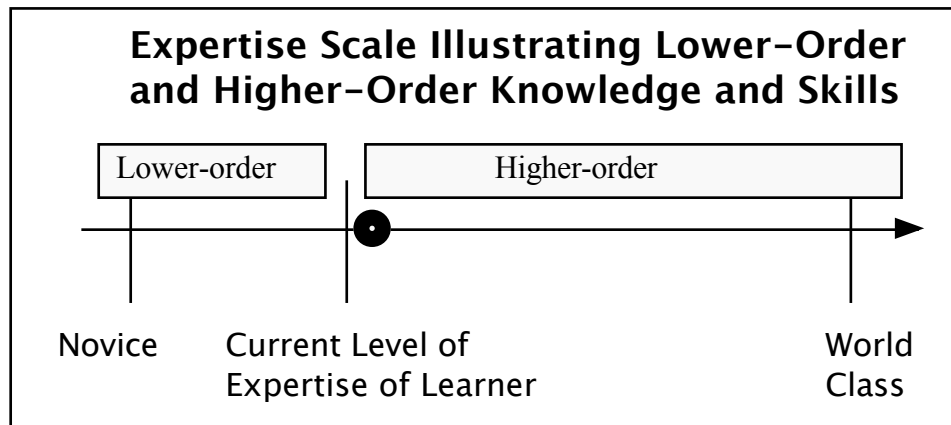


Figure 1.2. A student’s view of lower-order and higher-order.

Figure 1.2 helps to explain why TAG students find the curriculum and instruction in the regular classroom does not fit their needs. In domains 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 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.

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.

ICT provides powerful aids to solving problems and accomplishing tasks. Nowadays, in many areas a person’s level of expertise in an area is strongly related to the person’s ability to make use of ICT to help solve the problems and accomplish the tasks in that area. This is a recurring theme in this book. TAG students (and, of course, all other students) benefit by learning to make effective use of ICT within the areas where they are working to gain an increasing level of expertise.

## Exceptionalities

Many people tend to have a highly over simplified and incorrect model of students falling into one of three relatively distinct cognitive categories: 1) disabled, or cognitively challenged; 2) normal; and 3) talented and gifted. This model does a major disservice for all students. For a great many people, a combination of all three labels apply.

When I teach, I like to tell stories. Here is a story about myself.

I have been quite successful in the world of academics. I easily obtained a doctorate in mathematics and I have had a successful career as a faculty member in Mathematics, and then Computer Science, and then in a Teacher Education. I am the author of a great many books and articles, I have traveled extensively giving talks, presenting workshops, and doing consulting, and I have been the major professor of many doctoral students.

When it comes to spelling, my brain does not work very well. While I can memorize a list of words to pass a spelling test, for me this is a “memorize, regurgitate, and forget” exercise. Good spellers can “see” words in their mind’s eye—I can’t.

I have a very poor sense of direction. When I go into a new city, there is a good chance I will become directionally confused just by walking a block or two away from the hotel where I am staying. In a large building such as a convention center, after a couple of turns I am lucky to find my way back to the door where I came in. (My sister, who has a doctorate in physical chemistry, seems to have a similar difficulty.)

Related to the above, I have very poor spatial sense. When I graduated from high school I took a set of tests used in vocational counseling. My spatial IQ was 87, and the advice was that I certainly should not think about going into mathematics.

I have a great deal of difficulty in recognizing people. For example, my wife used to make fun of me for failing to pick her out from the crowd of people meeting passengers coming off an airplane. I have considerable trouble in recognizing my students. (My older daughter, who is a very talented and successful computer programmer, has the same problem.)

One way to study and think about exceptionalities is to think about the complexity of a persons mind and physical body. Research in mind and brain science has made considerable progress in recent years. Computers and computerized instrumentation are powerful aids in this type of research.

A typical human brain contains more than 100 billion neurons and more than a trillion cells. Even identical twins (with identical genes) that have been raised together have significant differences in their brains. A brain has a high level of plasticity and is constantly being changed as it receives and processes inputs and as it learns.

Our increasing knowledge of genes and brain science are helping us to see that a great many people have identifiable cognitive exceptionalities that are important enough that significantly affect their lives. Often these exceptionalities have not been recognized or identified by the people, and the people with these exceptionalities merely accommodated to them—without even recognizing that they were doing so.

### **Internal, Personal Accommodations**

The plasticity and intelligence of a typical person's brain facilitates the development of internal and personal accommodations that overcome or circumvent a large number of problems that might be considered to be cognitive disabilities. Thus, we tend to talk about cognitive disabilities only when they are so severe that a person cannot readily accommodate to them on his or her own. Many years ago when I had to write essays in class as part of a Freshman English Composition course, I had to carefully plan my sentences so that they did not include words I could not spell correctly. In addition, my handwriting left much to be desired. I struggled in such "real time" assessments, but I was smart enough to circumvent my spelling difficulties. Fortunately, much of the grade in the course was based on weekly writing assignments that were done outside of class. There, I could make use of a dictionary and I could put in the time needed to show that I could write reasonably well. Also, I could make use of a typewriter. Now, of course, I use a word processor with a good spelling checker. This computer-based accommodation is a powerful "equalizer" when it comes to my spelling and handwriting.

### **Dual and Multiple Exceptionalities**

Many students have two or more significant cognitive exceptionalities. For example, a child may be both severely dyslexic and brilliant. Quoting from an ERIC Digest (Dual Exceptionalities, 1999):

Gifted students with disabling conditions remain a major group of underserved and under stimulated youth (Cline, 1999). The focus on accommodations for their disabilities may preclude the recognition and development of their cognitive abilities. It is not unexpected, then, to find a significant discrepancy between the measured academic potential of these students and their actual performance in the classroom (Whitmore & Maker, 1985). In order for these children to reach their potential, it is imperative that their intellectual strengths be recognized and nurtured, at the same time as their disability is accommodated appropriately.

Many TAG students have cognitive disabilities such as autism, AD/HD, dyslexia, dyscalculia, dysgraphia, and so on.

Many TAG students have physical disabilities. Stephen Hawking, a brilliant physicist, is often cited as an example. Hawking has Amyotrophic Lateral Sclerosis (ALS). ALS is a relatively rare (approximately one in 50,000 people) neurodegenerative disease that attacks nerve cells and pathways in the brain and spinal cord. As these cells die, voluntary muscle control and movement dies with them. Patients in the later stages of ALS are totally paralyzed, yet in most cases, their minds remain sharp and alert (ALS).

