The Future of AI in Our Schools

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Brief Summary

I consider AI-using computers to be the largest change agent in human history since the development of written language some 5,500 years ago. The development of reading and writing led to the creation of the first schools. These early schools taught reading, writing, arithmetic (based on using reading and writing), and history.

The Future of AI in Our Schools draws a parallel between the human development of reading and writing, and the human development of computer-based artificial intelligence. Both help to solve the problems and accomplish the tasks that are the bedrock of current school curricula as well as every other discipline of study.

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Dedication

This book is dedicated to teachers throughout the world.

Table of Contents

Preface

"When I was just a little girl
I asked my mother, what will I be?
Will I be pretty?
Will I be rich?
Here's what she said to me,
Que sera, sera,
Whatever will be, will be.
The future's not ours to see,
Que sera, sera,
What will be, will be"
(Song by Jay Livingston and Ray Evans, link.)

Introduction

My goal is to help to improve the lives of all people and also all other life on earth. This Preface summarizes some of my current thinking about ways to make more effective uses of our rapidly growing Artificial Intelligence (AI) capabilities as we work toward achieving this goal.

To get us started, here are some historical milestones that seem important to me:

1. Our universe was formed by something often referred to as the *Big Bang* that occurred about 13.8 billion years ago. I chuckle when I say *years ago,* since a year is the length of time for our earth to revolve around our sun. Neither our sun nor our earth existed before about 4.5 billion years ago, so they are only about one third as old as our universe.
2. The earliest time that life forms first appeared on earth was 3.77 billion years ago. (It may have been as much as a half-billion years earlier.) In any case, life on earth is very old relative to that of current Homo Sapiens.
3. Homo Sapiens evolved from chimpanzees over a period of six or seven million years (Exploratorium, 2009, link). This occurred in a series of evolutionary steps separated by more than a million years. The most recent step, which occurred about 200,000 years ago, produced us Homo Sapiens. Physically and mentally, we current humans are genetically about the same as we were 200,000 years ago. And, somewhat surprising to me, we are not a whole lot genetically different from the chimpanzees from which we evolved.

   > Humans and chimps share a surprising 98.8 percent of their DNA. How can we be so similar–and yet so different?
   >
   > …
   >
   > Human and chimp DNA is so similar because the two species are so closely related. Humans, chimps and bonobos descended from a single ancestor species that lived six or seven million years ago. As humans and chimps gradually evolved from a common ancestor, their DNA, passed from generation to generation, changed a little each time (American Museum of Natural History, 2021, link).

4. I am amazed when I read about current humans evolving from chimpanzees over a period of only six or seven million years. That pace of evolutionary change seems quite amazing to me, but six or seven million years is a long period of time relative to the lifetime of current humans. Remember, life on earth has had well over 500 times that many years of evolution that started with the first life forms and produced the apes.

5. Many creatures have an oral communication system, but only we humans have the very large wide-scale vocabulary oral language that we call *speech.* This required the evolution of prehumans to having both the physical capabilities (a larynx, for example) as well as the cognitive capabilities that we currently have. What we call our *oral tradition* is unique among all life forms on earth.
6. We have good evidence of early writing being developed about 5,500 years ago (Wikipedia, 2021f, link). Notice that this development was done by Homo Sapiens that had been on earth for approximately 200 thousand years. **It was humans themselves, rather than evolution, that developed written language.** I think of this step as being somewhat similar to an evolutionary step, but it did not require a specific change in our genetic makeup to occur at that time.
7. Less than 90 years ago humans began to invent and build electronic digital computers. In1956, a group of researchers came together to discuss the emerging ideas of computer-based Artificial Intelligence. (Dartmouth, n.d., link.) I think of this step as being somewhat similar to an evolutionary step, but it did not require a specific change in our genetic makeup to occur at that time.

In brief summary, evolution led to Homo Sapiens having their current intelligence and oral languages, while it was the ingenuity and creativeness of humans that led to the development of written language and AI. It is possible, of course, that Homo Sapiens will continue to evolve, either by themselves or through some combination of evolution and genetic engineering, into creatures that have far more inherent abilities than current Homo Sapiens. However, the time frame for evolutionary change is very long relative to the time frame in which written language and computer-based AI have been developed. You and I just happen to be living during the time when computer-based AI has been developed, and when its capabilities are increasing rapidly.

I believe it is reasonable to conjecture that *natural* evolution is not apt to produce significant changes in human capabilities in the next 10,000 years or so. Thus, during the next 10,000 years, the changes in human capabilities will be via the aids that we produce for ourselves, and through our own genetic engineering of ourselves.

Other Examples of Non-evolutionary Change

Genetic engineering by humans on plants, animals, and ourselves is different from the evolutionary processes that produced them and us. In recent centuries, humans have made some changes on themselves that are vaguely like genetic changes, but (so far) are not considered to be genetic changes. For example, in essence we have come close to eradicating various diseases through vaccination. Current literature indicates that we have eradicated the human disease smallpox, and an animal disease named rinderpest (Wikipedia, 2021a, link); World Organization for Animal Health, 11/22/2018, link).

At various times in recorded history, humans have experienced epidemics that seriously sickened or killed a significant percentage of the infected population. We eventually learned enough about some of these serious diseases to develop vaccinations. It may seem like a little stretch of the vocabulary, but I like to think of a vaccination as a type of non-evolutionary change in our bodies. That is, the vaccination increases the *intelligence* or *capability* of our disease-fighting systems. A vaccination might last for a lifetime, or perhaps revaccination may be necessary after a number of years. Some vaccinations even provide some protection to the unborn child of a pregnant woman who receives the vaccination (Greenwood, 2014, link).

Next, let's consider a quite different type of change that we humans are bringing about in our own species. We have had schools to teach reading, writing, and arithmetic since shortly after the development of reading and writing. We developed these schools as a way to pass on literacy to our children. In some sense, this is like developing the vaccinations that we inject into our children to prevent our children from getting various diseases.

Survival of the fittest has genetically produced some humans who are more resistant to various diseases than are others. This is a genetic evolutionary process. In contrast, our deliberately working to eradicate a disease is a human process quite different from natural evolution. Thus, we have evolution working to eradicate certain diseases, and we have current human science and medicine working to eradicate certain diseases.

Neither the vaccinations nor the schooling produce permanent changes in human beings that can be passed on genetically from one generation to the next. But, they are major non-genetic changes in people that we can pass on from generation to generation. So, in my mind they are somewhat like an evolutionary change.

Where We Are Now

Roughly six to seven million years of evolution have taken us from chimpanzee-types of creatures to current Homo Sapiens. We humans are physically different from our prehumen ancestors, but we certainly are not physically superior to them. Where we differ is in our cognitive abilities. We have a long history of using our cognitive abilities to develop tools to aid our physical abilities.

I find it interesting to think about the fact that it took nearly 5,000 years to move from the development of reading and writing to the development of the movable type printing press for printing books and newspapers. Technological progress is much faster than evolutionary progress, but it still can take considerable time.

The rapid acceleration of the pace of technological progress in the past two hundred years has been astonishing! We have developed trains, cars, and airplanes that now are common aids to transportation. We have developed space travel. We have developed electricity, electric generators, and storage batteries as an important aid to the everyday lives of much of the earth's people. We have developed radio, television, telephones, cell phones and other aids to communication that (in retrospect) are mind blowing. Current computers and AI far outperform humans in many cognitive areas that we humans consider to be important. We accept these changes and, in general, are not bothered by the fact that the change has occurred.

We are only at the beginning of discovering and implementing the full range of capabilities of AI. The progress that has occurred so far has led some people to begin serious discussions about the future possibility of computers becoming more intelligent than humans over a very broad range of problem solving and task accomplishing activities that currently require the use of brain power. Some people worry about a coming *Technological Singularity*, a time when AI-based computers have more human-like intelligence than humans over the full broad range of human intellectual activities (Wikipedia, 2021j, link).

Final Remarks

You and I just happen to be living at a time when AI and electronic digital computers have been developed, and are increasing rapidly in their combined capabilities. My dream for this

oncoming future is that Homo Sapiens will make effective use of our continuing rapid technological progress to produce a good and sustainable quality of life for all humans, and also to create a balance with nature in which a huge range of forms of life are preserved and prosper.

Chapter 1
Artificial Intelligence

> "The hardest problems we have to face do not come from philosophical questions about whether brains are machines or not. There is not the slightest reason to doubt that brains are anything other than machines with enormous numbers of parts that work in perfect accord with physical laws. As far as anyone can tell, our minds are merely complex processes. The serious problems come from our having had so little experience with machines of such complexity that we are not yet prepared to think effectively about them." (Marvin Minsky; MIT professor and co-founder of the Massachusetts Institute of Technology's AI laboratory; 1927-2016.)
>
> "For more than 250 years the fundamental drivers of economic growth have been technological innovations. The most important of these are what economists call general-purpose technologies — a category that includes the steam engine, electricity, and the internal combustion engine. **The most important general-purpose technology of our era is artificial intelligence, particularly machine learning.**" (Erik Brynjolfsson and Andrew McAfee; Co-authors of several recent books, including *The Second Machine Age*.)

