Technology and Problem Solving:
PreK-12 Education for Adult Life, Careers, and Further Education

David Moursund
Professor Emeritus
College of Education
University of Oregon
Eugene, Oregon

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I welcome comments and suggestions. Please send them to moursund@uorgon.edu.


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Email: David Moursund at moursund@uorgon.edu.
# Table of Contents

**Front Matter** .................................................................................................................. 5  
  Author................................................................................................................................. 5  
  Information Age Education ................................................................................................. 5  
  Acknowledgements ............................................................................................................ 5  

**Chapter 1: Introduction** ............................................................................................... 6  
  Goals of Education ........................................................................................................... 7  
  Folk Computing ................................................................................................................ 8  
  Technology and Problem Solving: Some Background Information ......................... 9  
    Definition of a Problem .................................................................................................. 9  
    Problem Solving ............................................................................................................ 10  
  Final Remarks ................................................................................................................... 11  
  What You Can Do ............................................................................................................ 12  
    For All Readers Concerned about PreK-12 Education ............................................. 12  
    For Teachers of Preservice and Inservice Teachers .................................................. 12  

**Chapter 2: Robots Are Here and Lots More Are Coming** ........................................ 14  
  Some Roles of Artificial Intelligence ............................................................................. 15  
  Educational Implications ................................................................................................. 16  
  Final Remarks ................................................................................................................ 17  
  What You Can Do ............................................................................................................ 17  
    For All Readers Concerned about PreK-12 Education ............................................. 17  
    For Teachers of Preservice and Inservice Teachers .................................................. 18  

**Chapter 3: Introduction to the Future of Teaching Machines** .................................... 19  
  Isaac Asimov’s Vision of a Teaching Machine ............................................................... 19  
  Historical Background .................................................................................................... 20  
  My “Near Future” Teaching Machine ........................................................................... 20  
  Final Remarks ................................................................................................................ 22  
  What You Can Do ............................................................................................................ 23  
    For All Readers Concerned about PreK-12 Education ............................................. 23  
    For Teachers of Preservice and Inservice Teachers .................................................. 23  

**Chapter 4: The Teaching Machine Is Both Tool and Teacher** .................................... 24  
  The Medium Is the Message .......................................................................................... 24  
  Computer as a Medium .................................................................................................. 24  
  A Story about a 17-Year-Old ......................................................................................... 25
Improving Education is (Still) Part of the Answer..........................44

Appendix A: Some General Goals of Education ......................... 45
  Conserving Goals ...........................................................................45
  Achieving Goals .............................................................................46
  Accountability Goals .....................................................................48

References .............................................................................................49

Suggested IAE Readings .................................................................... 52
Front Matter

Author

David Moursund is an Emeritus Professor of Education at the University of Oregon. His professional career includes founding the International Society for Technology in Education (ISTE) in 1979, serving as ISTE’s executive officer for 19 years, and establishing ISTE’s flagship publication, *Learning and Leading with Technology*. He was the major professor or co-major professor for 82 doctoral students. He has presented hundreds of professional talks and workshops. He has authored or coauthored more than 60 academic books and hundreds of articles. Many of these books are available free online. See [http://iaepedia.org/David_Moursund_Books](http://iaepedia.org/David_Moursund_Books).

Email: moursund@uoregon.edu.

Information Age Education

Information Age Education (IAE) is an Oregon non-profit corporation founded by David Moursund in July, 2007. It works to improve the informal and formal education of people of all ages throughout the world. A number of people have contributed their time and expertise in developing the materials that are made available free in the various IAE publications.

IAE provides free online educational materials via its *IAE-pedia, IAE Newsletter, IAE Blog,* and books. See [http://iaepedia.org/Main_Page#IAE_in_a_Nutshell](http://iaepedia.org/Main_Page#IAE_in_a_Nutshell). For free access to the full collection of IAE publications, go to [http://iae-pedia.org/Main_Page](http://iae-pedia.org/Main_Page).

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Chapter 1: Introduction

“Try to learn something about everything and everything about something.” (Thomas H. Huxley; English writer; 1825-1895.)

“Each problem that I solved became a rule which served afterwards to solve other problems.” (René Descartes; French philosopher, mathematician, scientist, and writer; 1596-1650.)

“There is always an easy solution to every human problem—neat, plausible, and wrong.” (Henry Louis “H.L.” Mencken; American journalist, essayist, editor; 1880-1956.)

The goal of this short book is to help improve the education of precollege students throughout the world. It is written specifically for PreK-12 preservice and inservice teachers, and the teachers of such teachers. Other potential audiences include parents, school administrators, school board members, political leaders, and business leaders.

It is the basic nature of a healthy human brain to recognize and try to solve personal, societal, and other problems. We are intrinsically curious and motivated to do these things. Success or perceived success in dealing with problems is often communicated to others. Building on the previous credible and valid work of others is perhaps the most important concept in problem solving (Sylwester, October, 2014).

The development of reading and writing provided us with a dual-purpose tool. Reading and writing:

- Extend the capability of our brains;
- Allow us to preserve and pass on our steadily accumulating credible and valid knowledge and skill in understanding, representing, and solving a wide range of problems. (See the quote from René Descartes given above.)

The widespread use of reading and writing required the development of formal schools, as it takes several years of instruction and practice to develop a rudimentary level of reading and writing skills. The number of years it takes varies with the specific oral language that students are building on. Reading and writing in a phonetic, alphabet-based language such as Spanish is easier to learn than is a non-phonetic, character-based language such as Chinese.

Now we have computers. Computer technology provides us with tools that:

- Build on and extend reading, writing, and our other methods of communication. The Web is a humongous library used to make much of the accumulated knowledge of the human race available to educated people. The Internet and the Web together allow us to communicate routinely in ways that were undreamed of less than a hundred years ago.
- Are changing the content of our educational systems at all levels. Computers are an aid to representing and solving problems in every discipline of study.
- Are changing pedagogy and assessment in every discipline of study. Computers are an aid to making progress in solving the pedagogy and assessment problems of education.
The remainder of this book explores various aspects of computer technology, both as a content area in education and as an aid to teaching and learning. We begin with a brief introduction to goals of education.

**Goals of Education**

There are many possible goals in an educational system. At the current time in the U.S., the federal emphasis is on students graduating from high school and being [college and/or career ready](#).

College and career ready is a short, catchy phrase. However, it fails to capture the scope of the many other goals that people believe should help guide our schools. Adult life encompasses much more than higher education and careers. Think about aspects of education that prepare a person to be a responsible adult, a good parent, a contributing member of society, a person who understands and helps to solve global problems, and so on.

We need to think carefully about our current goals of education and how well we are achieving them. How well are these goals standing up over time? Should changes in technology and other changes in our world be leading us to significant revisions of these goals?

Some countries have educational goals set at a national level, and they expect that local school curricula will teach to these goals. The U.S. does not have such a top-down approach to education. However, the individual states, school districts, and schools tend to have many goals in common. For example, they all want students to achieve basic knowledge and skills in reading, writing, and arithmetic. Recent “Common Core” movements are aimed at achieving more uniform content and assessment in some of the core disciplines, but individual states continue to have considerable control (Moursund & Sylwester, March, 2013.)

**What to Learn?**

Please reread and think about the quote from Thomas H. Huxley given above. Our educational system faces the challenge of extremely rapid growth in the totality of human knowledge. At the current time, there are about [¼ of a million](#) new medical journal articles published each year. No human can keep up in the full area of medicine. So, medicine is divided into a number of narrower specialties. Later in this document we will briefly discuss use of artificially intelligent computer systems that can help us to “keep up” with this huge deluge of publications. A human brain and computer brain working together can often outperform either working alone.

It is clear that education must have as one of its major goals helping students learn to learn, to become a self-motivated lifelong learner, and to gain foundational knowledge that is a prerequisite to future learning. Intrinsic motivation, deep learning with understanding, higher-order thinking, and problem solving are very important parts of this foundation that every student needs.

At the precollege level, our educational system tries to provide students with breadth and also to lay some foundations for further in-depth studies. Appendix A lists 14 general goals for education in the U.S. that I have used for many years in my teacher education courses and workshops. These goals are divided into three categories: Conserving Goals, Achieving Goals, and Accountability Goals. The Achieving Goals category includes both a broad general education (including reading, writing, and arithmetic) and [problem solving](#). In each discipline that students study, we want them to gain higher-order knowledge, skills, and understanding. We
want them to make progress in learning to effectively deal with both routine (basic) problems and also non-routine (novel) problems that help to define the various disciplines they study.

**Learning about Computers and Computer Technology**

The first commercially available computers became available in the early 1950s. The year 1956 is generally acknowledged as the year in which the U.S. moved from being in the Industrial Age to being in the *Information Age*. In 1956, the number of white collar jobs first exceeded the number of blue collar jobs. The number of industrial manufacturing jobs was in rapid decline.

The academic discipline of Computer Science—now more frequently called Computer and Information Science (CIS)—has developed and grown rapidly during the Information Age.

In higher education, CIS is a well-established discipline of study. However, this is not the case at the precollege levels. The emphasis on teaching computer programming and computer science has waxed and waned over the years. Instruction in “computer literacy”—with an emphasis on learning to use computer applications such as word processing, spreadsheet, and graphics software—has also waxed and waned. Thus, there are no uniform expectations of CIS knowledge and skills for students graduating from high school or entering college in the U.S.

The net result is that by the time students complete their precollege education, there is little uniformity in their knowledge and skills with CIS and computer applications. This situation is troubling both to potential employers and to faculty in post secondary education.

**Folk Computing**

However, there is a major exception to this observation. Outside of school, students are developing considerable skill in using a Smartphone, in playing computer games, in using digital photography, in building and using a music playlist, in online communication, in social networking, and so on.

I call these aspects of computer use “Folk Computing” and discuss them in a recent *IAE Newsletter* (Moursund, January, 2015). Here is an excerpt from that newsletter:

"If you want to teach people a new way of thinking, don't bother trying to teach them. Instead give them a tool, the use of which will lead to new ways of thinking." (Richard Buckminster Fuller; American engineer, author, designer, inventor, and futurist; 1895-1983.)

You have heard about folk dancing and folk music. But, how about folk computing and folk mathing? They may seem to you as long-stretch analogies in the use of the term “folk.” However, these analogies offer interesting insights into an important part of the future of education. This IAE newsletter provides a brief introduction to the long-established discipline of folk math (often called street math) and uses this as a springboard into a discussion of folk computing.

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Folk computing learning styles are somewhat like those used by children of earlier generations in learning folk music and folk dance by observation and imitation. However, children learning folk computing have an added advantage—computers can be used in a self-study, self-play, anytime, anywhere mode, and they provide nearly instant feedback. For example, think about a child learning to take pictures using a digital camera, a quite sophisticated computerized device. The cost of this fun, learn-by-doing activity may be
only a few instructions from a relative or friend followed by a period of trial-and-error and feedback from self and others.

I am amazed by the skills that children can develop through playing with computers. The software they are playing with might be a game. But it might also be a creative art environment, a building block environment, a word-processing environment, an information retrieval environment such as the Web, a music creation and/or editing environment, and so on. Computer apps provide children of all ages with fun, interesting, challenging opportunities to do things, receive feedback, and make changes to better achieve whatever they are trying to accomplish.