### **Exceptionalities and Minority Students**

Special education and TAG education systems in our country have not done well in meeting the needs of minority students. Quoting from the book *Minority Students in Special and Gifted Education* by Donovan and Christopher (2002):

Special education and gifted and talented programs were designed for children whose educational needs are not well met in regular classrooms. From their inceptions, these programs have had disproportionate representation of racial and ethnic minority students. What causes this disproportion? Is it a problem?

*Minority Students in Special and Gifted Education* considers possible contributors to that disparity, including early biological and environmental influences and inequities in opportunities for preschool and K-12 education, as well as the possibilities of bias in the referral and assessment system that leads to placement in special programs. It examines the data on early childhood experience, on differences in educational opportunity, and on referral and placement. The book also considers whether disproportionate representation should be considered a problem. Do special education programs provide valuable educational services, or do they set students off on a path of lower educational expectations? Would students not now placed in gifted and talented programs benefit from raised expectations, more rigorous classes, and the gifted label, or would they suffer failure in classes for which they are unprepared?

As a preservice or inservice teacher, you want to do your best in meeting the individual needs of each of your students. As you gain in knowledge and skills (as you move up the “good teacher expertise scale”) you will get better at dealing better with a wide range of exceptionalities and with different levels or degrees of these exceptionalities. You will also get better at knowing when you need the help of experts who have more training and experience than you in dealing with specific types of exceptionalities.

### **Identification of Gifted Children**

There is no simple, widely agreed upon definition of TAG. Let me give an example of the difficulty. Suppose that someone makes up an (arbitrary) definition that students with an IQ of 130 or above are gifted, those with an IQ of 145 are very gifted, and those with an IQ of 160 or above are profoundly. That sounds simple enough.

IQ Comparison Site (n.d.). IQ Percentile and Rarity Chart. Accessed 3/19/05:

<http://members.shaw.ca/delajara/IQtable.html>.

But, it turns out that even these simple and quite arbitrary definitions are flawed. For example, some widely used IQ tests have a standard deviation of 15, and others have a standard deviation of 16. If the proposed cutoff points are 130, 145, and 160 for a test with standard deviation of 15, then the cutoff points need to be 132, 148, and 164 for a test with standard deviation of 16. Based strictly on the mathematics of these definitions, about one student is 33 is gifted, one in 407 is very gifted, and one in 11,307 is profoundly gifted.

Now, here are a few difficulties with this type of definition.

1. Are the IQ tests fair, reliable, and valid? Historically, for example, widely used tests have been designed that are not fair in male versus female, or in high socioeconomic versus low socioeconomic, or across races, or across cultures. Moreover, there can be considerable variations on how well a person scores on a test depending on their current stress levels, health, sleep patterns, test anxiety, and so on.
2. While an IQ test may be designed to produce a single number, it is well understood that a person (or, a person's cognitive capabilities) is much more than a single number. Howard Gardner, for example, has had a significant impact on education through his work on multiple intelligences. A person might be TAG in music and not in language, or TAG in math and not in interpersonal or intrapersonal areas.
3. The definition says nothing about charisma, courage, creativity, drive and energy, intrinsic motivation, optimism, persistence, sense of power to change things and other factors that play heavy roles in cognitive achievement.

While the list can be extended, its current length should be convincing to you. 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.

These ideas have been understood for a long time. The following is quote is from Former U. S. Commissioner of Education Sidney P. Marland, Jr., in his August 1971 report to Congress:

#### **Who Are Gifted Children?**

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 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, 1972).

...

Children capable of high performance include those with demonstrated achievement and/or potential ability in any of the following areas, singly or in combination:

1. general intellectual ability
2. specific academic aptitude
3. creative or productive thinking
4. leadership ability
5. visual or performing arts
6. psychomotor ability.

Here is a quote from an ERIC Digest (ERIC, 1990).

#### **What Does Giftedness Mean?**

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. A brief description of each area of giftedness or talent as defined by the Office of Gifted and Talented will help you understand this definition.

- General intellectual ability or talent. Laypersons and educators alike usually define this in terms of a high intelligence test score--usually two standard deviations above the mean--on individual or group measures. Parents and teachers often recognize students with general intellectual talent by their wide-ranging fund of general information and high levels of vocabulary, memory, abstract word knowledge, and abstract reasoning.
- Specific academic aptitude or talent. Students with specific academic aptitudes are identified by their outstanding performance on an achievement or aptitude test in one area such as mathematics or language arts. The organizers of talent searches sponsored by a number of universities and colleges identify students with specific academic aptitude who score at the 97th percentile or higher on standard achievement tests and then give these students the Scholastic Aptitude Test (SAT). Remarkably large numbers of students score at these high levels.
- Creative and productive thinking. This is the ability to produce new ideas by bringing together elements usually thought of as independent or dissimilar and the aptitude for developing new meanings that have social value. Characteristics of creative and productive students include openness to experience, setting personal standards for evaluation, ability to play with ideas, willingness to take risks, preference for complexity, tolerance for ambiguity, positive self-image, and the ability to become submerged in a task. Creative and productive students are identified through the use of tests such as the Torrance Test of Creative Thinking or through demonstrated creative performance.
- Leadership ability. Leadership can be defined as the ability to direct individuals or groups to a common decision or action. Students who demonstrate giftedness in leadership ability use group skills and negotiate in difficult situations. Many teachers recognize leadership through a student's keen interest and skill in problem solving. Leadership characteristics include self-confidence, responsibility, cooperation, a tendency to dominate, and the ability to adapt readily to new situations. These students can be identified through instruments such as the Fundamental Interpersonal Relations Orientation Behavior (FIRO-B).
- Visual and performing arts. Gifted students with talent in the arts demonstrate special talents in visual art, music, dance, drama, or other related studies. These students can be identified by using task descriptions such as the Creative Products Scales, which were developed for the Detroit Public Schools by Patrick Byrons and Beverly Ness Parke of Wayne State University.
- Psychomotor ability. This involves kinesthetic motor abilities such as practical, spatial, mechanical, and physical skills. It is seldom used as a criterion in gifted programs.

## Assistive Technologies

The term *assistive technology* comes up frequently in special education. However, in this book I want us to think more broadly. Since I was in elementary school, I have worn glasses. For me, these are certainly assistive technology. Recently my eye doctor told me I was beginning to develop cataracts. This led me to decide to have my (flesh and blood) lenses replaced by plastic lenses. I can now see much better and my eyeglasses are much thinner lenses than before.

You probably know people who wear a hearing aid, and perhaps people who have a pacemaker that helps regulate their heart beat. Perhaps you know people who have had shunts inserted into veins and/or arteries.