Introduction

I have followed the progress of Artificial Intelligence (AI) for many years. Over these years, AI has shown that it currently is and will continue to be a major change agent in our world. The corporate world is well aware of this, and is investing heavily in developing and implementing changes. For example, I just read the following announcement of an event being scheduled by IBM:

> Examine the ways advanced wireless technologies, including 5G and Wifi 6, accelerate and advance innovation through AI, the cloud, and the Internet of Things.
>
> Hear how IBM is moving away from infrastructure services and full speed ahead toward a future built on AI and hybrid cloud, and ultimately, quantum computing. (IBM, 12/19/2020, link).

Such change and its underlying vision of the future is now common in the corporate world. It is much less so in the world of education.

This chapter provides background information that will be useful as you read the entire book. It also offers insights into some of the types of problems that AI is addressing, and the progress that is being made. Subsequent chapters address changes needed in our goals of education in order to prepare out students for life in this everchanging world.

AI As a Change Agent

Increasingly, experts in the field of AI and education are beginning to understand the potentials for AI to make significant contributions to our ongoing efforts to improve education. They (and I) believe that, over the next decade, we will see very large changes in our formal and informal educational systems due to the increasing capabilities of AI, as well as to the increasing

availability and quality of the infrastructure required to make this capability readily available to learners of all ages.

The quote from Marvin Minsky given at the beginning of this chapter shows considerable foresight into the challenges faced by the emerging AI field. He was a pioneer in this field who made a number of major contributions during his long career.

In 2011, I wrote an *IAE Blog* about Artificial Intelligence and Artificial Muscle (Moursund, 2/16/2011). The blog poked fun at the idea that humans and prehumans have been developing tools to enhance their physical capabilities for more than three million years, but never referred to them as *artificial muscle*. Reading and writing obviously are tools to enhance the human brain, but they were never called *artificial brain* or *artificial intelligence.* Tools such as an abacus or calculator were never considered to be *artificial brains*, although they certainly are aids to our brain's capabilities.

I first became interested in learning about computers and AI shortly before beginning my doctoral studies in mathematics at the University of Wisconsin in 1963. By then, programmable electronic digital computers had been commercially available for more than ten years, and were already in wide use. The field of AI had been defined and established seven years earlier.

One requirement of my doctoral program was to demonstrate the ability to read mathematics texts written in two foreign languages. I chose French and German because I had two years of high school French and had completed second year German as a university undergraduate. I was not particularly good in languages, but I studied and practiced diligently and passed both tests on my first tries.

By that time, progress was already occurring in the development of language translation programs, and I wondered how soon AI would become quite successful in this endeavor. It certainly is fortunate that I persisted on my own, because it has taken more than 50 years of further progress since my graduate school days for language translation programs to become good enough to meet some of our contemporary needs. AI still has a long way to go in language translation before it becomes as good as human experts.

So, when you read about the potentials of AI to substantially improve education during the next five to ten years, be very suspicious. The long history of computer-based language translation will help to increase your insights into the challenges.

AI and Language Translation

Language translation has proven to be a very difficult problem in AI, and there are a number of funny stories about its early failures. One measure of the success of translation programs is to use them to both translate some text into another language, and then to translate the resulting translation back into the original language. The following is an amusing example:

> Rumors have it that early modules for English to Russian have mistranslated some idioms with amusing results. Translating the phrase "The spirit was willing, but the flesh was weak" to Russian and back to English resulted in: "The vodka was good, but the meat was rotten." Likewise "out of sight, out of mind" reportedly yielded the phrase "blind and insane." (Mikkelson, n.d., link.)

I recently used Google Translate to translate the paragraph quoted above, first into Russian and then back into English. Here is the English language result:

> It is rumored that some idioms were incorrectly translated from English to Russian in the early modules, which led to funny results. The translation of the phrase "The spirit was ready, but the flesh was weak" into Russian and back into English led to the following: "The vodka was good, but the meat was rotten." Likewise, the phrase "out of sight, out of mind" is reported to have morphed into the phrase "blind and insane."

Wow, not bad! Notice such changes as:

- *Rumors have it* was translated into *It is rumored that*.
- *The spirit was willing* was translated into *The spirit was ready.*
- Also note that the translation inserted a comma after the word *Likewise.*

However, the translation of *the flesh was weak* into *the meat was rotten* misses the original meaning entirely. It is clear that a computer translating from one language to another has absolutely no understanding of the meaning of what it is translating. It is amazing that computers can do a fairly good job of translation without having any understanding.

Here is a personal example. After I finished writing my 2018 book, *The Fourth R (Second Edition),* I used Google Translate to experiment with translating a short summary of the book. I was amused by the results of translating the following from English into Russian and then back into English. Here is the original English sentence:

> Like Reading, Writing, and Arithmetic (Reading, 'Riting, and 'Rithmetic), the 4th R of Reasoning/Computational Thinking is both a discipline of study in its own right as well as being an aid to representing and solving problems throughout the curriculum and at all grade levels.

In the 2018 Google Translate program, the computer decided that the *R* in the *4th R* above was an abbreviation for *Ruble*, a unit of money in Russian. So, this translation back into English demonstrated that the 2018 translation program had no understanding of what I was trying to say.

I used the same paragraph to repeat my language translation experiment on December 12, 2020, and achieved the translation:

> Like reading, writing, and arithmetic (reading, drawing and rhyming), Level 4 Reasoning / Computational Thinking is both a discipline in itself and a means of representing and solving problems within the curriculum and at all levels of learning.

This was an improvement over the 2018 result. However, the computer translates *writing and arithmetic* as *drawing and rhyming.* This clearly shows the difficulty of the computer not understanding that the *3 R's* is a phrase commonly used in talking about reading, writing, and arithmetic in the elementary school curriculum in the United States.

It is very important to understand that, although Google Translate and other language translation programs are continuing to be improved, they definitely have not achieved the capabilities of good human translators.

In essence, this problem of a lack of understanding runs through all current applications of AI. While AI is indeed a very powerful aid to solving a wide range of problems, it currently is achieving this with no underlying understanding of the problem being solved, nor of the task being accomplished. Humans far exceed computers in this particular aspect of intelligence. Humans doing simultaneous translations by speakers of two different languages are able to

receive and understand the input, and then instantly translate the meaning of the input into the second language.

As we explore both the current and possible future uses of AI in education, we need to be aware that the overall field of AI has made substantial progress, and currently still is making rapid progress. This is both because of more powerful computers becoming available, and also because throughout the world a large number of very smart and dedicated researchers are working to improve the capabilities of AI.

Exact Solutions Versus *Useful* or *Good Enough* Solutions

Suppose that I need to find the product of two 4-digit integers. This problem has exactly one correct answer. I might calculate this answer using pencil and paper, a calculator, or a computer. Or, when I do not really need an exact answer, I can make a mental estimate of an answer that may well be accurate enough to meet my needs. In my attempts to obtain an exact answer, I might make a mistake in entering the data or doing the calculation. And, although it is highly unlikely, the calculator or computer might make an error. In both cases, a mental estimate might help me to detect any error in these results.

This is a very important idea that I will discuss it more in later chapters. Think about the many decisions you make as you proceed through a day. How many of these decisions are correct because they are based on exactness in the information and thinking used in the decision? My point is that there are some situations when a high level of accuracy or exactness is desirable or necessary, but most of life is not that way. And, just because it is a computer that is making the decision, we should not automatically think that every computer-made decision represents perfection.

For example, suppose that a physician is making a medical diagnosis and prescribing a treatment. If you are the patient, you might be satisfied to hear the physician say “I have considerable knowledge about the ailment and how to treat it.” The physician might be able to tell you of encountering this problem many times before, that a variety of treatments have been tried, and they have had varying levels of success. Then you and the physician would carry on a conversation about the next possible steps that might be taken.

Finally, consider the same scenario, but in this case the physician is an AI-based system. It tells you that, while examining and talking to you, it has simultaneously retrieved and read 1,000 recent research papers on this ailment, and its recommended treatment is based on this research. However, it notes that success levels have varied considerably, as have the side effects.

Hmm. I’ll bet you would like to carry on a conversation with your AI-based physician before deciding on your next step. Unfortunately, today’s AI systems are not up to this conversational task. This illustrates an absolutely fundamental idea about AI uses in education. The AI systems of the future will be making decisions that affect students, and it is likely that neither the students nor their teachers will really know the basis for these decisions or the likelihood of possible outcomes.

A Challenge to Traditional Schooling

You undoubtedly are familiar with the fact that a computer program defeated the world’s reigning chess champion many years ago. More recently, another computer program became far better than any human players at playing the game of Go. There is no claim that each move the

computer makes in playing chess or Go was a perfect move. However, in total, the computer's moves were *good enough* to defeat its human opponent. Moreover, such an AI-based computer program can learn to play still better by playing games against itself.

However, the computer is unable to provide humans with a good human-understandable explanation for why it makes each move that it makes. Computers can defeat expert human opponents in many other different games. In all of these games, there is the concept of *winning or losing*. But, what does *winning or losing* mean in the education of a child? A child is not an opponent, and I certainly do not know what it means for a computer to *win* in the *game* of educating a child. With the help of AI, we can develop computer programs that are quite good at some aspects of teaching. If we decide that our goal is for large groups of students to do well on certain types of tests, then we can develop computer programs that are better than the humans who are teaching classes of 20 to 30 or more students. But, education is far more than obtaining high scores on tests.

It seems to me that researchers and implementors of AI as aids to teaching and learning face a daunting task. Users need assurance that, for each individual student, the decisions made by the computerized teaching machines will meet standards that are clear, understandable, and readily available.