Folk computing has added a new dimension to informal and formal education. A number of research and development projects are developing computer games and simulations designed to help teach the traditional curriculum content in our schools.

**Technology and Problem Solving: Some Background Information**

The term “technology” is sometimes taken to refer only to “modern” technology or even just to computer technology. However, it has a much broader meaning. Quoting from the [Wikipedia](https://en.wikipedia.org): Technology is the making, modification, usage, and knowledge of tools, machines, techniques, crafts, systems, and methods of organization, to solve a problem, improve an existing solution to a problem, achieve a goal, handle an applied input/output relation or perform a specific function.

This book focuses mainly on uses of Information and Communication Technology (ICT) as an aid to representing and solving problems. We are now well into the [Information Age](https://en.wikipedia.org/wiki/Information_Age), and ICT is facilitating major changes in our world.

The titles CIS (Computer and Information Science) and ICT (Information and Communication technology) sound similar and can be confusing. Computer and Information Science is rooted in math, physics, and engineering. Students of CIS study the underlying theory and practice of the development and use of computer hardware and software. This includes studying the types of problems occurring in areas such as the design of computer hardware, computer programming and the development of programming languages, artificial intelligence, computer graphics, telecommunications, and the storage and processing of huge amounts of data.

Information and Communication Technology (ICT) is used to describe applications of computers as an aid to representing and solving problems in all areas of human intellectual endeavor. As described in Folk Computing above, quite young children learn to make use of computer games and Smartphones well before they learn any of the underlying theory studied by students of Computer and Information Science. Obviously, there is an overlap between ICT and CIS. A six-year-old learning a graphics-oriented programming language is, in some sense, learning to play a very interesting game (using a computer to do animation) and at the same time is learning basic principles of computer programming, such as telling a computer what to do and debugging errors in the instructions.

**Definition of a Problem**

Each academic discipline or area of study can be defined by a combination of:

- The types of problems, tasks, and activities it addresses.
Technology and Problem Solving in PreK-12 Education

- 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, and language, including notation and special vocabulary.
- Its methods of teaching, learning, assessment, and thinking. What it does to preserve and sustain its work and pass it on to future generations.
- Its tools, methodologies, and types of evidence and arguments used in solving problems, accomplishing tasks, and recording and sharing accumulated results.
- The knowledge and skills that separate and distinguish among: a) a novice; b) a person who has a personally useful level of competence; c) a reasonably competent person, employable in the discipline; d) an expert; and e) a world-class expert.

Many problems are interdisciplinary. This set of bulleted items helps to unify the various disciplines that students study in school. In addition, it provides a foundation to build on in any particular discipline of study. If you are actively engaged as a teacher in a particular discipline, you can use this list to help access whether your students are getting a good “grasp” of the discipline. You can also use the list in a classroom compare and contrast activity between any two disciplines your students have studied.

There is an extensive literature on problems and problem solving. The following definition has served me well for any years:

You (personally) have a problem if the following four conditions are satisfied:

1. Initial situation. You have a clearly defined given initial situation.
2. Goal. 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. Resources. 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. These typically include some of your time, knowledge, and skills. Resources might include money, the Web, the telecommunication system, computers, friends, teachers, and so on. There may be specified limitations on resources, such as rules, regulations, guidelines, and time lines for what you are allowed to do in attempting to solve a particular problem.
4. Ownership. You have some ownership—you are committed to using some of your own resources, such as your knowledge, skills, time, energy, and (perhaps) money to achieve the desired final goal.

Problem Solving

My Google search on the expression problem solving produced more than 60 million hits. Problem solving includes exploring and attempting to resolve:

- Question situations: recognizing, posing, clarifying, and answering questions.
- Problem situations: recognizing, posing, clarifying, and solving problems.
- Task situations: recognizing, posing, clarifying, and accomplishing tasks.
• **Decision situations:** recognizing, posing, clarifying, and making good decisions.

• **Using higher-order critical, creative, wise, and foresightful thinking** to do all of the above. Often the results are shared, demonstrated, or used as a product, performance, or presentation.

In many problem-solving situations, Information and Communication Technology (ICT) and computerized tools are resources of the type mentioned in the **resources** part of defining a problem. These resources have grown more powerful over the years. That is one reason why it is so important to thoroughly integrate teaching the use of computers in problem solving into the basic fabric of academic courses.

The “ownership” part of the definition of a problem is particularly important. Unless you have ownership—through an appropriate combination of intrinsic and extrinsic motivation—you do not have a problem. So, you are unlikely to have intrinsic motivation to spend your time, energy, and other resources in an attempt to solve the problem.

For example, you glance at the headlines in your local newspaper and see that a drought in a particular country in Africa is causing widespread hunger. Hundreds of thousands of people are on the verge of starvation. This hunger and starvation situation meets the first three components of the definition of a problem. Moreover, the story touches your heart. But what—if anything—can or will you do about it? It is one thing for a problem situation to touch your heart. It is another situation entirely for you to make a decision to commit some of your resources such as time and money to do something about helping to solve the problem.

Now, think about the types of "problems" that we assign students in school. Many students look at the tasks assigned as homework and mentally respond, "I couldn't care less. These are just make-work busy work—a hoop that I am supposed to jump through." That is, these students have no ownership.

A good teacher creates learning situations in which students are willingly engaged in working on problems and tasks that they feel are personally relevant and important. There is an extensive literature on empowering students. My Google search of **empowering students** produced more than 3 million hits. See, for example, Adora’s article Five Ways to Empower Students (Svitak, 2/28/2012).

**Final Remarks**

(\*Note: Each major chapter of this book ends with a Final Remarks section and a What You Can Do section. The Final Remarks provide a very brief summary of key ideas, while What You Can Do offers some guidance to preservice and inservice teachers, and to teachers of teachers.\*)

Each tool that humans develop has some effect on education. Some tools—such as reading and writing—are so important that they lead to major changes in education. Computer technology falls into this category.

Computer and Information Science (CIS) is an important discipline of study, but by itself it is not a major game changer in terms of the curriculum content that our educational system wants and expects children to learn.

However, **ICT** is a game changer in education for three major reasons:
• It provides us with aids to problem solving in every discipline. Thus, it affects the content of each discipline of study.

• It provides new aids to learning the various disciplines. Folk computing provides numerous examples in which computer learning and computer use is so intrinsically motivating that children (and adults) learn it without the benefit of formal schooling.

• It is changing what it means to be ready for adult life, career, and college.

Later chapters in this IAE-pedia document focus on computer aids to learning (teaching machines), computer aids to problem solving (including robots and artificial intelligence), and the combination of these two areas.

What You Can Do

Please don’t just be a passive reader. Take what you are learning, share it with others, and use it!

For All Readers Concerned about PreK-12 Education

This document is intended for all people who are concerned about the education of PreK-12 students. I, personally, view every person as a lifelong learner and a lifelong teacher. Every interaction you have with another person is both a teaching and a learning experience.

As you learn more about how ICT is changing our world and our children’s educational needs, and the contributions that ICT can make to the content, pedagogy, and assessment components of schooling, you can help others learn about these topics. Specifically, think about what you can do to help others learn and understand what you are learning and understanding. Become an advocate for improving our educational system so that it better meets the current and future needs of our children.

For Teachers of Preservice and Inservice Teachers

Your goal is to help preservice and inservice teachers to gain the ICT and CIS knowledge and skills that are relevant to improving our current educational system and guiding it on into a better future. This is a huge task, and quite likely the amount of instructional time you have in working with any group of students is very limited.

The following discussion is specifically aimed at inservice staff development, but with minor tweaks it also applies to preservice education. There are four major stakeholder groups in staff development:

1. A person having a combination of staff development and budgeting authority who decides to improve education via staff development in the area of computers in education.

2. The person or group who will do the staff development.

3. The inservice teachers and school administrators who will participate in the staff development.

4. The students who will be served by the teachers and school administrators who participate in the staff development.

Perhaps you can immediately see a major difficulty. How does one align the needs of the four stakeholder groups so that each is satisfied by the whole operation, and so that the quality of education being received by students improves in a manner that satisfies all four stakeholder
groups? And, if this is not complex enough, you can add other stakeholder groups such as parents, taxpayers, business people, politicians, and so on. I find it hard to imagine a staff development activity that would satisfy such a range of stakeholders.

So, let’s just deal with the reality that you are going to do some staff development, and you have a variety of participants. How might you get started?

After the usual introductions, and a few very brief goals statements, I like to get some input from the participants. What personal educational problem or task do they hope will be addressed, and how do they expect to make use of what they learn? Ask participants to share in a group of two or three what they want to be able to know and do (that they do not already know or can do) as a consequence of participating in the workshop.

You can wander around and eavesdrop on the conversations to get a general feeling for what participants know, what they expect to learn, and how they will use their new knowledge and skills. After a few minutes in which every participant is expected to “speak their piece,” you can call on volunteers to repeat a few ideas you heard and/or to speak for their group. You can supplement what they say with your own interpretations of what they are saying, and your own ideas of what you will cover and how it fits in with the participants’ needs.

Follow this activity with one in which groups of two or three discuss how the quality of education students are receiving will be improved by the staff development. As the workshop proceeds, each participant should hold in mind that they are expected to make classroom, department, and school-wide use of what they are learning. Indeed, you might have each participant write a very brief memo to themselves about this, and to refer to it from time to time during the inservice. Remind participants that it is perfectly all right to make changes to this memo as the inservice proceeds.

Let me conclude this section with an example of something that each teacher-participant can do. (School administrators can make up their own version of this activity.) Remember, the focus is on staff development for the use of computer technology to improve the quality of education students are receiving. Each teacher can explore with their students what they already know about computers, how students are using this knowledge outside of school, how they are using it in school, and what would need to happen for them to make more effective, relevant, informal and formal educational use of computer technology. This activity can be done in a class using small group and whole class discussion, writing, and so on. The goal is have all students participate so that you and the whole class get feedback on what others know and would like to have happen.

Teachers can follow up in subsequent days of “normal” classroom teaching by exploring the roles of current technology that is available to individual students, to the whole class, and to the school—and that is applicable to whatever disciplines the teachers are teaching.
Chapter 2: Robots Are Here and Lots More Are Coming

“In the twenty-first century, the robot will take the place which slave labor occupied in ancient civilization.” (Nikola Tesla; Serbian/American engineer and inventor; 1856-1943.)

“Nothing could be more absurd than an experiment in which computers are placed in a classroom where nothing else is changed.” (Seymour Papert; South African/American mathematician, computer scientist, and educator; 1928-.)

While the history of robots goes back much farther than Isaac Asimov (1920-1992), his science fictions writing certainly popularized this subject. Here are his four laws of robotics:

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

The first, second, and third laws were written well before the “zeroth law” was added, and they are certainly the best known. The (possibly coming) Technological Singularity when robotic intelligence and capabilities far surpass those of humans and could potentially harm humans, led to the zeroth law.

We are now about 60 years into the Information Age. Our technological progress has been amazing. But, “You ain’t see nothing yet.” This chapter is about now and the future. It is a slight modification and expansion of an earlier IAE Blog entry (Moursund, 2/11/2015).

We all know about outsourcing jobs to countries that have low labor costs. Perhaps we are less concerned about another type of outsourcing when industrial robots in our country and in many other countries take over jobs formerly performed by humans. This second type of “outsourcing” is decreasing the number of industrial manufacturing jobs performed by humans in the United States—a large and rapidly growing change.