But, such assistive technologies are only a small part of what the future will provide. For example, computerized cochlear implants have helped restore hearing to many people, and significant progress is occurring in the development of replacement of a retina, in order to restore some vision to a blind eye. Perhaps you have read about brain implants to help control some types of brain seizures, and people learning to communicate directly to a computer by use of brain waves.

Suppose a student has dyscalculia, and is overwhelmingly challenged by the task of learning to do simple arithmetic calculations. For such a student, an inexpensive handheld calculator is assistive technology that can be very helpful. Suppose a student is very dyslexic and (among other things) finds spelling an almost impossible challenge. Such a student may find that a word processor with a good spelling checker is very helpful.

Now, let's carry this a little further. The Oxford English Dictionary has about a half million entries. This entire dictionary is easily stored in a computer storage device smaller than a 5-stick pack of gum. Now, suppose that you could retrieve information from such a storage device, seeing and/or hearing the results quickly in your mind. (This might be done through a mind to computer interface aided by a special display built into eyeglasses and hearing aid.) Such an apparatus would be an example of assistive technology for any person who could not readily memorize the Oxford English Dictionary.

Consider the GPS and map system now being built into many cars. With this assistive technology, a person can see a detailed map of where they are. The map may include lost of information about nearby stores, points of possible historical interest, and so on.

While this list is easily extended, the point being made should be clear. ICT is making possible a large and increasingly powerful set of assistive devices. Many of these can be thought of as brain/mind enhancements. They extend and/or supplement capabilities of one's brain.

## 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. Quoting from the Council for Exceptional Children (n.d.):

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 [standard deviation of 15] 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.

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 for Teachers

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 to be important. For each, rate yourself on the scale given in Figure 1.3. They analyze and discuss the results.

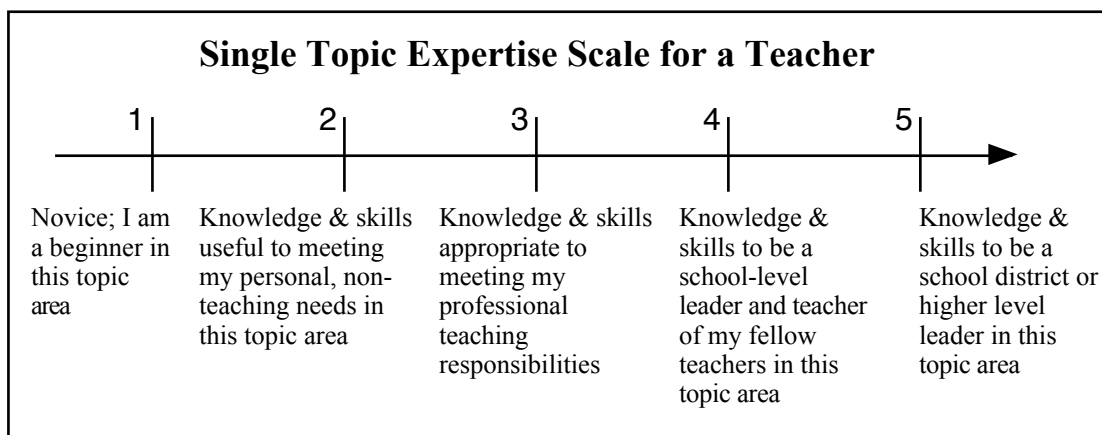


Figure 1.3. Single topic expertise scale for a teacher.

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?
4. If you are a teacher of 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.

## Activities and Projects for TAG Students

Each chapter ends with a short section for TAG students. The section summarizes a few key ideas from the chapter. It then contains some things for TAG students to think about or do—and perhaps write about in a personal journal.

This 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. (If you don't know what dyslexia is, look it up on the Web.)

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.

1. Here are some things to think about, and perhaps to write about in a journal. What evidence do you have, and how good is the evidence? When and how did you first learn that you are TAG? What have you done that makes good use of your special talents and gifts? Who is helping you to learn to make effective use of your talents and gifts? How could they better help you?
2. 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.
3. Analyze some of your areas of greatest expertise using the diagram of Figure 1.4. You might want to begin by developing a set of labels that are more appropriate to you.

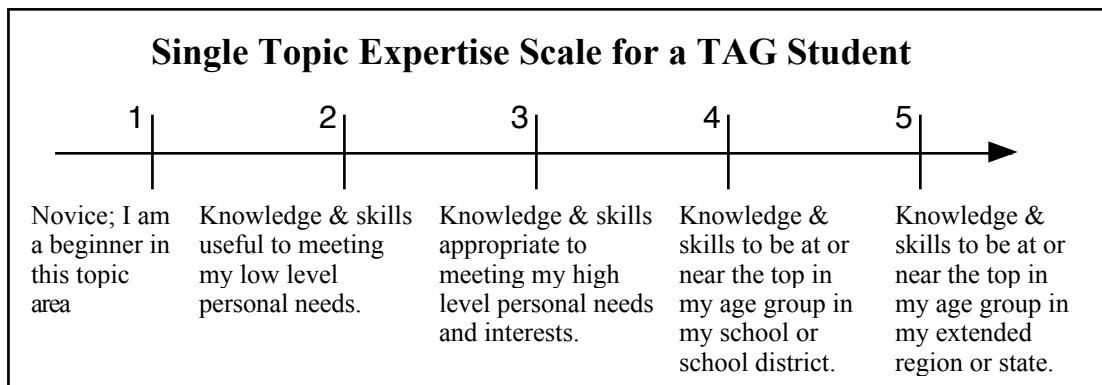


Figure 1.4. Single topic expertise scale.

## Chapter 2: Joseph Renzulli

Joseph S. Renzulli 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.

### Project-Based Learning

The heart of the Schoolwide Enrichment Model is a schoolwide approach to project-based learning (PBL). This section covers PBL while the next section provides an introduction to the Schoolwide Enrichment Model. The materials in this section are drawn from my ICT-Assisted Project-Based Learning Website (Moursund, PBL, n.d.).

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

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 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 the 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 the 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.

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-purposed planning table given in Figure 2.1.

<b>Goals: Students will learn:</b>	<b>Points</b>
1. The subject matter content of the project.	
2. ICT as integral part of the subject matter content area of your specific course.	
3. Some general aspects of ICT, not specific just to your course	
4. How to budget resources (including time) in doing a project, and to self-assess one's progress in doing a project	
5. To work as a team member 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. Etc. There may be many more goals.	
9. To learn to learn and to help others learn all of the above.	
The total of the points must add up to →	100

Table 2.1. ICT-PBL Planning Table

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.