First, consider a very simple case. A company develops AI-based Computer-Assisted Learning (CAL) materials that are designed specifically to help students prepare for and do well on a quite specific test, such as a widely-used college entrance exam. The company employs one or more highly reputable educational research organizations to do research on the effectiveness of their company's materials versus those of other companies, and also in comparison with other approaches students take in preparing for the exam.

These research studies meet high standards for reliability and validity. The results of the studies provide solid evidence that the company's materials are effective, both from a statistical point of view and from other points of view. The *other points* may include such things as the fact that the test score increases are of practical significance—large enough to make a meaningful difference to the students and to the people who make use of the test scores—and are an efficient use of a student's study time.

So, if a student's goal is to score well on this test, the use of the AI-based CAL will likely be helpful. **That does not make the student any more intelligent nor any more likely to do well in college.**

Next, consider larger aspects of education that are not measured by widely used standardized tests. This covers all of the materials currently used in the day-to-day education of students across a number of curriculum areas and in schools across the country. This presents a huge challenge in measuring the effectiveness of CAL, one that so far has not been addressed effectively in any of the curriculum areas that commonly are taught in schools in the United States. Countries that have a national curriculum have a distinct advantage in this regard, since their national standards are to a certain extent measurable, and can be accessed uniformly across all of their school systems.

In a recent *IAE Newsletter*, I proposed that the U.S. Federal Government pay for the development and regular updating of a large number of AI-based CAL precollege courses that then would be made available free, both in the U.S. and worldwide (Moursund, 11/16/2020). A

key idea in this proposal is a requirement that there be ongoing research on the effectiveness and impacts of the courses. There also would be major ongoing research on ways to improve these courses, including ways that make effective use of continuing progress in AI and other aspects of Information and Communication Technology (ICT). What do you think? Would you like our government or a collection of very reliable non-profit companies to undertake this task?

Final Remarks

The issue is not whether computers can be used effectively to help teach students. Rather, the question is about the quality of teaching, and the overall nature of learning that occurs in computer-student interactions versus human teacher-student interactions, interactions between and among students in the classroom, student-parent interactions, and so on. It appears obvious to me that, both now and for quite some time to come, education can be improved by an appropriate balance among these types of interactions. It would be a major mistake to greatly decrease the human elements that are of major importance in education today.

Information and Communication Technology (ICT) has made amazing progress during my lifetime. The pace of this progress has increased over the years, and continues to increase ever more rapidly. Our schooling systems certainly have made substantial progress since the first schools were developed nearly 5,500 years ago. They now are attempting to determine the changes needed in curriculum content, teaching processes, and assessment in order to make more effective use of steadily improving ICT. At the same time, schools need to help prepare students for adult life in this changing world. These are daunting tasks!

The next chapter takes a closer look at the goals of education. It address many of the ongoing changes in our world, together with a discussion of the ways that progress in AI and other aspects of ICT can and should be affecting our current schooling goals.

Chapter 2
Goals of Education

> "It isn't enough just to learn—one must learn how to learn, how to learn without classrooms, without teachers, without textbooks. Learn, in short, how to think and analyze and decide and discover and create." (Michael Bassis; American educator and author; 1946-.)

> "When you spoke of a nature gifted or not gifted in any respect, did you mean to say that one man may acquire a thing easily, another with difficulty; a little learning will lead the one to discover a great deal; whereas the other, after much study and application no sooner learns then he forgets." (Plato; Classical Greek philosopher, mathematician, writer of philosophical dialogues, and founder of the Academy in Athens, the first institution of higher learning in the western world; 428/427 BC-348/347 BC.)

Introduction

It is easy to say that we want to improve education. It is much more difficult to get wide agreement on what constitutes *education*, what would constitute an *improvement* in education, and what we actually can do to achieve widespread implementation of improvements. This chapter contains some of my thoughts on these challenges.

As I think about improving education, I always am drawn back to the issue of what the nebulous *they* should do versus what any concerned individual such as you or I might do. The *they* is groups, organizations, lawmakers, school boards, for-profit and nonprofit companies, and so on. As you read this chapter, pause from time to time and think about its relevance to yourself and what you currently are doing to improve education.

It is clear to me that significantly improving education will require a large number of *theys* as well as a large number of individual people working to better achieve goals that are mutually agreed upon. The individual people, including parents, teachers, siblings, and so on who work directly with children, are an essential component of any project to improve education.

No two human brains—even those of identical twins—are actually identical. In education, the *one size fits all* approach has some merits. However, we have long known that this is in no sense optimal. We know that people vary considerably. This reminds me of the above quotation from Plato that introduces this chapter.

Individualization of each child's education begins in the womb, and it continues throughout life. Just think of the differences in life experiences each child has during the early years before beginning formal schooling. So, as we work to improve education, we are faced both by the individual physical and cognitive differences of children, and by the differences in their educations that began well before birth and continues day after day both in and outside of the school environment.

Goals of Education

Your brain is active and learning every day, 24 hours a day. It is continually receiving and processing information from your external and internal senses, and from information stored in your brain. For millions of years prehumans and humans were educated by a combination of learning through the schools of hard knocks, imitation, and apprenticeship. The types of schools we are so dependent upon today did not exist.

Schools were developed to help students achieve certain learning objectives that can taught reasonably well and at reasonable cost to groups of students. As written language was being developed some 5,500 years ago, some formal schools were developed to teach groups of people reading, writing, arithmetic, and history.

Over thousands of years, the goals of education were gradually increased. In 1987, my colleague Dick Ricketts and I collaborated in a book-writing project that included creating a list of goals in education currently being used in K-12 schools. After many years of being a secondary school teacher of social studies and history, Ricketts entered my graduate programs in the field of computers in education, and received his doctorate in 1985. We published *Long-range Planning for Computers in Schools* in 1988, and the book includes the initial goals of education that we developed. I have updated this list of goals several times over the years with the most recent version now available as an article in the *IAE-pedia* (Moursund & Ricketts. 6/12/2020). The following quote is from the *IAE-pedia* article:

> The early part of my teaching career focused on teaching math and uses of computers to help solve math problems. I built on this background as I first began teaching teachers in summer institute programs funded by the National Science Foundation. At that time, the goals of education seemed clear and simple to me. They were:
>
> 1. To help students learn some facts.
> 2. To help students learn to think, solve challenging problems, and accomplish challenging tasks using the facts.

This still seems to me to be a good way to think about math education. But, the teachers I was trying to teach soon taught me how naïve I was. As I moved more and more into being a math educator, computer educator, and teacher of teachers, I gradually came to understand the complexity of education and the wide range of goals that help to define and drive our educational system.

What follows are very brief statements of 14 goals presented in the *IAE-pedia* document cited above. In this list, I have moved what was originally the twelfth goal to be the first goal in the list below. It is about computers in education. For each goal, I have added a comment about how the goal is being affected by ICT.

G1 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.* Ever since computers began to be available to students in their schools, people have been debating about what students should be learning about computers and their uses. For many years the focus was on what came to be called Computer Literacy. Giving it a name has helped some, but there are widely varying ideas as to what constitutes computer literacy (Moursund, 2016). The debaters face an added challenge that the depth and breadth of the relevant computer technologies and applications continues their rapid

growth. For example, although the term Artificial Intelligence had already been in use for years, early definitions of computer literacy usually did not include a discussion of AI. In the comments given for the remaining goals, I have not placed an emphasis on the more recent progress occurring in Artificial Intelligence. I will discuss some of that progress in subsequent chapters of this book.

G2 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. We have long had an issue regarding who has access to student records. In recent years, there have been a large number of instances of computerized databases of all sorts being broken into (stolen or damaged). This has happened to some student databased in schools, and the amount of such criminal activity has increased substantially in 2020. Because stolen student records can be used to do emotional and physical harm to students, safeguarding these records is a major challenge to schools.

G3 Values and Diversity: All students respect individual differences and the traditional values of the family, community, state, nation, and world in which they live.

Comment. The communication and language translation systems of ICT and AI contribute to making the world smaller. More and more, students need to learn to think globally and to act locally. Remember, we are all citizens of the world. Although the world is in some sense growing smaller due to improved transportation, trading of goods, and communication, prejudices are still widespread and deep.

G4 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 goal as currently stated focuses on environmental sustainability. Environmentalists usually are interested in having an environment that supports humans and also a very wide range of other life. However, the goal can be rewritten so that it has much broader applications. For example, people who are supportive of having free, fully integrated, and high quality, public schools are interested in the sustainability and improvement of our current free public school systems. People who are supportive of all children having the basics that support a decent quality of life want to sustain and improve efforts to provide all children with good housing, food, clothing, health care, education, and so on. A common approach to any sustainability issue is to gather data on the past and present current situation, and analyze this data to detect positive and negative trends. This process continues by examining current activities that may improve or degrade the current situation, then collecting and/or creating proposals that may lead to sustainable improvements. Computers and computer modeling are now routine aids to such research.

G5 Full Potential: All students are knowingly working toward achieving and increasing their healthful physical, mental, and emotional lifelong potentials.

Comment. Artificial Intelligence adds a new dimension to the mental potentials of its users. We have long known that two brains are better than one in many situations. AI-based computer *brains* are not the same as human brains, but people are routinely making use of this type of second brain in an increasing number of situations. Students need an

education that incudes learning to use this second brain resource in each area they study, both in their formal schooling and their informal education.