A recent report from The Boston Consulting Group provides current information and projections for the next ten years (BCG, 2/10/2015). Quoting from the reference:

The use of advanced industrial robots is nearing the point of takeoff, a development that could power a new wave of productivity growth in many industries and lead to changes of up to 5 percentage points in the cost competitiveness of major export economies relative to the U.S., according to new research by The Boston Consulting Group (BCG).

The BCG study projects that investment in industrial robots will accelerate markedly over the next decade, from annual growth that now averages 2 to 3 percent to around 10 percent. As a result, the total cost of manufacturing labor in 2025 could be 16 percent
lower, on average, in the world’s 25 largest goods-exporting nations than they would be otherwise. Depending on the industry and country, output per worker could rise by an estimated 10 to 30 percent over and above productivity gains that typically come from other measures.

I find the second paragraph particularly interesting. What does “the total cost of manufacturing labor in 2025 could be 16 percent lower, on average” mean to people working in industrial manufacturing? Here is another quote from the BCG article:

The inflection point for widespread robotics adoption will vary by industry and country, depending on factors such as wages, productivity, labor regulations, and the ease with which tasks can be automated. BCG estimates that manufacturers begin to ramp up investment in robotics when the costs of owning and operating a system reach a 15 percent discount over the cost of employing a worker. In industries such as automotive manufacturing in the U.S., where it costs around $8 an hour to use a robot for spot welding compared with $25 for a worker, that point has already arrived—and the cost gap will widen considerably in favor of robots. Similarly, in U.S. electronics manufacturing, it costs around $4 an hour to use a UR5 robot for a routine assembly task compared with $24 for an average worker. [Bold added for emphasis.]

You need to realize that the use of robots in industrial manufacturing is only part of the huge wave of change being brought on by Information and Communication Technology (ICT), and that this has been going on (and increasing) for many years. I am reminded of this every time I try to use my telephone to get some help from a company, and I first have to communicate with a computerized telephone answering system. I am reminded of this when I go shopping, and see the high level of ICT used in the check-out process. I am reminded of this when I make an online purchase. I still think of it as a modern miracle when I can purchase a “special sale” online book for $.99 and have it delivered to my tablet computer in a few seconds. No human worker is involved in this process.

Finally, think about how ATM machines have affected employment in the banking industry. This is an example of training people so that the customer and the machine together can do what an employee did in the past.

**Some Roles of Artificial Intelligence**

Artificial Intelligence (AI) has a long and somewhat rocky history. Early on, people thought of computers as giant brains and were quite optimistic that AI would bring us very smart computers and robots. I remember when I was studying French and German for my doctorate in mathematics. Doctoral students at the University of Wisconsin had to demonstrate reading ability in two foreign languages. I knew enough about computers at that time—and I knew about large funding coming from the U.S. Central Intelligence Agency to develop language translation software—that I was convinced that I was wasting my time. Now, 50 years later, reasonably good computer translation of natural languages is here. Indeed, systems that take voice input in one language and produce voice output in another language are now at a useful level.

The fact that all of this took about 50 years of research and development indicates how difficult some of the AI problems are.

At the current time, AI is making astonishing progress in “deep learning.” Roughly speaking, this is the use of computers that can learn to learn. I strongly recommend the *TED Talk* by
Jeremy Howard, The Wonderful and Terrifying Implications of Computers That Can Learn (Howard, December, 2014). Working alone or in conjunction with human experts in an area, computers are learning how to solve some quite difficult problems that humans have not yet learned to solve. The video gives a number of examples and argues that this area of AI is improving at an exponential rate.

Quoting from Howard’s presentation:

Perhaps the first big success of machine learning commercially was Google. Google showed that it is possible to find information by using a computer algorithm, and this algorithm is based on machine learning. Since that time, there have been many commercial successes of machine learning. Companies like Amazon and Netflix use machine learning to suggest products that you might like to buy, movies that you might like to watch. Sometimes, it's almost creepy. Companies like LinkedIn and Facebook sometimes will tell you about who your friends might be and you have no idea how it did it, and this is because it's using the power of machine learning. These are algorithms that have learned how to do this from data rather than being programmed by hand.

This is also how IBM was successful in getting Watson to beat the two world champions at "Jeopardy," answering incredibly subtle and complex questions.

IBM is now experiencing considerable success in using the Watson computer and machine learning to develop medical diagnosis software and programs that help to solve a number of other complex problems.

**Educational Implications**

As discussed above, the number of middle class jobs has been declining in the U.S. and other industrialized countries for many years. Quoting from the article, Job Polarisation and the Decline of Middle-class Workers’ Wages (Boehm, 2/8/2014):

The decline of the middle class has come to the forefront of debate in the US and Europe in recent years. This decline has two important components in the labour market. First, the number of well-paid middle-skill jobs in manufacturing and clerical occupations has decreased substantially since the mid-1980s. Second, the relative earnings for workers around the median of the wage distribution dropped over the same period, leaving them with hardly any real wage gains in nearly 30 years.

The major growth in jobs has been at the lower pay levels—there are still lots of jobs that require only a modest amount of education and offer only a modest amount of pay. For example, you might want to analyze the requirements for a high school diploma versus the skills needed to be a clerk in a fast food outlet.

Employers also have job openings at a much higher level—jobs that require good problem-solving skills and good abilities to make use of modern technology to aid in solving problems and accomplishing tasks. Indeed, employers complain about a shortage of qualified job applicants at this level, and this is one indication that our educational system is not doing nearly as well as it should.

My advice to the students I talk with can be summarized by:
• Develop your “people” and communication skills. Become fluent in face-to-face, written, and computer communication skills. If you have the opportunities to do so, become bilingual and bicultural. Learn to “think globally and act locally.”

• Focus your education on gaining higher-order, creative thinking, understanding, and problem-solving knowledge and skills in whatever areas you decide to study.

• Learn about current and near-term capabilities and limitations of computers and robots. Plan your education and develop your abilities so that you do not end up in head-to-head competition with computers and robots in areas that they are already quite good at and are getting better.

• Make very sure that you learn to make effective and fluent use of ICT, both in general use and in the discipline areas you choose to study. Remember, the combination of a human brain and a computer brain can increasingly outperform either one working alone (Moursund, 2014).

• If you are “really into” computers, continue to develop your knowledge and skills in this area, but also work toward gaining a high level of expertise in one or more other career fields. This will help prepare you for many of the jobs currently held by people who are not keeping up with changes in ICT, and for new jobs requiring a combination of ICT and “traditional” knowledge and skills.

• Develop learning skills and habits of mind that will serve you throughout your lifetime.

• Think about what you want in your future. What informal and formal education do you need to help ensure that you will have a decent quality of life?

Final Remarks

Computers and computerized robots are becoming more and more capable. Such aids to solving problems and accomplishing tasks can be mass-produced. In an increasing number of job situations, such technology is more cost effective and reliable than human workers.

What this means is that the “same-old-same-old” approaches to education won’t cut it. We need to be preparing ourselves and our students to cope effectively with the changes that are occurring.

What You Can Do

Please don’t just be a passive reader. Take what you are learning, share it with others, and use it!

For All Readers Concerned about PreK-12 Education

Notice that my bulleted list of recommendations is applicable in all curriculum areas that a student is studying at the K-12 level (and above). The importance of ICT varies from discipline to discipline, and the impact of robots varies from discipline to discipline. However, I believe that all students need to understand the basic ideas in this short book, and that all teachers and parents have a responsibility to help students understand these ideas. Think about what you are contributing to this teaching/learning task—are you doing enough?
For Teachers of Preservice and Inservice Teachers

Technological progress is producing unprecedented changes in our world and the demands being placed on its people. My belief is that our educational system has never before faced complexities of the magnitude that it is now facing.

Both preservice and inservice teacher education need to take a leadership role in preparing teachers to provide students with a modern and future-looking education. Think about your current insights into the changes that are occurring in business, industry, communication, entertainment, research and development, and in other areas not specifically oriented toward schooling. You need knowledge and skills related to what technology is doing, and what it can do, if you are going to help prepare preservice and inservice teachers to implement needed changes in our schooling system. Are you ready, and are you doing your part?
Chapter 3: Introduction to the Future of Teaching Machines

“There must be an ‘industrial revolution’ in education, in which educational science and the ingenuity of educational technology combine to modernize the grossly inefficient and clumsy procedures of conventional education.” Quoted from the 1933 book, *Psychology and the New Education* (Sidney Pressey; American psychologist; 1888-1979).

“Historically, the elementary school has been totally labor-intensive. Tomorrow's elementary school will be heavily capital-intensive.” (Peter Drucker; Austrian writer and management consultant, and self-described social ecologist; 1909-2005.)

This chapter explores ways that teaching machines will change the role of teachers by enabling schools to provide increased student individualization. They will change the content that is taught, because computers are such a powerful aid to problem solving. They will serve as a vehicle to help implement research results that are being shown to improve education. This chapter is a slightly modified version of an earlier *IAE Newsletter* (Moursund, September, 2014a).

Written materials—along with knowledge and skills in reading and writing—were the first general purpose teaching machines. What a great technological breakthrough! Teach students the rudiments of reading and writing, and then provide them with books and writing implements. The book, as a teaching machine, could help students to gain a steadily increasing level of literacy and could also help them to gain knowledge and skills in any area that could be represented in written form. Moreover, writing is a powerful aid to the human brain in both communication and problem solving.

The rapid growth of Information and Communications Technology (ICT) over the past 60 years has made possible the development of teaching machines that include all of the capabilities of book-based reading-assisted instruction and writing-assisted problem solving and communication—and also to greatly extend these capabilities.

**Isaac Asimov’s Vision of a Teaching Machine**

Science fiction writers have long considered the possibility of teaching machines that were better than books. Isaac Asimov, one of the leading science fiction writers of the 20th century, addressed this topic in his essay, *The New Teachers*, in which each student has access to a teaching machine that includes access to a global library. Quoting from the 1976 essay:

> We can reasonably hope that the teaching machine will be sufficiently intricate and flexible to be capable of modifying its own program (that is, “learning”) as a result of the student’s input.

> In other words, the student will ask questions, answer questions, make statements, offer opinions, and from all of this, the machine will be able to gauge the student well enough to adjust the speed and intensity of its course of instruction and, what’s more, shift it in the direction of the student interest displayed.

…
All teaching machines would be plugged into [a] planetary library and each could then have at its disposal any book, periodical, document, recording, or videocassette encoded there (Asimov, 1976).

Our technological progress during the years since 1976 now allows us to build teaching machines that surpass Asimov’s fictional futuristic teaching machine.

**Historical Background**

Beginning in the late 1950s, the United States and Canada built an “early warning” system of radar and computers that could detect and report on missiles being launched over the North Pole toward their countries. Operators viewed a computerized TV display screen and could act on the data they were receiving. The same display screen could show simulated (previously recorded or computer-generated) data. So, system operators could be trained/educated using quite authentic simulations. This integration of a problem-solving tool with a teaching tool was a huge breakthrough in teaching machines.

In 1960, the first PLATO (Programmed Logic for Automatic Teaching Operations) system became operational on a computer at the University of Illinois. Like any well-conceived teaching machine project, PLATO’s capabilities grew over time as better hardware became available, as data was gathered from users, as research progress occurred in theories of teaching and learning, and as the content developers and programmers became more adept at their tasks.