### Schoolwide Enrichment Model

The heart of Renzulli's Schoolwide Enrichment Model is a school decision to devote a half-day per week to project-based learning. During that time, all students in the school are engaged in PBL. A specific project may involve students from many different grade levels. Quoting from Reis & Renzulli (1985):

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.

The Reis & Renzulli quote given above mentions “service delivery components.” What Reis & 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 or disruptive or impolite behavior in the classroom.

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 class of students. However, these students will be doing something different than what the students in the other 4<sup>th</sup> 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 4<sup>th</sup> 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 5<sup>th</sup> grade, they create a dilemma for the 5<sup>th</sup> grade teachers.

As you can see, some of these problems go away if all 4<sup>th</sup> 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**

Purcell and Renzulli (1998) put forth the idea of each student having a Total Talent Portfolio (TTP). Quoting from their book:

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.

...

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.

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 student, the teacher develops an initial TTP for the student. This is done through an interactive discussion with the student as well 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 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. As a student gains in maturity, the student can take on more and more responsibility for and ownership of his or her own TTP.

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. I will return to this topic later, in the chapter *Me—A Course of Study*.

### **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 (1988) 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.

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.

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.

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.

We will focus on 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 not too good—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 we all took an Iowa Test of Basic Skills. The information I received about my test results gave me an increased understanding about myself.

Interest areas is the third topic on the list of possible TTP components. 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).
  - **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, this might make use of the three categories: Analytic (school smarts); Creative/Inventive; and Practical (street smarts). [Reference, the Higher Mental Functions component of: Accessed 3/28/05: <http://www.yale.edu/rjsternberg/#styles>. Another approach, also drawing on the work of Sternberg, is to make use of the three categories: *Legislative* (creating, planning, imagining, and formulating); *Executive* (implementing and doing); and *Judicial* (judging, evaluating, and comparing). [Reference accessed 3/28/05: <http://www.yale.edu/rjsternberg/#styles>.]
- 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 who 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.

[Note to self and to readers. The above can be expanded. However, it provides enough background for my first attempts to list some items that might be in a TTP in ICT for students. The next four subsections cover the four component areas of a TTP.]

### **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.

### **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 we listed four major components of Style Preferences:

- a. Instructional style preferences
- b. Learning environment preferences.
- c. Thinking style preferences.
- c. 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?

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. CT 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. 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.

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 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.

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 for Teachers**

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.

## Activities and Projects for TAG Students

This chapter is based on the work of Joseph Renzulli. He is one of this country's leading experts in TAG education. Three main topics are discussed:

- Project-based learning (PBL). In PBL, individuals or teams work on a project over an extended period of time. They work to product a product, presentation, or performance. Nowadays, PBL is routinely used when students (and adults) are doing projects.
- A Total Talent Portfolio (TTP). Such a portfolio contains information about a students strengths and abilities, weaknesses and challenges, interests, and preferences on a variety of possible ways to organize and carry out teaching and learning.
- A Schoolwide Enrichment Model (based on the two ideas listed above) designed to enhance learning opportunities for all students in a school. This approach is especially good for TAG students.

Here are some things to think about and/or do.

1. If you could make some major changes in the curriculum content, the instructional processes, and the testing (assessment, grading) in you school, what changes would you make? How would these help or hinder you, and how would they help or hinder other students?
2. This question assumes you have had previous experience with PBL. Analyze your previous PBL experiences from a personal learning point of view. What worked well, what didn't work well, how well did they facilitate your personal learning and growth, and how could they have been improved?
3. Name some of your current learning interests. To what extent does school facilitate your learning in these areas? What might school be doing to help your learning in these areas of interest? Explain why you think this might be a good or a bad idea.
4. Read about the Total Talent Portfolio. [See Renzulli, Joseph S. (1998) *The Total Talent Portfolio: A plan for identifying and developing Gifts and Talents*. Accessed 3/28/05: <http://www.sp.uconn.edu/~nrcgt/sem/semart09.html>.]

## Chapter 3

### Human Intelligence and Brain Science

#### Piagetian Cognitive Development Theory

Piaget’s four-level cognitive development scale is given in Figure 2. Let’s discuss some of the more recent insights into (improvement on) this theory, and possible ways that ICT may affect this theory.

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: Piagetian cognitive development scale.

#### ICT Developmental Scale

Figure 3 contains an ICT cognitive developmental scale based on the ISTE 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.

Stage “Title”	Age and/or Education Levels	Brief Discussion
Stage 1. Piagetian Sensorimotor.	Age birth to 2 years. Informal education provided	Infants use sensory and motor capabilities to explore and gain increasing understanding of their environments. ICT has brought us a wide range of sound and music-producing, talking,

	by parents, and other caregivers.	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.
Stage 2. ICT Preoperational.	Age 2 to 7 years. Includes both informal education and increasingly formal education in preschool, kindergarten, and first grade.	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. 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. 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.
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.	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. Operational thinking (mental actions that are reversible) develops. 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: <ul style="list-style-type: none"> <li>• Learn to use a variety of software tools such as those listed in the 5<sup>th</sup> 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.)</li> <li>• 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.</li> </ul>
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 understanding of topics in ISTE NETS for students finishing the 12 <sup>th</sup> grade.	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. Formal Operations in ICT includes functioning at a Piagetian Formal Operations level in specific activities such as: <ol style="list-style-type: none"> <li>1. Communicate accurately, fluently, and with good understanding using the vocabulary, notation, and content of ISTE NETS-S for the 12<sup>th</sup> grade.</li> <li>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 the software, save a document you have created, and later return to make further use of your saved document.</li> <li>3. Problem solve at the level of detecting and debugging hardware and software problems that occur in routine use of ICT hardware and software.</li> <li>4. Convert (represent, model, pose) real world problems from non-ICT disciplines into ICT problems, and then solve these problems.</li> <li>5. Routinely and comfortably use ICT in the other</li> </ol>

		<p>disciplines you have studied, at a level consistent with and supportive of your cognitive developmental level in these disciplines.</p> <p>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.</p>
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Figure 3: 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 software. It does not speak to specific 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. Here is some additional analysis of the ICT cognitive development and expertise scale.

### **ICT Sensorimotor and Preoperational**

Brain and mind are growing very rapidly during the Sensorimotor and Preoperational stages of the ICT developmental scale. A substantial amount of the learning that occurs is situational and cultural. If one’s home and community environment is bilingual or trilingual, a child becomes bilingual or trilingual. A child learns the culture in an unquestioning manner at a deep, long-lasting level.