G6 Basic Skills: All students gain a working knowledge of speaking and listening, observing (including visual literacy), reading and writing, mathematics, logic, and storing, retrieving, and communicating 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. These basic skills have been among the overriding goals of education for a very long time. Knowledge and skills to make effective use of the potentials of ICT in each of the basic skills areas is an obvious way to improve students' capabilities in these areas.

The steadily improving capabilities and availability of computers leads to the question of what now constitutes a basic skill. Is reading and writing cursive still a basic skill? Some schools no longer consider it to be one. Is using a word processor that includes a spelling and grammar checker now a basic skill? How about reading and writing multimedia documents? How about being skilled in learning from Highly Interactive Intelligent Computer-assisted Learning (HIICAL) materials? It is clear to me that the definition of basic skills needs to be expanded to include effective use of a broad range of computer capabilities now in wide use in our country and other parts of the world.

The next chapter of this book includes a focus on the issue of what capabilities and uses of AI now need to be considered basic skills. As an example, for myself as a car driver, use of GPS is a basic skill that I learned on my own. This suggests a need to consider which basic skills can be self-taught when needed, and which one might become part of the required school curriculum.

G7 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. My personal observation is that students are relatively good at self-assessment. It is in *the setting and achieving goals to improve themselves* where many students are weak. Consider the frequent situation where a student sees other students making enjoyable uses of a Smart Phone or a more general purpose computer. The students often realize that they can gain the same skills by taking advantage of personal help from other students. There are many useful computer skills that one can learn this way. An important part of this observation is that many students are being asked to learn content that they do not believe is worthwhile or useful to learn. I return to this specific topic later in the chapter.

G8 General Education: All students have appreciation for, knowledge about, and understanding of a number of general areas of education, including:

- Artificial Intelligence.
- Artistic, including the performing and graphic arts.
- Cultures and cultural diversity.
- Geography.

- Governments and governance.
- Health and medicine.
- Intellectual, scientific, social, and technical accomplishments of humanity.
- Nature in its diversity and interconnectedness.
- Religions and religious diversity.
- Science, technology, engineering, and mathematics (STEM).
- Social sciences: Anthropology, Archaeology, Economics, Geography, History, Law, Linguistics, Politics, Psychology, and Sociology.

  Comment. This goal does not specify any particular level of knowledge and skill in the various disciplines. Each discipline can be studied to the level of a doctorate and beyond. Nowadays, there are well more than a hundred different disciplines in which one can earn a doctorate.

This reminds me of the quotation by Samuel Johnson, the father of the English dictionary, "Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it." (*BrainyQuote,* n.d., link). A key unstated part of Johnson's advice is to know enough about the topic to be able to read and understand the information one can retrieve. With the Internet and Web, a person can access information on essentially any topic. But this is quite different from being able to understand and make use of the information one can retrieve. Thus, we want students to gain an education that facilitates their accessing, learning, and making use of a very broad range of knowledge and skills

> And don't forget that each of the disciplines named above is an area of continued research and growth. The totality of human knowledge is steadily increasing, and our access to it is steadily improving. (Just for the fun of it, I recently used Google to get an estimate of how many medical articles are being published each year. Much to my amazement, Google's response was that currently more than 2.5 million articles are being published each year. Obviously, these are not all new research-based findings. But, that very large number indicates the challenge being faced by medical practitioners. The same general problem exists in every area of human research and publication.

G9 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.* Computer technology provides students with access to a large and versatile set of aids to learning. It also provides access to a huge range of content that a person might want to learn about. This suggests to me that one routine part of a good education is for students to learn how to pose a question, problem, or task of personal interest that requires the use of knowledge and skills they do not currently possess, and then to be able to gain the needed knowledge and skills on their own. This presents a tricky issue. We know that a good teacher (human or computer) can help a student to learn more, better, and faster than when the student does not have this help. We also know that learning on one's own is a routine part of life and that through practice and appropriate instruction, a

person can gain skills in this endeavor. A good education prepares a student for both of these major approaches to learning.

G10 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 currently available technologies.

Comment. Problem solving is an important part of every discipline that students study in school. ICT is a very powerful aid to problem solving across the curriculum. Notice that the original statement of G10 mentions the use of technologies. From the very beginning, computers were developed as an aid to problem solving. Our schools face a steadily growing challenge regarding what students should be learning about solving the types of problems that computers can solve quickly and inexpensively. Students need to work together with computers when this type of cooperation is essential to acquiring needed knowledge and skills.

G11 Productive Citizenship: All students act as informed, productive, and responsible members of countries, organizations to which they give allegiance, and as members of humanity as a whole.

Comment. Computers have made this world smaller through their aids to communication, transportation, and trading goods and services between nations. Personally, I like the idea that every person is by birth a citizen of the world. Have you ever thought about what this world citizenship gives to a person, and what obligations it creates?

I strongly recommend that you watch Hugh Evan's 2016 *TED talk,* What Does It Mean to be a Citizen of the World? (Evans, 2016, link.) In brief summary, through the efforts of Evan and a large number of other volunteers, many millions of people are working to achieve a goal of every person on earth having a decent quality of life. Quoting from Evans' talk, "I'm convinced that if we had more global citizens active in our world, then every single one of the major problems we face—poverty, climate change, gender inequality—become solvable."

G12 Social Skills: All students interact publicly and privately with peers and adults in a socially acceptable and positive fashion.

Comment. All children learn about lies and lying. This is part of their education, whether or not they ever attend a school. ICT provides a variety of communication tools, and these tools offer new challenges to appropriate interaction among their users. Spamming and the creation of fake (false) news are now a routine ongoing problem, and dealing with this problem is becoming a basic skill taught in our schools (Farmer, 5/31/2018).

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 impact evaluative data that can be used in maintaining and improving the quality of the educational system.

Comment. Computerized assessment is now built into the Computer-assisted Learning materials that are being widely used in our schools. Computers now are used routinely in testing students. However, although some teachers give open book exams, currently few make use of open computer-with-connectivity exams.

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

- Students.
- Parents and other caregivers of the students.
- Teachers, administrators, and all employees and volunteers in educational systems.
- Voters, taxpayers, and funding agencies.
- Employers.

  Comment. Schools, by themselves, are a very complex human activity. Add to this the fact that one's brain is learning 24 hours a day, seven days a week, throughout one's lifetime. Formal schooling is only a modest part of one's education. However, it is a very important part. Remember the quotation: "The way the twig is bent twig is bent, so is the tree inclined."

Over the years, a number of people have worked to define the goals listed above and other goals of education in terms of *measurable behavioral objectives.* My 12/26/2020 Google search of the term *measurable behavioral objective* produced about 5.5 million results. So, the idea of establishing goals for education and having measures of student achievement of these goals is well established. However, it is clear that many students are not achieving the goals that their schools want them to achieve.

There are other goals that I strongly believe need to be added to the list given above. Some of these will be discussed later in this book.

Final Remarks

The goals of education discussed here were developed over a long period of years. The first schools were designed to help a small select group of students to gain knowledge, and it soon became apparent that students gaining these skills could immediately make meaningful contributions in government and business.

Now, move forward in time about 5,200 years or so to when the Industrial Revolution starting in England created a major problem of young children competing with adults for jobs—some of which were quite dangerous. Aha! A solution to this was to create child labor laws and to establish required schooling for children. This approach kept children from competing for adult jobs, and also provided a type of child care during the school hours. Over the years, it has become clear that good schools and a high average level of education in a country provide many benefits to the country. This topic area is also an important component of quality of life. One measure of the quality of a country's schools is how well the knowledge, skills, and experiences students obtain in their formal schooling continue to serve them well throughout the lives.

Chapter 3
Overview of Artificial Intelligence

In recent years, I have developed a habit of including one or two pithy quotations at the beginning of blogs, newsletters, book chapters, and other documents that I write. As a slight change, in this chapter I have inserted a comment after each of my two chosen quotations.

> "We have seen AI providing conversation and comfort to the lonely; we have also seen AI engaging in racial discrimination. Yet the biggest harm that AI is likely to do to individuals in the short term is job displacement, as the amount of work we can automate with AI is vastly larger than before. As leaders, it is incumbent on all of us to make sure we are building a world in which every individual has an opportunity to thrive." (Andrew Ng; former Head of Sanford AI Lab and pioneer in online education, entrepreneur whose online courses have had more than 2.5 million enrollments; 1975-.)
>
> > *Comment.* We humans have experienced and effectively dealt with major job-related changes in the past. In ancient times, we switched from being hunter-gatherers to being farmers. More recently, about 80 percent of the jobs in the United States in 1890 were in agriculture. Now, only about two percent are in agriculture. At the height of industrial manufacturing in the United States, about 50 percent of employment was in in this area. Now, this is under ten percent. As the number of AI job-related changes will continue to increase, it is a challenge to help our educational systems make the changes needed to better prepare students for the job markets and other aspects of the future they will face.
>
> "No computer has ever been designed that is ever aware of what it's doing; but most of the time, we aren't either." (Marvin Minsky; American cognitive scientist in the field of artificial intelligence and co-founder of the Massachusetts Institute of Technology's AI laboratory; 1927-2016.)
>
> > *Comment.* Minsky's statement is an interesting and insightful observation. So far, no computer has self-awareness, while self-awareness is an important aspect of being a fully functioning human being.
> >
> > However, Minsky also makes the interesting observation that most human activity occurs at a subconscious level. You probably have heard the statement, "The thought is the deed." But most of what we do (the deeds) occur without conscious thought. This currently is an active area of brain research. I explore some of the educational implications of this idea later in this current chapter in the section titled "The thought is the deed."