One of great powers of teaching machines is that they can gather data as they interact with students. As Asimov forecast, this data can be used to individualize instruction. In addition, it can be used in research into the areas of teaching and learning.

The results of this research can be incorporated into the software of teaching machines. Compare this easy upgrade of the machine’s capabilities to the task of “upgrading” hundreds of thousands of human teachers. This ease of updating teaching machines is one reason they will gradually play a larger and larger role in lifelong informal and formal education.

**My “Near Future” Teaching Machine**

Of course, my teaching machine will be small and portable. It will have a high-resolution color display touch screen, long battery life, fast connectivity to the Internet, voice input, voice output, and automatic translation among languages from both text and voice. Using its built-in intelligence, compute power, and connectivity, it will be able to solve or help greatly in solving a huge range of problems of the types that people encounter in school, in their everyday lives, and on the job. This teaching machine will be aware of its user’s location, will act as a GPS, and will access and process the visual and sound information that its user is receiving from both the physical and electronic environments. It will always be available, and it will facilitate “just in time” learning.

Here are some details elaborating the previous paragraph.

1. You are probably familiar with a computer named **Deep Blue** that defeated the reigning world chess champion Garry Kasparov in 1997, and a computer named **Watson** that defeated two of the best human players of the TV game Jeopardy in 2011. IBM’s work with its computer system captures the flavor of progress in using powerful computers to help solve a wide range of human problems in healthcare, research, and a number of other areas.
My “near future” teaching machine not only provides students with ready access to such systems but also integrates use of these systems into the everyday curriculum. See my *IAE-pedia* article, Two Brains Are Better than One (Moursund, 2014).

2. Here is a recent personal story. I had a question about some details of Piaget’s four-stages of human cognitive development, and I was unable to find an answer via an hour of Web searches. So I sent my question to a Piaget distribution list. A couple of the responses cited references in Spanish and French. Another then noted that he was unable to find an English translation of the French citation that he felt contains an answer. That led to a response from another person who said roughly, “That’s not a problem. Simply copy the French text into the free Google Translate system on the Web.”

We already have relatively good voice input systems that translate speech into text. We have good voice output systems that translate text into speech. The combination of these capabilities with language translation capabilities means that students throughout the world will be able to easily communicate orally and by text with each other.

3. We know a considerable amount about individual differences among learners, the value of individualization of instruction, the value of human tutors, and the value of computer tutors. My teaching machine will respectfully accommodate our understanding that there are many aspects of teaching and learning in which human teachers and student-human interactions are both absolutely necessary, and are much more effective, than our current computer teaching machines.

However, it will also reflect that there are already many things that a teaching machine can do better than human teachers, and there are many things that a human teacher plus a teaching machine working together can do better than either working alone. A student’s teaching machine will gradually learn which of these three approaches works best in a particular learning area for the student it is serving.

4. We know that there are considerable differences in beliefs and understandings among people of different nationalities, cultures, and religions. Many years ago, one of my students exposed me to the idea of the imperialism of one country inflicting its educational system and curriculum content on another country. This might be acceptable to both countries in the discipline of math, but quite unacceptable in global and national history, in politics, and in many other disciplines. For example, some of the curriculum content of the fine and performing arts that is broadly accepted in many areas of the world may not be at all acceptable in other areas. Add to this the need for students to learn to communicate in their native language and culture, and that inherent to a language is a great deal of culture and history.

This means that the teaching machine needs to have a great deal of content and teaching methodology that is specific to the huge number of different sects living throughout the world and to the many different political systems. In education, one size does not fit all at the individual student level, the family level, and for larger groupings.
5. The first Massive Open Online Courses (MOOCs) were developed in 2011. By making use of data about the performance of all students enrolled in a MOOC, we are gradually improving the MOOCs. My forecast is that eventually such courses will have the characteristics of today’s Highly-interactive Intelligent Computer-assisted Learning (HIICAL) courses. My teaching machine will provide students throughout the world with free access to a huge number of HIICAL courses will allow them to learn at a time and place of their choosing.

6. Some of our best success stories with teaching machines involve developing and using computer simulations. A good teaching/learning simulation engages a student in actually solving problems and accomplishing tasks. The simulated versions of the problems and tasks need to be close enough (authentic enough) to the “real thing” that there is very easy transfer from the learning to the use of the learning. We are making good progress toward creating Star Trek’s Holodeck simulations, and less sophisticated simulations are now of routine use in education and research.

7. My teaching machine will be quite portable, thus largely obviating the need for students to have individual walking/talking robots. A future version of Google Glass will be one of the interfaces to teaching machines. Thus, for example, a student will be able to glance at a person and the computer system will display the person’s name and identification information via the glasses. (If the person is someone I have met before, I want my teaching machine to retrieve information about previous meetings and conversations.) Similarly, students will be able to quickly retrieve information about almost anything (including people) they see, hear, or think about.

Final Remarks

The design, production, and distribution of teaching machines needs to take into consideration both the educational needs of today’s students and the changing educational needs of future students. We humans now have the knowledge, skills, and production capabilities to provide every person on earth with a quite good teaching machine. Once this approach to education is widely accepted, the capabilities of the teaching machines will increase rapidly as more and more materials are developed to facilitate this type of aid to teaching, learning, communication, and problem solving.

Human teachers and teaching machines working together can make education a lifelong endeavor and provide all people with an education that rivals the best education that currently is available to only a limited number of students.

We can overcome the technological and manufacturing challenges. But, can we overcome the acceptance, distribution, and other human challenges? I wish each of you a long life so that you can participate in and witness the outcomes of this endeavor.

What You Can Do

Please don’t just be a passive reader. Take what you are learning, share it with others, and use it!
For All Readers Concerned about PreK-12 Education

We have had books and libraries for a very long time. A book is a static type of teaching machine with a long and reasonably successful history as an aid to teaching and learning.

Modern teaching machines provide students with access to the Web, the world’s largest library. The Web and the Internet together provide powerful new aids to teaching, learning, and communication.

A modern education needs to routinely and thoroughly integrate the capabilities of computers as an aid to learning, an aid to information storage and retrieval, an aid to communication, and an aid to representing and solving problems. We want students to learn to solve authentic problems and accomplish authentic tasks in an environment that provides the tools that many adults routinely use as they solve problems and accomplish tasks.

In my mind this means—among other things—that in the same way we now provide students with pencil, paper, and (sometimes) calculators when they are taking tests, we should be rapidly moving toward providing students with computers and connectivity when they are taking tests. (This is an extension of the idea of open book exams.)

We have ample research attesting to the value of one-on-one tutoring. Computer technology to provide one-on-one tutoring is steadily becoming better and more cost effective. Computer tutors and computer-assisted learning are now at a level that can make it a cost effective aid to teaching, learning, and assessment.

So, look at the education your students are currently receiving. How well is it preparing them for lifelong learning, careers, and responsible adulthood in our rapidly changing word of technology?

For Teachers of Preservice and Inservice Teachers

Much of my professional career has been spent in teaching preservice and inservice teachers about appropriate roles of computers in education. While I am proud of my accomplishments, I am deeply troubled by the slow pace of technological change of our educational system.

My strongly held opinion is that our “traditional” preservice and inservice teacher education systems have been unwilling and/or unable to make the level of commitment that would allow them to keep up with the pace of change in the currently available technology aids to teaching, learning, and problem solving.

Please think about my belief. If you agree with it, think carefully about what you are currently doing to improve this situation. Then, “Just do it.”
Chapter 4: The Teaching Machine Is Both Tool and Teacher

My view of the future of teaching machines is summarized by the statement: The Tool Is the Teacher. I believe this is a paradigm shift that is beginning to occur in education. The ideas here are a slightly modified version of an earlier IAE Newsletter (Moursund, September, 2014b).

The Medium Is the Message

“The medium is the message.” (Herbert Marshall McLuhan; Canadian philosopher of communication theory and a public intellectual; 1911-1980.)

"If you want to teach people a new way of thinking, don't bother trying to teach them. Instead give them a tool, the use of which will lead to new ways of thinking." (Richard Buckminster Fuller; American engineer, author, designer, inventor, and futurist; 1895-1983.)

Marshall McLuhan is well known for his statement that “The medium is the message.” Like most people, I thought I understood what he meant by this statement. However, Mark Federman pointed out how wrong I was in his article, What is the Meaning of The Medium is the Message? (Federman, 7/23/2004). Quoting from his article:

McLuhan tells us that a "message" is, "the change of scale or pace or pattern" that a new invention or innovation "introduces into human affairs." Note that it is not the content or use of the innovation, but the change in inter-personal dynamics that the innovation brings with it…. A McLuhan message always tells us to look beyond the obvious and seek the non-obvious changes or effects that are enabled, enhanced, accelerated or extended by the new thing.

But McLuhan always thought of a medium in the sense of a growing medium, like the fertile potting soil into which a seed is planted, or the agar in a Petri dish. In other words, a medium—this extension of our body or senses or mind—is anything from which a change emerges.

[Quoting McLuhan:] "This is merely to say that the personal and social consequences of any medium—that is, of any extension of ourselves—result from the new scale that is introduced into our affairs by each extension of ourselves, or by any new technology."

Computer as a Medium

You are probably familiar with the stories of Bill Gates and Paul Allen who dropped out of college and stated Microsoft, and Steve Jobs who dropped out of college to work with his friend Steve Wozniak to start Apple. The microcomputer was a new medium, and here is my view of the message:

The new medium made it possible for relatively novice users of the medium to quickly become “world class” in some of their computer-related endeavors and help facilitate a huge change in the world.

Now, let me share three stories about examples of continuing changes being wrought by the computer-as-medium.
A Story about a 17-Year-Old

The December, 2013, issue of *Scientific American* includes a story about Eric Chen, who was a 17-year-old high school senior from San Diego, California, when he won the 2013 Google Science Fair (Kuchment, 10/21/2013).

Quoting Chen:

I live in San Diego, where some of the first cases of 2009 H1N1 swine flu took place in the U.S. It was then that I made a realization that flu can kill a lot of people. I thought, "Why can’t we use the new computer power at our fingertips to speed up drug discovery and find new flu medicine?" I came across Dr. Rommie Amaro of the University of California, San Diego, and she was willing to let me work in her computation lab.

Chen then goes on to describe his activities of using the computer to screen a half million chemical compound, separating out 237 likely candidates, and testing each of them in a “wet” lab (that is, a “traditional biology lab) to identify six that are worthy of animal studies.

With his good brain, some tutoring from a professor, and the help of computer technology, a high school student was able to do cutting edge research in medicine. What a marvelous learning experience!

Genetic Engineering

Quoting from the Wikipedia:

Genetic engineering (GE), also called genetic modification, is the direct manipulation of an organism's genome using biotechnology. New DNA may be inserted in the host genome by first isolating and copying the genetic material of interest using molecular cloning methods to generate a DNA sequence, or by synthesizing the DNA, and then inserting this construct into the host organism.

Genetic engineering equipment has now reached the stage that international and national student contests are held. Paraphrasing a story about a Genetic Engineering competition for college students in *The Seattle Times* (Hodson, 11/7/2011):

One project created enzymes that could convert sugar into diesel fuel.

The other engineered bacteria that could help people digest gluten.