Nowadays, the home environment of many children includes computerized toys, computers, cell phones, TV, and electronic games. Research into the effects of growing up in such an environment is rather limited. When I encounter good arguments against early use of computers, I collect them in my Website (OTEC, n.d.)

I like to analyze the situation of a child’s early years in terms of Robert Sternberg’s three-part definition of intelligence. His triarchic model considers creativity, street smarts, and school smarts (Sternberg, 1988). We know that large numbers of students enter kindergarten or the first grade a year or more behind others in terms of their school smarts. Much of this difference can be traced to the socioeconomic and school-oriented home and cultural environment. Students growing up in low socioeconomic environments that place relatively little emphasis on school-oriented activities tend to emphasize use their fluid intelligence and creativity in areas that are classified as street smarts. They are less well prepared for school (on average) than children growing up in higher socioeconomic, school-oriented home environment.

For me, personally, I want my grandchildren to grow up in a home environment that includes computerized toys and music, computers, cell phones, TV, digital still and video cameras, and electronic games. I think that this is an important aspect of preparation for school and their adult lives. And, it contributes to a child moving up the ICT developmental scale.

### **ICT Concrete Operations**

The approximate age range for Concrete Operations is the same as elementary school. The following is quoted from the ISTE National Educational Technology Standards (ISTE, 1998), indicating part of what ISTE feels a student should be able to do by the end of the fifth grade:

4. Use general-purpose productivity tools and peripherals to support personal productivity, remediate skill deficits, and facilitate learning throughout the curriculum.
5. Use technology tools (e.g., multimedia authoring, presentation, Web tools, digital cameras, scanners) for individual and collaborative writing, communication, and publishing activities to create knowledge products for audiences inside and outside the classroom.
6. Use telecommunications efficiently and effectively to access remote information, communicate with others in support of direct and independent learning, and pursue personal interests.

There is considerable emphasis on learning to use a variety of tools. Students tend to be good at learning the concrete operations aspects of a wide variety of computer tools. The tools tend to be concrete in nature. A sequence of mouse clicks and keystrokes produces concrete results that a student's visual and auditory systems can process. There is little need to understand what is going on behind the scenes—a "black box" type of knowledge tends to suffice.

However, this learning situation is made more complex because each tool is designed to help solve problems and accomplish tasks. Many ICT tools are inherently designed for higher-order use. This means that effective teaching of the tools needs to be done in a situated learning environment that has a strong learning toward higher-order cognitive activities. This needs to be done at a time when students are at a Concrete Operations level.

Seymour Papert worked with Piaget for five years and is well known for his work in helping to develop the Logo programming language. Papert has been a long time supporter of the idea that an appropriate learning environment (such as a Logo environment) can hasten a student's movement toward Formal Operations. Many neo-Piagetians support this idea.

Another important aspect of computer use during the Concrete Operations stage is that students can be empowered to address more interesting and challenging problems. Computer graphics, computer animation, and the editing of digital still and video pictures provide a wonderful environment for such activity, as do computer-based music composing and performance systems.

### **ICT Formal Operations**

I believe that many educational leaders understand that lots of elementary school teachers have not achieved Formal Operations over the full range of disciplines they are expected to teach. There tends to be an assumption that Secondary School teachers have reached Formal Operations in the areas they are certified to teach, as they have had to take a significant amount of college work in these disciplines.

Now, consider the situation in which every teacher is expected to routinely incorporate appropriate uses of ICT into their curriculum, instruction, and assessment. (Remember, this is somewhat akin to the expectation that every teacher is expected to contribute to students learning reading, writing, speaking, and listening within each discipline they teach.) Go back to Figure 2 and reread the Formal Operations part of the table. I believe that you will agree that relatively few teachers satisfy this definition of ICT Formal Operations.

This means that our educational system is creating (has created) a situation in which teachers are supposed to be moving their students toward ICT Formal Operations, but the teachers are not at this ICT developmental level. Quite a few teachers face a similar challenge outside of the ICT discipline if they teach a broad range of disciplines (such as elementary teachers do) or teach outside their credentialing areas (as many secondary school teachers do).

This problem does not have a simple solution. However, most teachers have at least one discipline area in which they function at the Formal Operations level. Thus, they know what it means to function at a Formal Operations level. With appropriate thought, most teachers can transfer a number of the key concepts of being at Formal Operations in one discipline they teach, to other disciplines they teach were they are not yet at formal operations.

## **Activities and Projects for TAG Students**

You have a good mind/brain. By some combination of nature and nurture your mind/brain is much better than average in learning and in applying this learning to solving complex problems and accomplishing complex tasks.

Mind science (psychology) and brain science (cognitive neuroscience) are large, vibrant disciplines. I, personally, find them to be very interesting and fun. Studying these disciplines and writing about them is one of my hobbies.

You already know quite a bit about your mind and brain. You continue to add to this knowledge through introspection, through the materials you read and view, through your interactions with people, and so on.

However, many students find that they want to learn much more about mind/brain in general, and their specific mind/brain. One approach is to wait until you get to college. There you will find a large range of relevant courses. Some high schools offer a course in psychology. By and large, however, our current educational system is doing a poor job in helping students learn about mind/brain.

Fortunately, the Web is a very rich source of information about mind/brain. This information ranges from newspaper and magazine articles written for the general public to current research articles. The field of cognitive neuroscience is still rather young. ICT and other advances in science and technology are helping to push this field quickly forward. It is a good example of a field where a person can move rapidly to the research frontiers.

Here are some things to think about and/or do.

- 1.

## Chapter 4

### Problem Solving

We all solve problems, all of the time. The mind/body processes of living involve continually dealing with a host of problems. Almost all of this problem-solving activity takes place at a subconscious level, and you are born with the ability to solve such problems at a subconscious level.

When you carry on a conversation or read a book, you are solving complex communications problems. While much of what you are doing is taking place at a subconscious level, it took thousands of hours to train your brain to perform the needed tasks quickly and with little conscious effort. Simultaneous with the automated subconscious efforts, your brain is actively and consciously involved in making meaning and conveying meaning in these endeavors.

This chapter presents an overview of the field of problem solving. It is oriented toward roles of ICT in problem solving and education to help TAG students increase their levels of expertise in problem solving. Most in the material in this chapter comes from one of my books on problem solving (Moursund, 2004).

#### Problem Solving and Critical Thinking

Your brain has a considerable ability to learn. Learning and practicing what you have learned are natural and ongoing activities within your brain. That is, we are all life-long learners.