Introduction

The term *Artificial Intelligence* came into prominence as a consequence of the Dartmouth Summer Research Project on Artificial Intelligence held in 1956. Quoting from the Dartmouth workshop (Wikipedia, 2021d, link):

> In the early 1950s, there were various names for the field of "thinking machines": cybernetics, automata theory, and complex information processing. The variety of names suggests the variety of conceptual orientations.

> In 1955, John McCarthy, then a young Assistant Professor of Mathematics at Dartmouth College, decided to organize a group to clarify and develop ideas about thinking machines. He picked the name 'Artificial Intelligence' for the new field. He chose the name partly for its neutrality; avoiding a focus on narrow automata theory.

At about the same time, the term Machine Intelligence (MI) came into use in Europe, and both AI and MI now are widely used names for the field.

Human intelligence has a long history. Researchers believe the earliest prehumans appeared about six million years ago. These earliest prehumans had a combination of physical and mental capabilities built into their genes that allowed them to survive. About six million years of evolution led to Homo Sapiens who had the physical and mental capabilities to learn and use oral languages. A key aspect of this is that, while today's children are born with the innate capability to learn to speak and communicate in an oral language, it requires considerable learning over a long period of time to actually develop these skills. That is, evolution provided the physical and mental capabilities for such oral language, and education is the vehicle for passing on oral communication skills from generation to generation.

We have evidence of drawings and paintings on cave walls going back more than 40,000 years, and of using marks on small stones (including some made out of clay) as a means of communication more than 10,000 years ago. The first development of written language evidently occurred about 5,500 years ago in Sumeria. I like to think of this as one of the earliest important steps in the development of AI. Written language is a very important aid to human intelligence, and we humans created it and pass on its use from generation to generation.

Counting provides a good example of current human cognitive abilities. Humans and some other animals have an innate ability to learn to count. As humans developed their early civilizations, counting and simple arithmetic proved to be useful aids to representing and helping to solve a variety of problems. The tally stick was developed as an aid to counting and keeping track of some numbers at least 40,000 years ago (Wikipedia, 2021g, link). We now have paper-and-pencil arithmetic, calculators, and computers as aids in dealing with arithmetic and other math-related tasks.

In brief summary, through a combination of evolution and human ingenuity, humans develop tools that can be used to enhance their intellectual capabilities. Some of these can be mastered quickly, while others take years of study and practice to meet contemporary standards. These intelligence-enhancing tools can contribute significantly to our quality of life. Their use also may sometimes decrease the quality of life for their users and/or others. Thus, AI is a change agent, and for any particular person the effects of using a specific AI-based product will lie some place on a scale of very bad to very good.

Artificial Intelligence Explained in 5 Minutes!

If you want a very quick overview of AI, I recommend the short video by Ashish Bhatnagar, Artificial Intelligence Explained in 5 Minutes! (Bhatnagar, 2020, link).

The video explains AI in terms of the use of computers to carry out a number of activities that humans can do. It identifies a number of human capabilities that make use of human intelligence, and relates these to specific areas of AI research. The goal of AI is to develop systems that can function intelligently and independently. In the list below, the names of these areas are given in parentheses.

The human capabilities mentioned in the video include:

- Speak and listen. (Speech Recognition.)
- Write and read text in one or more natural languages. Note that many people are bilingual, and that people who do simultaneous translation are displaying very high linguistic skills. (Natural Language Processing.)
- See with their eyes and process what they see. (Machine Learning; Machine Vision.)
- Recognize a scene around them. Remember the past and integrate (parts of it) with the present. (Image Processing.)
- Understand their environment and move around fluidly. (Robotics.)
- See patterns, such as groupings of like objects. (Pattern Recognition, Neural Networks, Deep Learning.)

Humans have many capabilities not in the bulleted list given above. However, all of the items in the list relate to various components of AI research, development, and use. The list will help you begin to expand your personal insights into the current and emerging capabilities of AI.

Humans use their capabilities to deal with problems and tasks they encounter in their everyday lives. Much of human informal and formal education focuses on learning to recognize, understand, and decide on the importance and immediacy of a problem one encounters, and then to decide on one's own capabilities to deal with and possibly to solve the problem. So, over the years, we learn either to solve or in other ways to deal effectively with many of the myriad of problems we encounter throughout the day.

We know that a person cannot develop a high level of expertise in every area of human cognitive endeavor, and thus learn to appreciate and make use of experts in each area of human cognitive and physical endeavor. Now, we are developing AI systems having cognitive abilities that exceed even the best human experts in some areas. While some of these systems require that humans attain a high level of knowledge and skills to use them, others can be learned on one's own or with a minimum of instruction. For example, I had no trouble in taking a paragraph that I wanted to translate into Russian and then back into English, using Google to find a site that provides translation for 100 different languages, following the instructions, and thus accomplishing my task.

Using AI, humans are able to develop tools that will enhance their physical and mental capabilities. In brief summary, here are three key ideas:

1. AI can provide aids to solving problems and accomplishing tasks that we have dealt with in the past without the use of AI.
2. AI can provide aids to solving problems and accomplishing tasks that we have wanted to deal with in the past, but could not handle with the then current aids to problem solving.
3. AI opens up new problem areas that we have not considered in the past, and can contribute to the exploration of and possible solution of some of these problems.

All three of these are of interest to people working to improve schooling and lifelong education.

What Is AI?

AI is a broad and very complex field. A very simple definition is that it is the study of the uses of computers to solve problems and accomplish tasks that, if being done by humans, would require human intelligence, thinking, and judgement.

AI also is a powerful change agent, but is only one component of the overall field of Information and Communication Technology (ICT). And, ICT one only part of what needs to be considered as we work to provide learners (that is, all of us) with a good, ongoing, lifelong education.

I recently read *AI and the Future of Learning: Expert Panel Report* (Roschelle, Lester, & Fusco, December 2020, link). The 27-page document is based on the work of 22 carefully selected experts in the field of AI in education. Here is the executive summary from the report:

> Artificial intelligence (AI), machine learning, and related computational techniques have the potential to make powerful impacts on the future of learning. Technology's impact on education is often to amplify impacts, regardless of whether the impacts are intended. Due to the accelerating pace of integration of technology in learning environments, the knob on the amplifier is rapidly going from low to high. Impacts on learning, whether positive or negative, could soon have consequences for many more students. Now is the time to begin planning for how to best develop and use AI in education in ways that are equitable, ethical, and effective and to mitigate weaknesses, risks, and potential harm.

Prehumans had millions of years to adjust to their increasing abilities to make and use tools. The first tools they made were relatively simple to make, to learn to use, and to use. Skill in using the tools came through *on the job* training. This description continued to be accurate even as a large number of Homo Sapiens became farmers starting about 10,000 years ago. The knowledge and skills that children needed in order to function well in this new environment could be gained without anything remotely like the schools that first were established about 5,500 years ago based on the need to use the newly developed skills of reading, writing, and arithmetic.

The following quotation is from a section of the Roschelle, Lester, & Fusco report that summarizes one way of thinking about a set of rapidly advancing AI capabilities:

- Perception, via multiple sensors and ability to recognize complex sets of features (e.g., use of cameras and motion detectors to recognize particular faces entering a building).
- Representation and Reasoning, building models of people and their behaviors and making inferences based on those models about what might happen next.
- Learning, discovering meaningful patterns in large amounts of data.
- Natural interaction (e.g., interacting through speech or gesture).
- Societal impact, leveraging infrastructures to do all the above at a massive scale and in ways that directly affect people's lives.

Each of these statements identifies an emerging capability of AI, and each is an active area of research in this field. Spend a little time comparing the complexity of each of these five areas of study and research with the specific task of translating written and/or spoken language from one language to another. You will see that each is important to the use of AI in education, and each is a major challenge to current and emerging AI capabilities. I find it rather amazing that AI-based systems can do as well as they currently do for language translation and for other tasks in which humans need to use their human understanding of what they are doing.

AI and the Future of Learning

Perception is the first item in the panel's list above of five rapidly advancing AI capabilities. You and I take in information using five senses (eyes, ears, nose, taste buds, and touch) and our

brains integrates this multi-part stream of information as we go about our everyday activities. The knowledge and insights we extract from the information will depend upon our personal knowledge and experiences. Thus, the results of processing the input will be quite different for each of us.

Now try to imagine the challenge an AI-based speech recognition system faces as it not only must deal with just the sounds of the words, but also deal with the intonations, facial expressions, posture, gestures, overall context/environmental situation, and so on of the speaker as it attempts to process human speech.

I find it hard to imagine having an AI-based computer system that can do such a thing, but substantial progress is occurring. The panel of experts collaborating on the Roschelle, Lester, & Fusco report has created a list of seven recommendations for research priorities, the report indicates that progress is occurring. Research is being done to:

1. Investigate AI Designs for an Expanded Range of Learning Scenarios.
2. Develop AI Systems that Assist Teachers and Improve Teaching.
3. Intensify and Expand Research on AI for Assessment of Learning.
4. Accelerate Development of Human-Centered or Responsible AI.
5. Develop Stronger Policies for Ethics and Equity.
6. Inform and Involve Educational Policy Makers and Practitioners.
7. Strengthen the Overall AI and Education Ecosystem.

Following are brief summaries/comments regarding the seven recommendations from this report.