Both projects constitute cutting-edge science. They came from a team of undergraduate students at the University of Washington. The projects garnered the team—and the university—a world-championship prize at an annual competition at the Massachusetts Institute of Technology.

In brief summary, computer technology has reached a stage in which “mere” undergraduate college students can do such projects as “building two enzymes that could be put into bacteria to convert sugar into diesel fuel.” What a marvelous learning experience!

Current Research in Materials Science

A *Scientific American* article by Gerbrand Ceder and Kristin Persson describes how the computer has changed the entire field of materials science (Ceder & Persson, 11/19/2013).

Quoting from the article:
In 1878 Thomas Edison set out to reinvent electric lighting. To develop small bulbs suitable for indoor use, he had to find a long-lasting, low-heat, low-power lighting element. Guided largely by intuition, he set about testing thousands of carbonaceous materials—boxwood, coconut shell, hairs cut from his laboratory assistant's beard. After 14 months, he patented a bulb using a filament made of carbonized cotton thread. [Bold added for emphasis.]

Here is a short summary of the article:

Engineered materials such as chip-grade silicon and fiber-optic glass underpin the modern world. Yet [as illustrated by Thomas Edison’s work] designing new materials has historically involved a frustrating and inefficient amount of guesswork.

Streamlined versions of the equations of quantum mechanics—along with supercomputers that, using those equations, virtually test thousands of materials at a time—are eliminating much of that guesswork.

Researchers are now using this method, called high-throughput computational materials design, to develop new batteries, solar cells, fuel cells, computer chips, and other technologies.

**The Tool Is the Teacher**

The message that I take from these three examples is that the computer being used in tool mode helps to create powerful learning and research experiences that in some sense circumvent and/or greatly speed up many years of conventional education and time spent gaining experience.

I find this to be an interesting way to think about teaching machines. We know, of course, that a teaching machine can be designed to help students to better solve the problem of learning certain content. I have always wondered about the fact that, for a teaching machine to be effective, it has to in some sense “know” the content it is teaching. This idea is obvious in the traditional drill and practice in math facts programs that generate random problems, present the problems to a student, and check the student’s answers against answers generated by the computer.

But, today’s computers can solve a steadily increasing range of problems—and many of these are beyond the capabilities of a human being. So, what should students be learning? Let me repeat a sentence from the Ceder and Persson quote given earlier:

Streamlined versions of the equations of quantum mechanics—along with supercomputers that, using those equations, virtually test thousands of materials at a time—are eliminating much of that guesswork.

Quantum mechanics is a very challenging field of study. The development of streamlined versions of the equations of quantum mechanics, and of computers that could solve these equations, produced a new “medium” that could be mass-produced and widely distributed. Students can use these new types of teaching machines to do cutting edge research. This provides an excellent example of a tool being a teacher.

Here are more examples that I like to use in illustrating “The Tool is the Teacher.” I have numbered them as a continuation of the seven examples in Chapter 3.
8. As mentioned in Chapter 3, the Web and the large amount of artificial intelligence incorporated in modern search engines is a powerful aid to learning. Through using this tool, one learns to use the tool. One’s personal Web-searching skills improve. And, over the years, both the amount of content in the Web increases and the quality of search engines improves.

9. How can a person who does not know how to play a musical instrument learn to compose for that instrument? (And, consider the challenge an orchestral composer faces.) We now have powerful computer programs and music generation equipment that can perform the music a person is composing. The tool plays an important role in the teaching. Moreover, the tool can perform the final music that is composed. What a marvelous learning experience!

10. Recently I have been reading Michio Kaku’s 2014 book, The Future of the Mind. His focus is on human consciousness and many of the cutting edge technologies that are now available or are soon likely to be. He discusses “mind reading”—input and output connectivity between a computer brain and a human brain.

Here is a Kaku quote about this idea: “Stephen Hawking, my colleague, is totally paralyzed, and he has a chip in his right [eye] glass. Next time you see him on television, look in his right frame, and you see a brain sensor that picks up radio from his brain and allows him to type mentally.”

Michio Kaku predicts that such technology will come into widespread use in about ten years. This technology requires both that the tool teach its user and that the user teaches its tool.

11. We have long had computer-aided design and computer-aided manufacturing equipment. A skilled operator of CAD-CAM equipment both designs a component of a product and also produces instructions that control a computerized machine to produce the component. An automated loom provides an excellent example.

As another example of CAD-CAM equipment, we now have relatively inexpensive robot-like 3-D printing machines that function much like a laser printer. The printers use “ink” that consists of various types of plastics and metals that can be used to build physically solid products by “printing” one very thin layer at a time. These three-dimensional printers allow sculptor artists to both design and produce their sculptures. A recent article in Campus Technology suggests that widespread use of this technology in schools and higher education is still a decade away (Nagel, 8/19/2014). But, current uses in schools are being “hyped” and these certainly can be fun and interesting for students.

12. There are many disciplines of study in which a computer and/or computerized robot is an important aid to representing and solving discipline-related problems. Nowadays, the frontiers of computer use in the various disciplines focus on a human accurately specifying a problem to be solved or a task to be accomplished. That is, a human poses a clearly stated problem or asks a carefully stated question. Given such a specification or question, the computer or computerized robot takes over the detailed task of figuring out to solve the problem or accomplish the task. A dialogue between the human and the computer system will likely occur. The human
has to learn the types of questions the computer system can answer and how to state questions in a format that the computerized robot is designed to handle. The programmers work to improve the human-machine communication system. The Watson computer system that performed so well in a 2011 Jeopardy contest illustrates progress that is occurring in the types of questions a computer system can “understand” and answer.

Final Remarks

Every academic field of study and research is developing computer tools that are specifically designed to aid students and researchers in its field. These tools have built-in knowledge and skills that are part of the fundamentals of the discipline. As these tools become more powerful and essentially indispensable to a specific discipline of study, they lay the groundwork for the tool becoming the teacher. This trend is now well started. I believe over the next few decades it will become a dominant force in education. Much in the manner that we now expect all students to learn to use computer search engines, in the future we will expect students to learn to use the specialized computerized tools now being developed in the various disciplines the students study.

What You Can Do

Please don’t just be a passive reader. Take what you are learning, share it with others, and use it!

For All Readers Concerned about PreK-12 Education

Examine the school education that today’s precollege students are getting. How well does it reflect the growing capabilities of computer tools as aids to representing and solving problems? Students face both the problem of learning the various disciplines and the problem of learning to solve the problems in each discipline they study. Modern teaching machines—or, a combination of less modern teaching machines plus the Web—are now integral to attacking these two major goals in education.

Parents and other people concerned about children getting a modern education can examine the extent to which “computer as an aid to teaching/learning” and “computer as an aid to problem solving” is routinely integrated into the various subject areas their children are studying. Don’t just ask, “What did you learn in school today?” Instead, ask about what use of computers they made. If they indicate some use, probe to see whether it was just mundane drill and practice or whether it was for higher-order thinking and problem solving. If they indicate no use or quite mundane use of computers, do something about this situation!

For Teachers of Preservice and Inservice Teachers

One of the things you can do is to role model the processes involved in making routine use of computer technology to address the types of problems and tasks you face in your teacher of teachers career and in your everyday life. When you teach teachers or other students, do you role model the effective use of computer technology? Do you require your students to be engaged in small group and large group discussions and other interactions using computer technology? Do you make assignments that require your students to make appropriate use of technology with the students they currently teach or are learning to teach?

If you are teaching preservice or inservice teachers who are currently taking other inservice work or courses, ask them what they are learning about computers in these areas. My opinion is
that now-a-days all preservice and inservice teachers should be getting a good dollop of computing in all of their instruction.
Chapter 5: Top-Down Approaches to Attacking “Big” Problems

"It is not enough that you should understand about applied science in order that your work may increase man's blessings. Concern for man himself and his fate must always form the chief interest of all technical endeavors, concern for the great unsolved problems of the organization of labor and the distribution of goods—in order that the creations of our mind shall be a blessing and not a curse to mankind." (Albert Einstein; German-born theoretical physicist and 1921 Nobel Prize winner; 1879-1955.)

"He who asks a question is a fool for five minutes; he who does not ask a question remains a fool forever." (Confucius; Chinese thinker and social philosopher, whose teachings and philosophy have deeply influenced Chinese, Korean, Japanese, Taiwanese and Vietnamese thought and life; 551 BC-479 BC.)

This and the next chapter provide an introduction to uses of computer technology in solving problems. Chapter 5 focuses on really big, challenging problems that are attacked through the coordinated efforts of a large number of researchers. It is a somewhat modified version of an earlier IAE Blog entry (Moursund, 2/7/2015a).

Jason Pontin is the editor-in-chief and publisher of MIT Technology Review. His 2014 TED Talk is titled: Can Technology Solve Our Big Problems? Examples of really big problems include: global warming; an increasing shortage of fresh water; sustainability; worldwide poverty, hunger, and disease; and war and terrorism.

I add education to this list, because general education is usually considered one of the keys to solving the previous list of problems.

Here is Pontin’s summary of four conditions that he argues must all be present if technology is going to help solve really big problems in a top-down manner:

• Political leaders and the public must care to solve a problem;
• institutions must support its solution;
• it must really be a technological problem; and
• we must understand it [the problem] (Pontin, 10/4/2014).

All four conditions were present in the Apollo astronaut project. At the current time, there are many big problems, but none that appear to satisfy all four conditions.

Transporting People to the Moon and Back

In his 1961 Inauguration Address, John F. Kennedy said:

“First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth.” (John F. Kennedy; 35th President of the United States; 1917-1963.)

Quoting again from Pontin’s TED Talk:
The Apollo program was the greatest peacetime mobilization in the history of the United States. To get to the moon, NASA spent around 180 billion dollars in today's money, or four percent of the federal budget. Apollo employed around 400,000 people and demanded the collaboration of 20,000 companies, universities and government agencies.

Our country had the resources and the technological knowledge and skills to undertake and accomplish this huge task. Although considerable technological progress occurred as a result of the investments being made, no fundamental new “far out” discoveries were needed to accomplish the task.

**War on Cancer**

The War on Cancer is an example in which the fourth condition (we must understand the problem) was not satisfied. In 1971, President Richard Nixon declared a “War on Cancer.” Quoting from the National Cancer Institute (NCI, n.d.):

> In 1970, the American people made clear their desire for a cure for the second-leading cause of death in the United States. President Nixon responded during his January 1971 State of the Union address: "I will also ask for an appropriation of an extra $100 million to launch an intensive campaign to find a cure for cancer, and I will ask later for whatever additional funds can effectively be used. The time has come in America when the same kind of concentrated effort that split the atom and took man to the moon should be turned toward conquering this dread disease. Let us make a total national commitment to achieve this goal."

Big problems sometimes elude solution because we don't really understand the problem. In this case, we soon discovered there are many kinds of cancer, most of them fiendishly resistant to therapy. By 2009, $30 billion had been spent by the U.S. federal government, and very little progress had occurred.

We are gradually coming to understand the cancer problem, and we have begun to develop technology to help us attack the problem. However, during the 1971-2009 time period, we made more progress in the cancer problem area by reducing the number of people who smoke than by all the rest of our research progress put together. It is only in the last 10 years that effective, viable therapies have come to seem a real possibility. In 2010, heart disease (596,557 deaths) and cancer (576,691 deaths) were still by far the leading causes of death in the United States.