Our PreK-12 and higher formal education systems were designed to develop the capacity of your brain to deal with the problems that our society feels you might encounter as you grew into adulthood. As you progressed along this formal education trail, you gradually took more responsibility for yourself in deciding what courses to take and what general academic areas to pursue. You developed your knowledge and skills in knowing how to learn. You gradually gained increased expertise in being an independent, self-sufficient learner in the types of areas covered by formal education and other areas that interested you. You got better at solving the types of problems and accomplishing the types of tasks that you encountered at work, school, play, and in other components of your everyday life.

It may feel strange to you to think about life from the point of view of getting better at solving problems and accomplishing tasks. However, I find that this is a useful way to think about our informal and formal education systems. If you are going to spend your life increasing your capacity as a problem solver, likely you will find it worthwhile to gain efficiency in this endeavor. If you are a preservice or inservice teacher, then certainly you want to get better at solving the problem (accomplishing the task) of helping your students get better at problem solving. That is the purpose of this document.

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.

Indiana University Purdue University Indianapolis provides a somewhat more functional definition of critical thinking (IUPUI).

[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.

The term “higher-order” thinking is often used in discussing problem solving. 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.

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

Problem solving and critical thinking are very broad ideas and activities. They are an important aspect of every academic area.

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 goals. Learning to write in a manner that communicates effectively is a higher-order goal. In some sense, each writing task is a new problem to be solved.

Moreover, writing is a powerful aid to the brain. Miller (1956) discusses the magic number  $7 \pm 2$ . He and many others have observed that a typical person's short term memory is limited to about  $7 \pm 2$  pieces or chunks of information. Thus, probably you can look up a phone number (seven digits) and remember it long enough to key in into a telephone pad. Your short-term memory is easily overwhelmed by a problem that contains a large number of components that need to be considered all at one time. Skill in reading and writing extends the capabilities of your brain to deal with complex, multi-component problems. That is, reading and writing are brain tools that significantly increase your problem-solving abilities. A similar statement holds for ICT, and this is discussed later in this chapter.

### **What is a Formal 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.

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 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 (PBL) 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.

### **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 many, if not all domains, is to become skilled at information retrieval as an aid to solving problems. Research librarians are highly skilled in this type of information retrieval. But, 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 higher-road transfer. A teacher who is teaching one of these strategies within a particular domain has a responsibility of teaching it for 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.

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 manipulation.

### **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, 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.

### **Trial 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 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 Polya (1957) and can be called the Polya Strategy or the Six-step strategy. 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 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. This idea will be discussed later in this document. The 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.

### **Some Other Widely Used High-Road Transferable 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, as a consequence 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 point of view, we thus want to help each student 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 students combination of learning styles that is most appropriate to the specific materials being taught (materials that the student is expected to learn)

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, ICT systems are very good at rote memorization. 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 themselves. 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 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**

Here are two definitions quoted from <http://www.hpcc.gov/pubs/blue94/section.6.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 (CIS) 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.

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, some (TAG) students have been very successful in learning programming on their own and/or from peers and acquaintances. The BASIC language and the Stagecast language are likely to be good starting points for elementary school students. A local compute club may well be able to provide a volunteer to help a TAG student who has interest in learning computer programming.

### **Artificial Intelligence**

Artificial Intelligence (AI) is a component of CIS that addresses the issue of studying the development of “smart” or “intelligent” computer systems (Moursund, 2004). Here are two examples of definitions of the term:

In the early 1960s Marvin Minsky indicated that “artificial intelligence is the science of making machines do things that would require intelligence if done by men.” Feigenbaum and Feldman (1963) contains substantial material written by Minsky, including “Steps Toward Artificial Intelligence” (pp 406-450) and “A Selected Descriptor: Indexed Bibliography to the Literature on Artificial Intelligence” (pp 453-475)

What is artificial intelligence? It is often difficult to construct a definition of a discipline that is satisfying to all of its practitioners. AI research encompasses a spectrum of related topics. Broadly, AI is the *computer-based* exploration of methods for solving challenging tasks that have traditionally depended on people for solution. Such tasks include complex logical inference, diagnosis, visual recognition, comprehension of natural language, game playing, explanation, and planning (Horvitz, 1990).

In brief summary, 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. Goals of education are discussed in chapter 2 of this book.

You may have noticed that the 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.
- 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.

Our precollege educational system mostly ignores AI and the progress occurring in this field. Thus, the typical teacher does not know if AI systems can solve the types of problems that he or she is teaching students to solve by hand or with lower-order capabilities of computer systems. Students are not learning whether their studies of a particular topic are helping them to learn things that computers can do really well, or whether they are learning to do things that computers do very poorly or not at all.

Many TAG students find AI to be a fascinating area of study. Some enjoy getting involved in working with robots. For example, see <http://www.active-robots.com/products/lego/lego-index.shtml> for kits of materials used in building Lego Logo robots.

## **Summary**

Measures of ability, aptitude, and intelligence are designed to indicate a person's potential to learn to solve complex problems, accomplish complex tasks, and function in other cognitively challenging arenas. A high level of ability, aptitude, or intelligence in an area indicates good potential to achieve a high level of expertise within the area.

An increasing level of expertise in an area means an increasing level of knowledge and skills to solve problems within the area. One can get better at problem solving with a specific area by studying within that area. In addition, some aspects of problem solving knowledge and skill transfer among domains. That is, it is helpful both to gain domain-specific problem-solving knowledge and skills, and it is also helpful to work across disciplines and gain domain-independent problem-solving knowledge and skills.

ICT provides tools (as well as ways of thinking) that cut across many disciplines. Thus, ICT fits in well with many TAG students who are aiming at both breadth and depth in education.

## **Activities and Discussion Topics for Teachers**

1.

## **Activities and Projects for TAG Students**

## Chapter 5: Computer Games

All the world's a stage,

And all the men and women merely players:  
Assessment and Group Discussions

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: Self-

They have their exits and their entrances;

And each person in their time plays many parts, ...

(Dave Moursund—Adapted from Shakespeare.)

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

(H.T. Leslie)

This chapter focuses on games that can be played using a computer. Some of the games discussed in this chapter can also be played without the use of a computer. Various forms of solitaire (played with one or more decks of cards) as well as many board games such as chess provide examples of such games.

For many people, games are fun. Games can be used to learn about oneself and about learning. Games can be an important aid to social interaction. These and other game-related ideas are explored in this chapter.