1. Investigate AI Designs for an Expanded Range of Learning Scenarios

Quoting from the report:

> Many important opportunities, such as AI agents to support learning in open-ended science inquiry environments, social studies simulation tools, or curricula to encourage design thinking, are still under-investigated. Likewise, AI learning scenarios may support better preparation for the workplace.

Comment: The point is that we now have had more than 50 years of ongoing research and development on various forms of Computer-assisted Learning. As AI grew in its capabilities, we began to develop Highly Interactive, Intelligent Computer-assisted Learning (HIICAL) systems. Such systems lend themselves to detailed data collection and research on the impact of HIICAL on student learning. Increasingly, we will have HIICAL systems that are more effective than the various traditional methods of teaching, learning, and student evaluation in many parts of the curriculum.

2. Develop AI Systems that Assist Teachers and Improve Teaching

Quoting from the report:

> Experts were aware that today's AI systems have dashboards and other interfaces for teachers, but that these often fall short of being usable, friendly, or instrumental for teacher's work. They fall short of the idea of augmenting the teacher's intelligence and helping the teacher to grow, and often only make more work for teachers. … Experts called for a vision of AI in the classroom that is more centered in assisting and supporting teachers.

Comment: Being a good, effective classroom teacher is a very challenging and difficult task. Computers and AI can help teachers do a better job, and simultaneously save them considerable time they now spend on rather mundane, busywork. Success in this endeavor will help to gain the support of teachers for a greater use of HIICAL.

3. Intensify and Expand Research on AI for Assessment of Learning

Quoting from the report:

> Although AI already has been used in assessment of writing, science, and mathematics, much work is still needed to expand the bounds of the student learning activities that can be automatically assessed, the range of competencies that can be captured, and the breadth of assessment across settings and over time.

Comment: Assessment is an ongoing and very challenging component of a teacher's job. This reminds me of my periodic visits to my medical doctor. A broad range of blood tests are ordered and carried out by technicians and highly automated equipment before my visit. Much of my visit is spent discussing the test results with my doctor and coming to understand the ensuing recommendations. The doctor's time is spent on the individualization of the treatment I receive. An appropriate use of HIICAL can significantly increase the individualization of instruction in our schools and also free up teacher time to provide more individualized help to students.

4. Accelerate Development of Human-Centered or Responsible AI

Quoting from the report:

> Limits in design processes and approaches can be as much of a barrier as issues with how AI collects and uses data. Included in this call is the need for AI that addresses learners with disabilities, learner variability, and the need for universal design for learning in AI applications.

Comment: I would have stated this goal somewhat differently. Every student is unique. Thus, no curriculum, pedagogy, assessment, or overall school environment is ideally designed to fit any specific individual student. A good education contains components of helping a student to learn to cope with what a school can provide, as well as with schools doing what they can do to meet the needs of individual students. We currently single out students with various disabilities and also those with various special gifts in order to make special provisions for them. We need to support more research, development, and implementation of the progress that AI can bring to the individualization of instruction in situations that will be beneficial to students.

The statement about *the need for universal design for learning in AI applications* bothers me. It suggests that there are a number of design principles that all instructional materials making use of AI should be following. As an example, consider a statement such as, "The content, pedagogy, and assessment of CAL materials should be free of *bias*." But, we have not universally agreed on a definition of bias. You have heard the statement, "Beauty is in the eye of the beholder." To a certain extent, each person has their own definition of bias.

5. Develop Stronger Policies for Ethics and Equity

Quoting from the report:

> In the expert panel discussions, there was a clear need to rapidly intensify the work to understand what core standards, guidelines, policies and other forms of guidance are for

> effective, equitable, and ethical practices in this emerging area. Researchers doing the work have to participate in building the guidance that helps the field grow in a safe and credible manner.

Comment: The process of increasing the use of AI in education provides us with an opportunity to revisit many current educational practices and to explore how ethical they are. For example, how ethical is it to do the amount of separation we currently make between Special Education students and other students? Some countries use much less separation than we do. How ethical is it to place as much emphasis as we do on lock-stepping many students into the day-by-day curriculum content that is being presented to them? As we continue to make progress in developing high quality HIICAL, how ethical is it to **not** make routine use of such materials in our schools?

6. Inform and Involve Educational Policy Makers and Practitioners

Quoting from the report:

> To participate in making decisions, building capacity among practitioners to understand AI is important. Capacity building is also important so that educators have the infrastructure to test and evaluate emerging AI and so they can inform design decisions. Schools and other educational institutions may need incentives to get more involved in evaluation and policies. Policy makers are learning about AI in general, but may be less aware of specific risks and barriers in education that need policy attention.

Comment: The substantial use of AI in education should not be undertaken lightly. The people making the decision to implement more use of AI and the teachers actually doing the implementation need to understand what they are doing and be convinced that the decisions being made will be beneficial, both to students and to the overall educational system.

7. Strengthen the Overall AI and Education Ecosystem

Quoting from the report:

> Experts saw strong ecosystems of educational leaders, innovators, researchers, industry leaders, start-up companies, and other stakeholders as an important mechanism for shaping AI for educational good. Many of the dark scenarios, in contrast, involved poor information sharing or imbalances of power—and ultimately, one industry player acting alone.
>
> Experts also repeatedly called for more attention to building infrastructure for collaboration and techniques for partnerships among researchers, practitioners, policy makers, developers, industry, and other stakeholders.

Comment: The *one industry player acting alone* statement especially caught my attention. Schooling currently is impacted strongly by a number of people and organizations with relatively specific agendas. In addition, there are a modest number of publishers of instructional curriculum materials and the related training that control much of the market. I find Alphabet, Inc., which owns Google, the Google search engine, and a number of other companies to be an interesting example to explore. Google's products and services are used widely in education, with Google's roles in the development of *Chromebooks* as a part of this. Google's search engine makes substantial use of AI as it gathers, stores, and uses information about each of its users. I frequently use this free search engine, and in recent years I have seen more and more of my

search results that are accompanied by ads. So, I am paying for the use of Google's search engine by having to deal with the barrage of ads appearing in the search results presented to me, and also I must accept Google's sale of information about me to a huge range of different companies. I do not think our school children should have to have this happening to them.

I specifically am concerned about the possibility (perhaps likelihood) that a very few publishers will come to dominate the development and sale of instructional curriculum materials and the related training.

The Thought Is the Deed

I believe that the report being discussed here is quite weak in the area of assessing the possible impacts of AI on the content of the curriculum. For years I have asked and thought about the following question:

> If a computer can solve or greatly help in solving a type of problem or accomplishing a type of task that we want students to learn about in school, how should curriculum, pedagogy, and assessment address this situation?

I initially only asked this question about math education, since quite early on huge progress was occurring in developing computer programs that can solve a very wide range of types of math problems. Very good software to accomplish such tasks is available free from a variety of sources. For one example, see WolframAlpha (WolframAlpha Intelligent Systems, 2021, link.)

This same question can be asked about every discipline now being taught in our schools. For example, what do we want students to learn in second language courses? Suppose the main goal in these courses is for students to gain modest skills in speaking, listening, reading, writing, and translating between their native language and the second language. We now have computer programs that are relatively good (and still being improved) in these tasks.

A variation of my question is simply to ask, **"What do we want students to memorize and what do we want to have them become skilled in retrieving from the Web?"** This is a challenging question!

At the beginning of this chapter, I quoted Marvin Minsky's statement, "No computer has ever been designed that is ever aware of what it's doing; but most of the time, we aren't either." Here is an example that I find interesting. In my conscious problem-posing mind, I decide I want to move myself from one room in my apartment to another. My conscious mind then turns the problem over to my subconscious mind, and it directs my body in the details of performing the walking task.

As another example, I can tell my computer to send an email message I have just composed to a particular person whose name I keyboard into the "To" space. The computer takes over and the task is completed. In essence, with a computer there are an increasing number of situations where the thought of a human becomes a deed of the computer. Interestingly, a current area of brain research is to develop a brain implant that can take a *human thought* such as, "Send the message I have just keyboarded to my daughter Beth," and a computer will handle this task.

The educational ramifications of this line of thought already are profound, even without the futuristic concept of thought-input to a computer. I currently must keyboard my instructions to solve the problem, but I do not need to provide the details on how to solve the problem. The

computer *knows* how to solve the problem, and automatically does so. More and more problems are being handled by this process (Metz, 8/31/2020, link).

Final Remarks

In the years yet to come, we will be making huge changes to the curriculum, pedagogy, and assessment in our schools. This will be a long, difficult process, and will be going on during a time when our available technology is continuing its rapid change.

Many of the people involved in our current schooling system will have trouble adjusting to these changes. It is likely that the transitions will be quite disruptive and disturbing to many parents, teachers, school administrators, school board members, politicians, and others. Patience and tolerance will be essential. Remember, the goal is to do as well as we can in providing an education that will serve our children effectively during their childhood while they are gaining this education, and in their adulthood in our changing world.

I will leave you now with one more exceedingly important thought about education. The great Greek philosopher Aristotle once said, "**Give me a child** until he is seven and I will show you the man." Much more recently, B.F. Skinner said, "**Give me a child**, and I'll shape him into anything." We have known for more than 2,000 years the importance of education from birth through age seven or eight. Formal education during these years currently is coming from a combination of parents, guardians, child care providers, preschools, and the earliest school grades. Informal education comes from friends, picture books, and online media. Television, especially, has come to have a significant impact on the early education of children, and now computer games and edutainment have become quite important in the lives of many young children.