The initial $30 billion from the U.S. Federal Government, along with a subsequent $2 billion or so a year, is only part of the money that has been spent. Many non-profit foundations have contributed to this task, and many for-profit companies are working on it.

**Roles of For-profit Corporations**

There are many big problems that can be attacked by for-profit corporations. IBM is a leading corporation in research spending. It has a research budget of about $6 billion a year. Recently it announced a five-year plan to spend $600 million a year (a total of $3 billion) in one project area. Quoting from Konrad (7/10/2014):

> IBM’s spending much of its $3 billion to push for 7 nm silicon chips. As research executive John Kelly said in a statement in the company’s release, IBM is no longer doubtful whether 7 nm is possible—the question is how to produce them at acceptable prices.
Much of the money, however, is allocated to post-silicon technologies that are still more commercial pipe dreams, but will be needed to make chips brawny and low-powered enough to handle advanced computing needs. They include quantum computing, neurosynaptic computing that makes the chip channel data more like a human brain, and silicon photonics that transmit pulses of light instead of using physical copper wire.

When a company makes such a long-term research commitment, it believes it will pay off. Notice that five years is about half the length of the Apollo project, and $3 billion to be spent over five years is about 1/3 of what the Apollo project cost per year.

Jason Pontin argues that for-profit corporations are unwilling to make the types of investments needed to address the really big world problems:

Even when venture capitalists were at their most risk-happy, they preferred small investments, tiny investments that offered an exit within 10 years. Venture Capitalists (V.C.s) have always struggled to invest profitably in technologies such as energy whose capital requirements are huge and whose development is long and lengthy, and V.C.s have never, never funded the development of technologies meant to solve big problems that possess no immediate commercial value (Pontin, 10/4/2014).

**Final Remarks**

At the current time, the U.S. government is not engaged in any long-term massive project that satisfies Pontin’s four conditions. Our current political wrangling makes it very difficult to achieve either the political will or the federal funding for any such project. I find it interesting that corporations are now playing a major role in our space program.

Similarly, on a worldwide basis, the nations of our world are struggling to achieve a unified political and economic will to attack many ongoing global problems.

**What You Can Do**

Please don’t just be a passive reader. Take what you are learning, share it with others, and use it!

**For All Readers Concerned about PreK-12 Education**

To begin, wrap your mind around some of the world’s and your country’s really big problems. How would major progress in addressing these problems contribute to long-term improved quality of life for large numbers of people? For example, hunger is a major and continuing problem, but our world is currently producing enough food so that the current population can be fed. However, we do not yet have a distribution system in place that can wipe out hunger. Indeed, we are struggling with this even in the U.S.

Select one of the problems that particularly interests and concerns you. Think about what you, personally, can do to address and help to make progress on a very small part of the problem. Try out some of the ideas that occur to you, and share your ideas, successes, and failures with others.

If you are a teacher, think about the really big problems in the discipline(s) you teach or are preparing to teach. What are your students learning that can help them to understand these problems and be responsible adult citizens as their nation and the world work to deal with these problems?
If you are a parent of a middle school or high school student, engage your child in talking about what they consider to be some of the major problems facing our nation and the world. Ask them about what their friends think about these problems and whether they talk seriously about them. Ask if these problems are discussed in the classes they are taking.

**For Teachers of Preservice and Inservice Teachers**

Remember, the types of problems a discipline addresses define the discipline. In teaching preservice and inservice teachers, you can bring up the idea that the really big problems of a nation or of the world are interdisciplinary and require the attention of very large numbers of people working over long periods of time.

My opinion is that, as students gain in maturity, they should be learning about the national and global problems the adults of our world currently face, and the problems that today’s students will likely face when they become adults. Such inquiry should be one of the unifying interdisciplinary problems studied throughout the precollege curriculum.

Engage the preservice and inservice teachers you teach in discussions about what their students can/should be learning about such national and global problems. How might such instruction be integrated into the various subject areas that precollege students study? What level of cognitive maturity do students need before they can begin to understand national and global problems? How does a problem such as a growing shortage of fresh water relate to what students are learning in social studies, humanities, and the STEM areas?
Chapter 6: Applying “Big Problem” Ideas to Local and Regional Problems.

“We never doubt that a small group of thoughtful committed citizens can change the world; indeed, it's the only thing that ever has.” (Margaret Mead; American cultural anthropologist; 1901-1978.)

“We can't solve problems by using the same kind of thinking we used when we created them.” (Albert Einstein; German-born theoretical physicist and 1921 Nobel Prize winner; 1879-1955.)

This chapter is a somewhat modified version of an IAE Blog entry (Moursund, 2/7/2015b). It focuses on what an individual or a small group of people can do at a local level to help address a local or regional “big” problem. It considers the use of technology with a specific focus on problems of improving education.

Technology that Empowers Individual People

The Industrial Revolution was built through the use of technology that enhances and/or supplements the physical capabilities of people and animals. Consider a 175-horsepower car. This car is driven by an engine that is approximately 1,000 “people power.” Petroleum-powered engines—together with supportive infrastructure—empowered individual people, and changed our world.

The Information Age is built on technology that enhances and/or supplements the mental capabilities of people. The Internet and Smart Phones empower individuals. Of course, a huge infrastructure is needed to support this modern technology. A similar statement holds for computer and robot technology that enhances and/or supplements both our physical and mental capabilities.

Computers were initially envisioned as tools to rapidly and accurately perform arithmetic calculations. My desktop computer, which is several years old, can do a billion multi-digit calculations per second. Compared to my paper-and-pencil skills, this machine is well over 10 billion times as fast as I am. So, suppose that one of the really big problems facing the world could be solved by an arithmetic calculation requiring many trillion operations, and we needed to solve this problem every day, with no calculation errors. Such a task cannot be accomplished using paper-and-pencil calculation. And yet, this is a routine task in today’s weather forecasting.

Access to Information

The Library of Alexandria was a marvel 2,200 years ago. It reportedly contained somewhere between 40,000 to 400,000 scrolls. Scrolls vary in length from perhaps one to a hundred modern book pages. The U.S. Library of Congress contains nearly 25 million books. This is many thousands of times the content of the Library of Alexandria.

Consider the educational problem of providing every student with easy and quick access to the print, photo, audio recordings, and video recordings stored in the Library of Congress. This would have been impossible even 50 years ago. In 1945, Vannevar Bush proposed the development of a microfiche storage and retrieval machine he called the memex. At that time we
did not yet have appropriate (computer-based) technology to provide an adequate solution to the information storage and access problem he posed.

Eventually technology developed to a level that made the Web feasible. As they say, “And the rest is history.” The Internet and the Web exist because of a combination of bottom-up and top-down activities and funding. They empower each individual user—including hundreds of millions of students throughout the world.

The telephone system developed in the 1870s empowered individuals by allowing them to exchange voice information over great distances. Our current system and its easily portable handheld Smart Phones now provides routine communication services, access to the Web, and a number of other tools to individuals. More than a billion smart phones were produced and sold in 2013, and a similar number in 2014.

**Big, Important Problems Amenable to Bottom-up Solutions**

Here are two important questions:

1. What really important “big” problems can be solved in a bottom-up manner by the billions of people who now have good access to the communication, information retrieval, and calculation capabilities provided by Information and Communication Technology?

2. What do we want our educational systems to do to prepare students to be responsible, informed, and empowered adult citizens in a world with its steady improvements in technology?

I like to think about the question of “big” problems in terms of who can and should do something about them. Should “they” (governments, large corporations, the world’s most wealthy people) take responsibility for doing something about such problems? Can “we” (ordinary individuals empowered by technology) do something about such problems?

The following subsections provide examples of “big” but quite manageable bottom-up educational problems.

**Individual Teacher**

No matter what you teach, some of the tools that empower the bodies and minds of your students are relevant to the content you teach. You, an individual teacher, become the place where “the rubber hits the road” for your students. No matter what the top-down educational system prescribes and tries to enforce, you have the power to help your students understand the capabilities and limitations of modern technology in learning, understanding, and making effective use of the content that you are teaching.

A good starting point is to ask your students what they know about the combination of the modern technology they personally routinely use and the subject matter you are teaching. This is a good way for you personally to role-model appropriate uses of technology as a teacher. Every day of teaching provides you with opportunities to show how the technology that your students have been learning on their own is important and relevant to what they are learning from you and from their other teachers.

Take history, for example. Name any important era of history that your students are studying. What roles did technology play in that period of time or for those events in history? How might things have been different if our modern communication system had been available at that time?
Over the time of recorded history, how have advances in technology empowered some countries, companies, or people more than others? How accurate is the content you are teaching, and how can you and your students make use of the Web to do some fact checking?

When you communicate with your fellow teachers, do you routinely share your personal insights and experiences with technology as an aid to student learning and using what they are learning? Do you routinely work to “keep up” with technological progress that is relevant to you, your students, and your subject matter?

**Small Groups of Teachers**

Here is one of my favorite quotes:

“A single conversation across the table with a wise man is worth a month's study of books.” (Chinese proverb.)

I treasure the weekly lunches I have with a small group of my retired College of Education colleagues. Each meeting brings me up-to-date on some local and national gossip and sports, and each meeting also allows me to probe their minds and share my insights into some of the current problems in education. The Chinese proverb quoted above tells the story.

As a teacher, you are a gold mine of experience and knowledge. It is well within your capabilities to create and maintain a small professional learning community. My guess is that four or five people is an optimal size, as they can sit around a table and carry on a face-to-face conversation in which all can readily participate. If your small community happens to have run out of good ideas to discuss, select one of the IAE blogs that appeals to you and use it for a conversation starter. And, of course, there is nothing wrong with supplementing face-to-face meetings with some online communication.

**Groups of Students and/or Parents**

Think of a problem that is “big” with respect to a school or part of a school, and that satisfies the four conditions discussed in the previous section of this IAE-pedia document:

- Political leaders and the public must care to solve a problem;
- institutions must support its solution;
- it must really be a technological problem; and
- we must understand it [the problem] (Pontin, 10/4/2014).

Now, redefine these conditions so they are satisfied at an individual school level, or even a still smaller unit such as a grade level or in one classroom. Think of problems that are of interest to you, your students, and parents of your students. If you like, these problems can fall into the category of “Think globally, act locally.” Or they can just be local, such as working to ensure that all of the students in your school have adequate meals over the weekends.

Often local problems can be successfully addressed at a local level by a small, committed group. You have heard the expression, “Where there’s a will, there’s a way.” A small, local group can now use the Web to draw on the collected experiences of thousands of individual schools that tell the stories of what they have done and what they are doing to turn themselves around. They can involve their members through a combination of traditional small group and large group face-to-face meetings, and through the use of electronic aids to communication.
Moreover, a successful project can be shared with the world through use of the Web. Isn’t the Web wonderful?

**Final Remarks**

Technology empowers its users. We now have technologies that allow an individual or a small group of individuals to accomplish tasks that used to require very large groups of workers in a hieratically-structured organization. Our educational system can and should help students to learn to use and make effective use of these new tools.

The education we provide our students empowers them. With their increasing knowledge, skills, and power, students can make a significant contribution to their world.

**What You Can Do**

Please don’t just be a passive reader. Take what you are learning, share it with others, and use it!