### Games as a Discipline

You have some knowledge about a lot of different disciplines such as art, biology, chemistry, dentistry, economics, forestry, and so on. A discipline—a coherent area of human endeavor—can be analyzed from the point of view of:

- The types of problems, tasks, and activities it addresses.
- 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 artifacts.
- Its methods of teaching, learning, and assessment.
- Its tools, methodologies, and types of evidence and arguments used in solving problems, accomplishing tasks, and recording and sharing accumulated results.

From this rather broad perspective of a “discipline,” one can think of games as constituting a discipline. There are players, writers, developers, referees, contests, history, research, journals, and so on. One can make a career in this field.

## Some Definitions

### Play

Play is something that one can choose to do for fun, pleasure, entertainment, and enjoyment. Play helps to satisfy a person's intrinsic, innate curiosity and exploratory drive. Play can be completely absorbing.

Play can be done all alone or in groups. When done in groups, play can promote social interaction and facilitate the pleasures of such social interaction. Whether done individually or in groups, play offers possibilities of novelty, complexity, and surprise.

Play is a natural and important part of a child's life. Indeed, the early years of a child's life can be thought of as a time of play during which a huge amount of learning occurs. As children get older, we (adults) tend to separate play from schooling, work, and other activities. However, in a broad sense play is an ongoing and important part of a person's entire life.

Play, and the use of games in playing, predates our oldest historical records. Computer games expand add some new dimensions to roles of games in play.

### Games

One way to think about games and game playing is expressed in the quote "All the world's a game ..." given at the start of this chapter. However, I don't take such a broad approach in this chapter.

In this chapter, a game is an organized set of activities involving one or more players. A game has rules, goals, competition, and payoffs or consequences. Nowadays, a player in a game might well be a computer. Indeed, some people take pleasure in developing computer programs that play against each other.

### Pleasure

There has been considerable brain research on pleasure. A brain has pleasure centers or pleasure systems. Quoting from Bozarth (1994):

Because humans most often describe their own behavior in terms of subjective experience instead of the behavioristic terms of operant conditioning theory (e.g., positive reinforcement), it is appropriate to use reward and pleasure as descriptors of events governing human behavior. Indeed, the phrase introduced by Olds (1956), "pleasure centers in the brain," remains generally descriptive of the neural basis of reward, but the word *center* (suggesting a single neuroanatomical focus) has been replaced by the word *systems* (emphasizing multiple neural elements) as additional neural linkages have been identified.

Brain research has led to an increasing level of understanding of neurotransmitters involved in pleasure. Dopamine is a key neurotransmitter in our pleasure systems. Quoting from Bozarth (1994):

Initial work suggested that a number of brain regions could produce rewarding effects, but many of these seemingly diverse stimulation sites were quickly linked through a common neural pathway—the medial forebrain bundle (Olds, 1977). Although it is true that activation of other brain systems can produce rewarding effects, activation of the medial forebrain bundle as it courses through the lateral hypothalamus to the ventral tegmentum produces the most robust rewarding effects. And several neurotransmitters may be involved in the rewarding effects from various electrode placements, but dopamine appears to be the neurotransmitter essential for reward from activation of the medial forebrain bundle system (see Fibiger & Phillips, 1979; Wise, 1978).

## Curiosity

Curiosity is an innate characteristic of humans. It is a drive to know why, to understand, to explore. It can be thought of as a type of intrinsic motivation. Quoting from an ERIC Digest (Arnone, 2003):

When students are magnetized by a new idea or a new situation and are compelled to explore further, regardless of external rewards, they can be said to be truly motivated. In each new project, they discover seeds for a future project or a new question to examine. Curiosity is a heightened state of interest resulting in exploration, and its importance in motivating scholarship cannot be ignored. Curiosity is also a critical component of creativity, and fostering curiosity and creativity in today's learners is a challenge faced by educators and instructional designers alike.

If you have ever been around preschool children, you know that “why” is a key part of their vocabulary. Some people feel that schools tend to stifle the “why” in many children.

### Three “Happy Messenger” Neurotransmitters

Game playing and many other types of activities can affect the pleasure centers of your brain. In addition, many different drugs affect the pleasure centers. Steve Burns (n.d.) provides an excellent introduction to these aspects of how the brain functions. The Website is based on his book, *How to Survive Unbearable Stress*. The following is assembled tidbits quoted from the Website give a flavor of some of its content and readability level:

There are three Happy Messengers: Serotonin, Noradrenalin, and Dopamine. These are the brain chemicals that begin to malfunction when stress levels become more than a person can handle.

#### Serotonin

The Happy Messenger, Serotonin, must work properly in order for you to sleep well. Serotonin is responsible for making sure that your body's physiology is set for sleeping. If Serotonin does not do its job properly, you will not be able to obtain a restful sleep, no matter how hard you try.

#### Noradrenalin

I am sure you have all heard of "Adrenalin". When you are frightened, Adrenalin is released into your blood stream by your adrenal glands. Your heart beats faster, blood flow is shunted away from your skin and intestines and towards your muscles. Perspiration appears on your palms and forehead. You are ready for "fight or flight". A cousin of Adrenalin, named Noradrenalin is one of the Happy Messengers. Noradrenalin has many important functions in the body's nervous system. The one that most concerns us here, however, is the role of Noradrenalin in setting your energy levels. Proper functioning of Noradrenalin in the brain is essential for you to feel energized. Without enough brain Noradrenalin you feel exhausted, tired, droopy and without energy. You just don't feel like doing anything. You just want to sit.

#### Dopamine: Your Pleasure and Your Pain

Dopamine, seems to be concentrated in areas of the brain immediately adjacent to where the major Endorphin releasing mechanisms lie. When Dopamine function declines, Endorphin function also declines. Hence, when too much stress causes failure of Dopamine function, it also causes loss of your body's natural "pain killer".

Dopamine also runs your body's "Pleasure Center". This is the area of your brain that allows you to enjoy life. When stress interferes with your Dopamine function, the Pleasure Center becomes inoperative. Normally pleasurable activities no longer give any pleasure. With severe Dopamine/Endorphin malfunction, life becomes painful and devoid of any pleasure.

## Chapter 6

### Me: A Course of Study

#### Me—A Course of Study.

This chapter explores the idea that one of the goals of education should be for students individually and collectively to learn about themselves. While the focus is on TAG students, the ideas are applicable for all students.

The title for this chapter is a take off from the title *Man: A Course of Study* (MACOS), which was a highly successful set of curriculum materials developed during the 1960s. Many of the ideas in this chapter come from MACOS and have been modified to fit the focus of this book on computers and TAG education.