Hmm. I wonder how long it will be before robots begin to play a significant role in childcare and rearing. What do you think about the idea of a robot serving as a babysitter in the home of a parent or guardian?

Chapter 4

The Future of Education in a World of AI

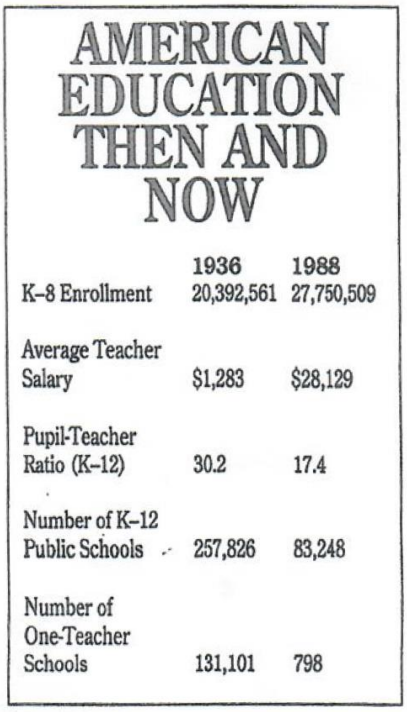
"The most dangerous experiment we can conduct with our children is to keep schooling the same at a time when every other aspect of our society is dramatically changing." (Chris Dede; American computer educator and futurist; from written statement to the PCAST panel, 1997.)

"School days, school days
Dear old golden rule days
Reading and 'riting and 'rithmetic
Taught to the tune of the hickory stick."

Song by Will D. Cobb and Gus Edwards published in 1907 (Wikipedia, 2021i, link).

Introduction

I was born in 1936. I tend to think that our schools have not changed a lot since I was in our K-12 public education system, but I am wrong. There certainly have been some major changes. Recently the following diagram caught my eye. It is from the February 1991 issue of *Instructor* magazine that became *Scholastic Teacher* in 2015 (*Scholastic Teacher*, October, 2015, link).



AMERICAN EDUCATION THEN AND NOW

	1936	1988
K–8 Enrollment	20,392,561	27,750,509
Average Teacher Salary	$1,283	$28,129
Pupil-Teacher Ratio (K–12)	30.2	17.4
Number of K–12 Public Schools	257,826	83,248
Number of One-Teacher Schools	131,101	798

Figure 4.1. American schools in 1936 and 1988.

Three especially noteworthy changes are the almost compete end of one-teacher schools, the huge decrease in the total number of public schools, and the fact that average teacher salaries increased at a far faster pace than did inflation. Indeed, average teacher salary was well above

middle income in the United States. Now, in 2021, average teacher salaries are significantly below average income in the United States.

While on the faculty at the University of Oregon, I met and soon became close friends with a professor who had four years of teaching experience in a one-room elementary school before he went on for a doctorate. During those four years, he also served as the school bus driver, and he could take the group of students on a field trip without getting prior parental approval. From talking with him, I gained the impression that these students received a superb elementary school education that was well balanced among course content, individualization of instruction, social interaction of students, and learning about their community. For those students, the schooling part of those *good old days* really were good old days!

My Life Today

As I eat breakfast in the morning, I use my tablet computer to browse the news. Here are a few headlines from my morning's (2/7/2021) browsing. For me, they provided a snapshot of some major aspects of current and future challenges faced by our educational systems.

- Elon Musk says his start-up Neuralink has wired up a monkey to play computer games using its mind.
- Melting glaciers, rising seas: Approaching climate tipping points.
- MIT's New Neural Network: "Liquid" machine-learning system adapts to changing conditions.
- Sea level rise could be worse than feared, warn researchers.
- SpaceX plans for phone service, emergency backup, and low income access.
- The first steps toward a quantum brain: An intelligent material that learns by physically changing itself.
- *The Hidden Spring* by Mark Solms review—the riddle of consciousness solved?

Such headlines are designed to catch the attention of ordinary readers who like to know what is going on in their country and in the world. They want us to understand the types of news content being made available to the general public. They are designed to catch the eye and attention of readers who are concerned about their own future, the future of people they know and care about, humanity, and the world.

I believe that all educators need to be aware of the first item on my list. Progress is occurring in developing a brain implant that can be used to create a direct connection between a brain and a computer. Wow! That sounds like "way out" science fiction to me. Right now I can speak to my computer. In the future it seems likely that people will think to their computer (Lewis & Stix, 7/17/2019, link).

Here and in the next chapter, I present some of my thoughts about needed educational changes being brought about the increasing use of AI in education, and some forecasts about such changes. My focus is on schooling in the United States where our schools, as well as schools in a number of other countries, have the wealth and infrastructure necessary to provide all of their students with reasonably good access to computers, the Internet, the Web, and a variety of instructional materials designed to make effective use of such computer resources.

Here is a fundamental idea. Our schools have thoroughly integrated the idea of having students *learn to read*, and then having students learn to make effective use of *reading to learn across the*

curriculum. A somewhat similar thing is beginning to happen with the use of AI. We will teach students to become effective learners in a HIICAL environment, and such an aid to learning will become available to all students. My forecast is that this will prove to be as big a change agent in education as was the development of reading, and (in my opinion) will become a commonplace, major component of schooling in the future.

The (Possibly Upcoming) Technological Singularity

Computer futurists use the term *technological singularity* (or simply the word *singularity*) to refer to the time when computers will become more intelligent than humans. Such futurists suggest that this may happen as soon as about ten years from now, some forecast it will occur much later in this century, and still others argue that we are a very long way from this ever happening. All agree, however, that in an increasing number of situations computers will develop a type and level of intelligence that can solve problems and accomplish tasks that are beyond the capabilities of humans (Kurzweil, 11/3/2019, link).

Thus, it behooves all of us to examine each goal of education to better understand how it is and/or could be affected by the level of AI already available or likely to become available during the next ten years or so.

From time to time, I try to wrap my mind around what it might be like to live after a technological singularity. I am somewhat calmed by the realization that throughout my entire lifetime I have lived with machines with physical capabilities that exceed mine. I also have lived with a wide range of tools such as radio, television, audio and video recording, the Internet and the Web, and so on. These all provide services to me that are important to my life style.

Some people fear that AI-using computers will become self-aware, and then decide to take over and run the world. They fear that such computers will be harsh dictators, or even decide that humans are no longer needed. So far I have not seen any indications that this will occur, and it is not one of my personal fears. My primary fear today is that people whose values are far different than mine, many of whom have a current focus on usurping powers that I strongly believe belong to the people, will be able to make use of computers and AI to achieve their goals.

Tools

Prehumans and humans have long developed and used tools that aid and extend their physical capabilities. Also, through evolution and their own work, they have developed tools such as oral and written languages, telephones, and many other aids to their physical and cognitive capabilities.

I imagine that the first prehumans who developed rock knapping to make very sharp edges on small stones did not think about the long term consequences of their invention. A similar statement holds for many of the tools that have become a routine part of our lives. So, why should we be concerned about the possible long term effects of learning about and using AI-based tools in schools and in other parts of our lives?

It is not new for people to be concerned about what is going on in their children's schools. Consider the variety of printed materials now made available to students while they are in school. Most schools are very careful to not provide their students with access to library materials and textbooks that the general population in their community might regard as being offensive.

And, what about tools? The simple handheld calculator provides a good example to consider. Adults certainly accept that it is perfectly fine for adults to make use of calculators in dealing with arithmetic problems they encounter. However, parents and schools continue to believe that learning paper-and-pencil arithmetic is a very important goal of math education in the schools. A modest counter trend is illustrated by the fact that the widely use SAT exam has allowed certain types of calculators to be used in the math part of the exam since 1994. Gradually, as more sophisticated calculators were developed and came into widespread use, the types of calculators allowed on the exam changed. Graphing calculators now are included in the current list of allowable calculators (DeGeurin, 8/9/2019, link).

This example illustrates a key idea. We want to provide students with an education designed to help prepare them for everyday life, work, and leisure as responsible and contributing adults. In addition, we know that an appropriate education contributes greatly to an adult's quality of life and to the overall success of the adult's country. Thus, we should look at each current goal of education in terms of how well it contributes to meeting these educational expectations, and how the goal is being affected by the ongoing changes that computers and AI are bringing to our world and to its educational systems.

Now think about the Web that has become a ubiquitous and everyday tool used by essentially all students in the U.S. and other economically developed countries. I like the analogy between using a calculator for arithmetic and many math-related tasks, and using the Web as an interdisciplinary tool that can be useful in all areas of academic inquiry and study. Access to and use of networked computers is now a routine part of the school day for a great many students, and this number is increasing steadily. Since AI is used in much of today's software, essentially all computer users are now making routine use of AI.

The issue of the use of calculators on exams such as the SAT is actually modest when compared with the issue of the use of the Web when taking school exams. You certainly know about the idea of open book and/or open notes exams. Some teachers make use of such exams. But, what about *open networked-computer* exams? Do you know any teachers who make routine use of this type of exam?

For me, the issue is one of *authentic assessment* (Mueller, 2018, link). Authentic assessment has long been an important idea in education. As computers become a routine part of the lives of all students, schools need to develop assessments in which it is expected that students will make use of computers in completing the assessments.