**For All Readers Concerned about PreK-12 Education**

What is it that you like about your local school(s)? What is it that you dislike? Are you alone in your opinions, or are your likes and dislikes shared by many parents and other local people?

Instead of just complaining, do some careful thinking about how to increase the occurrences of things you think are good, and how to decrease the occurrence of things you think are bad. In both cases, do this in a constructive manner that is apt to engage the support of well-meaning parents, other teachers, administrators, and local people.

Parents and their children are in a powerful position to make a difference. For example, if you are a parent of a middle school or high school student, engage your child in talking about what they consider to be some of the major problems facing our nation and the world. Ask them about what their friends think about these problems and whether they talk seriously among themselves about them. Find out what your child is learning about such problem at school.

If you are feeling really feisty, you might try out an idea that I used with students in my freshman Computer Literacy course about 40 years ago. Of course, you will need to modify it to something that you personally can do or that you are willing to have your child try out.

I assigned my students to select one of the courses they were taking and wait until the faculty member asked, “Are there any questions?” At that moment, they were to ask an appropriate version of the question: “How are computers affecting what you have been telling us?” The remainder of the assignment was to write a paragraph on the faculty member’s response. I was quite surprised by the results. All faculty members treated the question with respect. One student reported that her faculty member provided an “off the top of his head” response that was 40 minutes in length!

A suitable modification of this might be asking the question of a teacher in a parent-teacher conference, or raising it in a PTA meeting. Ask the question of your child, and encourage your child to raise the question with a teacher. A non-feisty way to do the latter would be to have your child ask the teacher for something to read that would explain how computer technology is affecting the content area in the course.

If you are a precollege-level teacher, think about the really big problems in the discipline(s) you teach. What are your students learning that will help them to understand these problems, to
be responsible students, and to become responsible adult citizens as their nation and the world work to deal with these problems?

**For Teachers of Preservice and Inservice Teachers**

Every preservice and inservice teacher has the potential to be a change agent. However, most teachers seem to begin their teaching by teaching in the same way that they were taught, and we know that it is hard to change this behavior. Presumably, as a teacher of teachers, you have changed with the times and you base much of what you teach on research and your insights into changes that will improve education. Openly discuss this approach with your students, and help them to learn and discover changes that they are capable of making with their current levels of knowledge and skills.

When you work with inservice teachers, by the end of a session you want to have each teacher make a personal commitment to try out a change based on what you have been teaching. You can do this via an assignment that requires the teacher to write down what he or she will try, and then write about what worked and what did not work when the idea was tried in the classroom. You want to cultivate a mindset of “theory into practice” together with an understanding that change can be a slow, challenging process.

The same type of assignment works well with preservice teachers who are doing “field placements” in local schools. They can try out an idea in a one-on-one interaction with a student or a very small group of students. In this situation, they can discuss the experiment with the students and get their suggestions on what might work better the next time the idea is tried.
Chapter 7: Technology-based Mini-singularities in Education

This chapter was first published in Moursund (5/16/2015).

The term singularity has different meanings in different disciplines. For example, physicists consider a black hole to be a singularity. Mathematicians think about the function \( f(x) = 1/x \) and say that the point \( x = 0 \) is a singularity. (Division by zero is a “no-no” in math.)

In computer technology, the singularity is when computers become more intelligent than people. I have written about this idea in the articles (Moursund, 3/5/2015 and 2/25/2015).

Of course, we don’t know when—if ever—computers will become more intelligent than people. But, some people like to speculate about that possibility. They note that artificially intelligent computers and robots are steadily becoming more capable. They point to examples where, in an increasing number of problem-solving and task-accomplishing situations, computers and robots already are more capable than people.

Notice that in the previous paragraph I used the term more capable rather than more intelligent. I use the term capable to refer to the ability to solve problems and accomplish tasks. That is quite different from being intelligent. A computer can accurately add a list of a million integers in less than a second. This does not in any sense say that the computer is intelligent.

A computer can read and memorize thousands of books letter-perfect. Does that mean the computer is more intelligent than a person? No, it means that in the specific task of memorizing books, a computer is much more capable than a person.

What Is a Mini-singularity?

In terms of computer and robot capabilities, I define the term mini-singularity to be a problem-solving or task-accomplishing situation in which a computer or robot can far out perform a human. We have long had machines that can far out perform humans in various manufacturing processes. And, certainly, we have cars and airplanes that can far out perform humans in these machine “areas of expertise.”

For the remainder of this IAE Blog entry, let’s focus specifically on the discipline of education. Here I consider content to be learned, teaching processes, and assessment.

Content

First, consider content. The Web is now by far the world’s largest single repository of content data, information, and knowledge. For simplicity, let’s call the combination of these three terms information. When a student does a Google search, the student is searching a database that is equivalent in size to roughly a hundred billion books. And, of course, the total amount of information accessible by Google and other online search engines continues to grow quite rapidly.

Computerized databases are an important type of mini-singularity. They change the basic nature of the content to be learned aspect of education. Rather than think about content to be
learned, think in terms of learning access and the ability to make effective use of available content. The essence of this idea has been with us for a long time:

“Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it.” (Samuel Johnson; British author and father of the English dictionary; 1709-1784.)

**Teaching Processes**

Children are natural born learners. Our informal and formal educational systems speed up and focus the learning processes. Oral tradition—for example, family groups and small clans telling and listening to stories while sitting around an evening fire a hundred thousand years ago—has gradually been supplanted by written language, formal schools, mass production of books, audio recordings, radio, films, television, and computer technology.

I find it useful to think about written language, along with various methods of printing and distributing printed material, as a mini-singularity. Written language is a powerful aid to human intelligence, but by itself does not have intelligence. Indeed, written language is such a powerful aid to human intelligence, teaching, and learning, that we have decided that all students need to develop a high level of written language skill. Thus, our schools have a very strong focus on this endeavor.

Computer technology is just at the beginning of producing a massive change in teaching processes. We are seeing the development of a number of mini-singularities in teaching. For example, consider the drill-and-practice components of instruction. Computers cost more but are a more capable aid to teaching and learning than flash cards. They work much better in adaptive drill-and-practice sessions that can adjust to a student’s responses. They also can be designed to incorporate relevant aspects of learning theory.

An appropriately computerized flash card system can display video, audio, and text—and in many languages when appropriate. It can receive and process keyboard, touch screen, and voice input. It can keep cumulative records of a student’s performance over both a single session and a sequence of sessions. In summary, this specific technology-based mini-singularity has advanced far enough so that it has become a standard component of teaching/learning in many different disciplines.

Of course, drill-and-practice activities are only a modest part of instruction. Computers can’t yet read and understand a student’s essay in order to provide the level of feedback a competent human teacher can provide. Computers similarly can’t yet read a student’s responses to problem-solving in math, assign appropriate partial credit, and provide good feedback that is specific to the needs of an individual student.

However, significant progress is occurring in more sophisticated computer tutor systems. We now are developing and putting into place Highly Interactive, Intelligent, Computer-assisted Learning (HIICAL) systems.

HIICAL is no longer “new.” One of my early articles about HIICAL is available at Moursund (2002). The individualization of instruction, the research-based learning theory, and the breadth of content that can be made available through HIICAL systems is well along toward being a mini-singularity. We also now have Massive Open Online Courses (MOOCs) that can simultaneously teach a class of a hundred thousand or more students. As MOOC-based
courseware becomes more and more HIICAL-like and available, it will constitute a mini-singularity of instructional delivery.

While MOOCs were initially designed for higher education, use has spread to the precollege level. For example, (Bull, 11/17/2013) discusses 10 uses at the high school level.

Assessment

We have a steadily growing science of how humans learn, and we know that feedback is an essential component in learning. High-quality feedback, suited to the material being taught/learned as well as to the learning characteristics of the learner can produce faster, better learning.

In education, we make use of formative, summative, and residual impact assessment. See Chapter 7 of Moursund, (2005) for a quick overview of these three types of assessment. All three can be built into a computerized drill-and-practice system and into HIICAL. I find it interesting to watch the current Common Core State Standards project struggle to computerize a summative assessment system. I find this to be an interesting example of the birth struggles of a potential mini-singularity.

Adoption or Acceptance of Mini-singularities

The occurrence of a technology-based mini-singularity is dependent both on the development of the technology and on the widespread adoption and use of the technology. There has been considerable research on the diffusion of (adoption of) innovations. This research literature presents information about four categories of adopters—early, early majority, late majority, and laggards.

The adoption diffusion process is dependent on the unit of adoption. Thus, for example, compare the adoption process of individual people deciding whether to buy a Smartphone versus the diffusion process of whether a state will adopt CCSS and its online summative evaluation system. In the former case we have millions of individual consumers able to make an adopt/not adopt decision. In the latter case, we have 50 states and the District of Columbia each making an individual adoption decision.

Final Remarks

Content, instruction, and assessment are interwoven in education. We already have technology-based mini-singularities in each of these areas.

Typically, an early adopter of computer technology in one component of education—such as sophisticated drill-and-practice software—is actually making an across-the-board adoption of a change in content, instructional processes, and evaluation. Thus, some of the potential educational mini-singularities are sneaking up on us. The large number of individual parents and students making decisions on computer use in education are paving a road to eventual massive adoption of computer technology throughout curriculum, instruction, and assessment. The result will be a “large” mini-singularity in our education systems.

What You Can Do

Introduce your students to the general idea of technological singularity and to specific examples of mini-singularities. You and your students can work together to discover and explore mini-singularities that are relevant to the content, instruction, and evaluation for the course.
material they are learning from you. See Moursund (2015) to learn more about self-assessment and to access a number of self-assessment instruments available free on the Web.

If your students have reached a level in which they can make effective use of self-assessment instruments, use such materials as an example of a mini-singularity that is developing in the assessment component of education. You might try the following assignment.

In this assignment, students are asked to select a topic or area that is personally interesting to them. If you think it is necessary, then add the requirement that the topic or area must be in some way related to the course you are teaching. But be aware that this requirement may damage intrinsic motivation on the part of your students to take the assignment seriously!

Select a topic or area that interests you. Decide on ways in which you can measure your own current knowledge and skills in this area. Then decide on a plan of action to improve your knowledge and skills, and carry your plan out for a “reasonable” period of time. Then assess yourself to see what progress you have made. Finally, produce a written or oral report on the overall process you carried out and the progress you made.

Note that developing skill in carrying out such an assignment—and gradually incorporating use of this skill into one’s overall life routines—can be thought of as developing a personal mini-singularity.
Chapter 8: Final Final Remarks

For many years, the pace of technological change has challenged and then outstripped the pace of change of our educational systems. This might be an acceptable situation if technology and education were unrelated or only loosely related. However, that is not the case.

Over the past two hundred years, our educational system has adjusted by making elementary school nearly universal, by increasing the number of required years of precollege education so the widely accepted goal is now a high school diploma, and by building an extensive post-secondary system of schools and programs of study. In the U.S., there is strong pressure for still more students to attain a two-year or four-year college degree.

We can still increase the number of school days in a year and get still more students into post-secondary programs of study. We can make education more of a lifelong endeavor. But eventually, more and more time devoted to formal schooling will not help us to keep up with the pace of change of computer technology.