*Man: A Course of Study*, was a curriculum project stressing a cross-cultural view of human behavior. It was designed for middle school and upper elementary grades. At its peak, it was being used in about 1,700 schools in 47 states in the United States. Quoting from a history of Educational Development Corporation (EDC, n.d.):

1962-1975. *Man: a Course of Study(MACOS)* produces films, simulations, and booklets for the study of human behavior by elementary and middle school students. The award-winning curriculum is widely used in the U.S. and wins the American Educational Publishers Institute award, an American Film Festival award, two CINE Golden Eagle awards, and an Emmy Award (1971). *Funders: National Science Foundation and Ford Foundation*

The organizing questions of MACOS were:

- What makes human beings human?
- How did they get that way?
- How can they become more so?

The design and development of the course assumed:

1. As students increase their awareness of their own culture, they also experience an increased self-confidence and comprehension of their operating assumptions about life.
2. Learning is largely a social process by which children and teachers articulate and share ideas with one another.
3. The world can be observed, conjectured about, ordered, and understood using the modes of inquiry of the biological and social sciences.
4. An individual life can be viewed as part of the larger flow of human existence within a given environment.

## Some Ideas for This Chapter

TAG kids often become obsessed with something, such as dinosaurs, trains, action figures, etc. Within a particular area of obsession they can become far more knowledgeable than the other students and adults in their lives. This fits in with the idea of carving out a narrow domain and becoming highly knowledgeable within the domain. But, think about dinosaurs from an adult researcher in this field, versus a child's knowledge. Research in this field typically cuts across several relatively deep areas of science, and it may involve fieldwork and lots of experience. Thus, the nature of a child's knowledge is different than that of an expert in the field. From an adult point of view, the goal may be to advance the field, to generate and test theories, to contribute to our knowledge and understanding. That is probably quite different than a child's goals.

In a number of situations, some computer tools can be learned relatively quickly to a level that gives the child capabilities to do things that many adults cannot do. We see this in computer graphics (animation), music (composition and performance), and ... Hmmm. How about an extended list of such examples?

The young person lacks the years of experience of the older person. But, some of this experience can be gained through appropriate use of media. Thus, we need examples where useful levels of experience can be gained much more quickly through this use of media.

Acceleration. Evidently acceleration and enrichment are the two main approaches to TAG education. Quoting from <http://www.nagc.org/>:

NAGC is pleased to endorse a new report, released on September 20, entitled A Nation Deceived: How Schools Hold Back America's Brightest Students.

The report, also known as the Templeton Report, was developed by the Belin-Blank Center at the University of Iowa and is co-authored by Drs. Nicholas Colangelo, Susan Assouline, and Miraca Gross. It compiles the decades-long evidence that supports acceleration in its many forms as a successful strategy for high-ability youth. Unfortunately, in spite of the evidence, schools often reject acceleration as an intervention to support excellence.

We encourage gifted education advocates to use the report with the media, elected officials, school leaders, and the public in support of the needs of high-ability students. Click here for NAGC's news release on the report.

The full report may be downloaded from <http://nationdeceived.org>. Bound copies of the report will be available in early October and may be ordered from the nation deceived website. NAGC annual convention attendees will receive a copy of the bound report in Salt Lake City in November.

## Learning On Your Own

<http://www.webmd.com/>

Perhaps some discussion of self-assessment goes in here.

## Key Ideas on Possible Areas Where One Can Excel

You are probably aware of prodigies who accomplished truly amazing things when they were relatively young. Mozart and composition of music is a good example. As I think about this, I see sort of two levels of judgment of quality of such work:

1. The work is truly outstanding compared to what others of this age are able to do at that age. The comparison may be worldwide, and over time. Thus, perhaps few people in the world and in the time of recorded history have done what

Mozart did at age eight. But his compositions were not nearly as good as he did later as he got older, or as older people did at the time Mozart was eight.

Nationwide or world wide, contemporary.

Compared to others currently and in recorded history. Note that this tends to preclude head to head competition, How do you compare the work or performance of a person who is 14 years old now, to the work of a person who was 14 years old a hundred years ago?

2. 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.

Now, add to the above the general idea that it tends to take 10 years of more of experience and hard work in an area for a person to achieve somewhat close to their potential in the area. With this in mind, we can begin to divide areas into broad and narrow. For example, gymnastics would be considered to be a narrow area. Chess is a narrow area. Math is a narrow area. Philosophy is a broad area. [I need to think more about broad versus narrow. The idea is that if the area is narrow enough, a person can move to world class in a more limited amount of time. In gymnastics, there is the added issue of physical development of the body. Hmmm. The brain does not reach full maturity until one is in their 20s. So, what areas require full mental maturity for a high level of expertise?]

In any case, I am looking for examples in which a person can excel at a very high level through their talent and a “reasonable” amount of time and effort. The competition can be quite local, but how about citywide, county or statewide, nationwide, internationally?

The lack of overall life experience of a young person is not a detriment if the domain of problems/tasks is narrow enough. Of course, keep in mind the physical and/or mental maturity that is needed. If the competition is mainly in the physical area, we are quite aware of what it takes to become world class while still a teenager.

Thus, I am looking for areas that are cognitive, dependent on mental prowess. There, by and large, the completion needs to be with others in the same age range, since people continue to grow in mental prowess well into adulthood. The information about great scientists (age 30), and so on is relevant. I wonder whether this holds in other areas such as art, music, and so on. I suspect that it takes still more years to achieve one’s potential in such field.

[Aside. As I paused here, I thought about learning foreign languages. People growing up in Luxemburg become trilingual or 4-lingual. This is no big deal—it comes with growing up in that environment. People who start on languages later are already handicapped by the paring of neurons that goes on in the brain. They , in essence, cannot hear some of the phonemes in the various languages they may want to learn. Also, here we have a specific area corresponding to Howard Gardner’s thoughts on multiple intelligences. Clearly people vary in their linguistic intelligence. Note, however, that essentially all people have a high level of linguistic intelligence relative to other animals on earth. We need to think about how the ability to make a wide range of sounds and to hear and process a wide range of sounds is a key part of linguistic learning and performance.]

So, I am looking for examples of disciplines or domains or areas in which a person can excel intellectually at a very high level relative to his age group, and the level of performance must be impressive to most older people. However, the level of performance need not exceed that of

older experts within the domain. One key to this is some form of measurement of accomplishment that allows of comparison.

The Robot kit-building and programming falls into the category of being a good example, Stuff that my daughter Beth is doing with high school students is a good source on this. See: <http://robotics.nasa.gov/first/2005/kickoff.htm> as well as her email at the end of this document.

### **Activities and Discussion Topics for Teachers**

- 1.

### **Activities and Projects for TAG Students**

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