Employment and the Distribution of Wealth

Computer-related technology is not only changing rapidly, the rate of change is accelerating. During the Industrial Revolution, the changes affected some people more than others, and the nature of industrial manufacturing changed greatly. Many people lost their jobs, but many more jobs were created. The average standard of living increased substantially. The United States and other “developed” nationals had a substantial increase in middle-income jobs. Lots of these jobs required less than a high school diploma, or only just a high school education.

In the developed nations, this situation is now long past. The number of middle class jobs has shrunk substantially. Post-secondary school is now common, and even with a bachelor’s degree many job seekers have to take jobs that do not pay middle class wages. It is possible that many of today’s children in the developed nations will not do as well financially as their parents have done.

It is, of course, difficult to accurately predict how well today’s children will do financially as adults compared to how well their parents have done. It used to be that the “rising tide” of our nation’s success would “raise most ships.” It is possible that this is no longer the case—instead, the rich are getting a considerably disproportionate amount of the nation’s increasing wealth. The Pew Research Center has surveyed current adults’ opinion on this subject. Quoting from the link:

…the public has somewhat conflicted views about the economic prospects for the next generation. When asked about the future prospects of “children today,” Americans generally said that when today’s kids grow up, they would be worse off financially than their parents. Nearly two-in-three respondents expressed that view in a Pew Research Center survey conducted in spring 2013. It is an opinion that was shared by rich and poor, young and old, men and women. Similar if not greater pessimism was also apparent in 10 of 13 advanced nations polled by Pew Research’s Global Attitudes Project.

In addition, there is a growing accumulation of wealth at the top end. Quoting from the Wikipedia:

Wealth inequality in the United States (also known as the wealth gap) refers to the unequal distribution of assets among residents of the United States. Wealth includes the
values of homes, automobiles, personal valuables, businesses, savings, and investments. Just prior to President Obama's 2014 State of the Union Address, media reported that the top wealthiest 1% possess 40% of the nation’s wealth; the bottom 80% own 7%; similarly, but later, the media reported, the "richest 1 percent in the United States now own more wealth than the bottom 90 percent"….In Inequality for All—a 2013 documentary with Robert Reich in which he argued that income inequality is the defining issue for the United States—Reich states that 95% of economic gains went to the top 1% net worth (HNWI) since 2009 when the recovery allegedly started.

**Improving Education is (Still) Part of the Answer**

The problems of job and income inequality are largely political problems. However, education plays a major role for two reasons:

1. Voters need to understand the complexity of these problems and possible solutions. They need to understand the following quote:

   “There is always an easy solution to every human problem—neat, plausible, and wrong.”

   (Henry Louis “H.L.” Mencken; American journalist, essayist, editor; 1880-1956.)

2. We have many years of experience in which people learned to work with machines that supplemented and extended their physical capabilities. The issues having to do with this type of automation have largely been identified and dealt with in a reasonably satisfactory manner.

   Such is not the case for machines that supplement and extend our cognitive capabilities. We need an educational system that prepares students for responsible and satisfying adult lives in a world where computers and robots will become increasingly more capable. Employment success will occur more often for those who can combine their own physical and cognitive strengths with those of computers and robots.

   Interestingly, we have known about idea (2) above for a long time. Quoting from J.C.R. Licklider’s 1960 paper on Man-Computer Symbiosis:

   Man-computer symbiosis is an expected development in cooperative interaction between men and electronic computers. It will involve very close coupling between the human and the electronic members of the partnership. The main aims are 1) to let computers facilitate formulative thinking as they now facilitate the solution of formulated problems, and 2) to enable men and computers to cooperate in making decisions and controlling complex situations without inflexible dependence on predetermined programs. In the anticipated symbiotic partnership, men will set the goals, formulate the hypotheses, determine the criteria, and perform the evaluations. Computing machines will do the routinizable work that must be done to prepare the way for insights and decisions in technical and scientific thinking. Preliminary analyses indicate that the symbiotic partnership will perform intellectual operations much more effectively than man alone can perform them (Licklider, 1960).
Appendix A: Some General Goals of Education

In 1997-1988, my colleague Dick Ricketts and I spent considerable time analyzing the commonly discussed goals of education and we published our findings as an appendix in Long-range Planning for Computers in Schools (Moursund & Ricketts, 1988). Since then I have used this list in teaching many different courses and in several of my books. Over the years, I have refined and updated the list a number of times.

The list has been divided into three categories: Conserving Goals, Achieving Goals, and Accountability Goals. In most societies, education has a major goal of conserving and preserving the culture and values of the society. Interestingly, this tends to create some stress between Conserving Goals and Achieving Goals. As students gain increasing knowledge and skills, they sometimes rebel against the conservative nature of schools and their society.

Conserving Goals

G1 Security: All students are safe from emotional and physical harm. Both formal and informal educational systems must provide a safe and secure environment designed to promote learning.

Comment: In recent years there has been a great deal of media coverage about potential physical and emotional harm that students may encounter in school. This includes bullying, shootings, and access to inappropriate information through use of the Internet.

G2 Values and Diversity: All students respect individual differences and the traditional values of the family, community, state, nation, and world in which they live.


Reaffirming the purposes and principles of the Charter of the United Nations with regard to the promotion and encouragement of respect for all human rights and fundamental freedoms for all without distinction as to race, sex, language or religion,

Reaffirming also that every individual and every organ of society shall strive by teaching and education to promote respect for human rights and fundamental freedoms,

Reaffirming further that everyone has the right to education, and that education shall be directed to the full development of the human personality and the sense of its dignity, and enable all persons to participate effectively in a free society and promote understanding, tolerance and friendship among all nations and all racial, ethnic or religious groups, and further the activities of the United Nations for the maintenance of peace, security and the promotion of development and human rights…

G3 Sustainability: All students value a healthy and sustainable local, regional, national, and global environment, and they knowingly work to improve the quality of the environment.

Comment: The following is quoted from http://en.wikipedia.org/wiki/Sustainability:
…since the 1980s sustainability has been used more in the sense of human sustainability on planet Earth and this has resulted in the most widely quoted definition of sustainability as a part of the concept of sustainable development, that of the Brundtland Commission of the United Nations on March 20, 1987 (http://en.wikipedia.org/wiki/Brundtland_Commission): “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

At the 2005 World Summit on Social Development it was noted that sustainability requires the reconciliation of environmental, social equity, and economic demands—the "three pillars" of sustainability…

Achieving Goals

**G4 Full Potential:** All students are knowingly working toward achieving and increasing their healthful physical, mental, and emotional lifelong potentials.

Comment: Notice the emphasis on students “knowingly” working to increase their potentials. The goal is to empower students to empower themselves to develop lifelong physical and mental habits that promote and sustain personal well-being.

**G5 Basic Skills:** All students gain a working knowledge of speaking and listening; observing (including visual literacy); reading and writing; mathematics; logic; and the storage, retrieval, and communication of information. All students learn to solve problems, accomplish tasks, deal with novel situations, and carry out other higher-order cognitive activities that make use of these basic skills.

Comment: Basic skills tend to have long (perhaps lifelong) value. However, new developments can change existing basic skills and add new basic skills. For example, the fluent use of Information and Communications Technology systems is an emerging basic skill.

**G6 Setting and Achieving Personal Learning Goals:** An alternate title for this goal is Self-assessment and Self-improvement. All students learn to self-assess, set personal goals based on these assessments, and work to achieve these personal goals.

Comment: This goal focuses on a person taking personal responsibility for their own education. Such knowledge and skills, along with self-understanding of one's interests, intrinsic motivation, drives, and ambition, can serve a person through their lifetime.

**G7 General Education:** All students have appreciation for, knowledge about, and understanding of a number of general areas of education, including:

- Artistic, intellectual, scientific, social, and technical accomplishments of humanity.
- Cultures and cultural diversity.
- Geography.
- Governments and governance.
- Health and medicine.
- Nature in its diversity and interconnectedness.
Religions and religious diversity.

Science, technology, engineering, and mathematics (STEM).

Social science.

Comment: A good education is a balance between breadth and depth, and it varies considerably from person to person. “Try to learn something about everything and everything about something.” (Thomas H. Huxley; English writer; 1825-1895.)

**G8 Lifelong Learning:** All students learn how to learn and how to make effective use of what they learn. They have the inquiring attitude and self-confidence that allows them to pursue life’s options. They have the knowledge and skills needed to deal effectively with changes that affect them.

Comment: The pace of technology-based change is quickening, and the total collection of human knowledge is growing very rapidly. All students need to develop lifelong habits of mind that help them to gain the knowledge, skills, and understanding needed to effectively accommodate ongoing change. Some current areas of rapid change include genetics (genome projects), nanotechnology, cognitive neuroscience, medicine, and computer technology.

**G9 Problem Solving:** All students make use of decision-making and problem-solving skills and tools, including the higher-order skills of analysis, synthesis, and evaluation. All students pose and solve problems, making routine and creative use of their overall knowledge and skills, and of the currently available technologies.

Comment: Recognizing, understanding, clearly communicating, and effectively working to solve problems lie at the heart of each academic discipline.

**G10 Productive Citizenship:** All students act as informed, productive, and responsible members of countries, of organizations to which they give allegiance, and as members of humanity as a whole.

Comment: The world is growing smaller. In some sense, each person is a citizen of the world, one or more countries, one or more states/provinces, and so on. During a lifetime, a person is apt to hold a variety of jobs and/or pursue a variety of careers. A person is apt to belong to a variety of organizations and/or groups.

**G11 Social Skills:** All students interact publicly and privately with peers and adults in a socially acceptable and positive fashion.

Comment: Information and Communication Technology has brought us new forms of communication and social interaction, including email, computer conferencing, Smartphones, and social networking.

**G12 Information and Communication Technology (ICT):** All students have appropriate knowledge and skills for using our rapidly changing ICT as well as related technologies relevant to their lives and our world.

Comment: ICT is both a discipline in its own right and a driving force for change in education and in many different areas of technology, science, and research. Computational thinking is becoming a standard complement of each academic discipline (Moursund, 2013).
Accountability Goals

G13 Assessment: The various components of an educational system that contribute to accomplishing the goals (such as those listed above) are assessed in a timely and appropriate manner. The assessments provide formative, summative, and long-term residual impact evaluative data that can be used in maintaining and improving the quality of the educational system.

Comment: Accountability and assessment are strongly intertwined. In the past two decades, the issue of authentic assessment has received a lot of attention. As ICT is more thoroughly integrated into curriculum content, authentic assessment of student learning becomes a new challenge to educational systems. Electronic portfolios are gradually increasing in importance as an aid to authentic assessment.

G14 Accountability: All educational systems are accountable to key stakeholder groups, including:

Students.

Parents and other caregivers of the students.

Teachers, administrators, school board members, and all employees and volunteers in educational systems.

Voters, taxpayers, and funding agencies.

Employers.

Comment: Accountability includes gathering and effectively using information from formative, summative, and long-term residual impact assessments that are fair, reliable, valid, and timely. It is difficult to make changes to our educational system because of the need to address the widely divergent interests of the various stakeholders. However, this democratic approach to our educational system is one of its strengths.

An educational system is a compromise among known teaching and learning theories, current and other possible teaching practices, and stakeholders. The complexity of an educational system and its compromises makes it difficult to substantially improve the system. However, there are powerful change agents at work, such as Information and Communication Technology, research in cognitive neuroscience, and national and global competition. We now have the technology and research base to substantially improve education.
References


Suggested IAE Readings