Authentic assessment includes testing students' abilities to use the *tools of the trade* in solving the types of problems and accomplishing the types of tasks that we want students to learn about in their education. This is and will continue to be a major challenge in education, because the capabilities of AI will continue to improve significantly year after year. It will be fun to see how we progress in addressing this challenge in the coming years.

The above comments are some of the types of thoughts that go through my head as I consider current and possible future roles of AI in schooling. Here are three basic questions I ask myself:

1. What are some routinely used AI-based tools in our current schools, and are these uses advancing the schools' goals for education?

2. What are some currently available AI-based tools that might be quite suitable for use by students and teachers, tools that currently are either not being used at all or are used only lightly?
3. What are some AI-based tools currently being developed or envisioned that have the potential to have a significant impact on schools?

The remainder of this chapter and the following one will explore these questions.

Thinking about AI and the Goals of Education

Thinking about the three questions listed above leads me to go back and consider the general purposes and uses of computers. The first electronic digital computers were tools developed to help solve problems and accomplish tasks that humans working with the other tools available at that time could not accomplish. Arithmetic calculations provide an excellent example. The first commercially available computer in 1952 could perform 1,000 arithmetic operations per second. At that time, people had many problems they wanted to solve in which such computational speed was very helpful. As computer speeds and availability increased, the discipline of business data processing developed. Routine learning about computer use in data processing—a use that made only very rudimentary use of AI—became commonplace and so became a subject taught in high schools.

During the nearly 70 years since 1952, the speed of the fastest commercially computers has been increased by a factor of about 400 million million (400 times 10^{12}). Researchers and computer programmers have learned to make use of that speed to accomplish many tasks that are far beyond the capabilities of humans.

Let's look at just one of these tasks—the storage of information on the Web and its retrieval using a browser. Each of these tasks makes extensive use of AI. It is not necessary to have any knowledge about AI in order to use these capabilities effectively. This is an important idea about AI, and I like to think about various analogies to explain what I mean. For example, a person does not need to know the details of building a car in order to drive one. This holds true for many of the routinely used tools humans have developed.

It boggles my mind to think of how I can use AI to search through billions of online documents in less than a second! Yet this is only one example of the many applications of AI that now are an accepted component of schooling. However, our school systems have made only modest progress in dealing with the possible changes in content, pedagogy, and assessment that I believe need be made based on these computer capabilities.

My forecast for the future is that schools still will be struggling with these challenges for many years to come. I currently rank the effective integration of computers and AI into the K-12 curriculum as the most important challenge that schools have faced since reading and writing were first developed.

I assume that all of my readers have concerns about the future of jobs and employment. In chapter 2, I discussed a broad list of goals of education. One currently unifying goal of education is to prepare students for gainful employment. Such an education is viewed by many as a vehicle to getting a well-paying job, and also contributes to building a strong and economically successful country.

This emphasis on preparing students for jobs, when combined with the fact that an increasing number of available jobs now require the skilled use of computers, forces us to pay a great deal more attention to the types of computer knowledge and skills currently being taught in our schools. In making forecasts about the future of AI in education, I assume that one unifying purpose of education for gainful employment will continue to be a major and appropriate goal for schools.

However, intelligent computers and automation may well eventually change this emphasis on preparation for wage-earning jobs. Many science fiction writers envision and explore future worlds in which schooling no longer focuses on preparation to obtain and hold jobs. Instead, all people in these future words receive a level of income from the government that is deemed to be adequate to support an adequate standard of living. In such stories, nobody has to work in order to live comfortably. The authors typically posit a wide variety of higher paying jobs being available for those who are qualified to do the work and want to have the additional income.

Today in the U.S., we already have very large-scale examples of government payments to some segments of our population. We have Social Security payments and Medicare for people of retirement age. We also have various forms of supplemental income payments for people with either no income or one that is totally inadequate, and for people with certain types of disabilities. We continue to explore possible ways to deal with the need for all people to have a good quality of life, one that includes access to adequate medical care. In a number of countries, the costs of medical of care are paid fully by the government.

The length of the work week and minimum rates of pay are another quality of life issue. Over the past 200 years, the average length of the work week for fulltime employees in the U.S. has decreased from being 72 hours or more to 40 hours (Sawyer, 12/25/1977, link). This decrease in the average length of the work week certainly has helped to improve our quality of life.

Examining Some Current Goals of Education

Fourteen currently widely accepted goals of education were presented in chapter 2. Preparation for employment, one of the unifying ideas in this list, was introduced in the section above. My focus here is on the first of the 14 goals, with the next chapter examining how AI will strongly affect some of the other goals.

> **G1. 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.

Dick Ricketts and I wrote about this goal more than 30 years ago in our book, *Long-range Planning for Computers in Schools.* I have updated these goals over the years and they now are available as an article in the *IAE-pedia* (Moursund & Ricketts, 6/12/2020).

Other visionaries already had seen how computers can empower their users, and that quite young students could learn to use computers at a level beneficial to them. The visionaries made use of an analogy between students becoming *reading and writing literate,* and becoming *computer literate.* For many of them, computer literacy includes having students learn to write their own computer programs. Over the years, I have had the opportunity to interact with a number of elementary and middle school students who already had become very good computer programmers.

For nearly 50 years, educational leaders have been thinking about and making a variety of attempts to address the issue of computer literacy for all students. During this time the cost, availability, and capabilities of computers have changed markedly. In some sense, schools have been playing a catch-up game. Unfortunately, it appears likely this will continue to be the case for many years to come.

I tend to think about this challenge in a number of different ways. Perhaps first is the issue of providing all students with good access to computers and related hardware, the Internet, and the Web, both at home and at school. The Coivid-19 Pandemic has greatly speeded up progress on this task. It is equally important to provide the instruction needed to help all students learn to make effective and appropriate use of such computer facilities. For years, I have raised the question, "What do we want students to learn about a type of problem deemed important in the curriculum content, a problem that computers can solve independently and/or greatly help in solving?"

I find that that an analogy with reading and writing is useful. Over thousands of years, we gradually have determined the levels of reading and writing literacy that typical students can achieve through various amounts of schooling. The advent of the mass produced Gutenberg *Bible* in 1455 led many people to decide that it was desirable for students to be able to read at the level needed to access this now widely available book. This provided a motivation for many to support teaching reading and writing in schools. As a steadily increasing number of students learned reading and writing, the benefits to the students and to the societies they lived in became apparent. Thus, one measure of the success of education is the worldwide level of literacy. Education that includes learning to read and write is now considered to be a birthright of most children throughout the world.

There is a substantial difference between being able to read one particular book, and being able to communicate effectively in writing. Desired levels of writing skills—including spelling and grammar—are difficult to achieve. We have not yet decided on the extent to which an educational goal should be for students to write well in a word processor environment that includes a spell checker and grammar checker. Interestingly, we now have some computer programs that are able to write entire documents independently based on a list of ideas or topics provided by the user.

This brings to my mind an analogy of a business executive who has a highly competent secretary, one to whom he can give a simple outline of the points the executive wants to make, and the secretary has the skills required to write and distribute to the appropriate recipients a very professional letter covering that list of points. We still have a long way to go before AI can accomplish this task at the level of a well-qualified secretary. But, it would not surprise me at all to find that some students are making use of such computer capabilities as a major aid to completing some of their required writing assignments.

There are some significant advantages in teaching students to access computers as a routinely-used aid to their writing. The final results are legible and easy to edit. This raises an interesting question. Who needs to be able to read and write cursive, when keyboarding and computer aids are readily available and being used so routinely? A number of schools already have dropped cursive handwriting from their required curriculum.

Here is another challenging question. Do we want students to learn to read and write multimedia? Since the development of the BASIC and Logo programming languages, we have

known that quite young children can learn to write computer programs. Moreover, the success of young students in learning the programming language Scratch and other modern programming languages designed for children, and also in doing programming-like activities in a number of computer-based games, provides ample evidence that young students are capable of learning to create multimedia documents. Here are two questions to ponder. Should instruction in reading and writing multimedia be required in schools? If so, should the routine use of these skills become an ordinary, everyday part of the curriculum at all levels?

Final Remarks

Children growing up in our country today gain a considerable level of computer literacy independently of any formal instruction in this area that they receive in schools. But, there is much that students can be learning in school about the overall topic of *computational thinking.* (Moursund, 2018). In brief summary, computational thinking is the type of thinking used in analyzing and figuring out how to solve problems in which a computer may be a valuable aid to actually solving the problems. Achieving the effective integration of computational thinking throughout the curriculum is a major challenge. The next chapter explores various aspects of this challenge.

Chapter 5

More About the Future of Education in a World of AI

> "Artificial intelligence would be the ultimate version of Google. The ultimate search engine that would understand everything on the web. It would understand exactly what you wanted, and it would give you the right thing. We're nowhere near doing that now. However, we can get incrementally closer to that, and that is basically what we work on." (Larry Page, one of the co-founders of Google, 1973-.)

> "Artificial intelligence will reach human levels by around 2029. Follow that out further to, say, 2045, we will have multiplied the intelligence, the human biological machine intelligence of our civilization, a billion-fold." (Ray Kurzweil, American invertor and futurist, 1948-.)

> "Students will spend more time interacting with simulations. The next generation of simulations and virtual labs tools will be maturing." (Jeff Rubenstein; American executive in a number of educational and technology companies; 1/24/2019, link.)

Introduction

Current research suggests that it has taken somewhat over six million years for a particular type of ape to evolve into what we now call prehumans, and for these prehumans to evolve into Homo Sapiens capable of learning and using a comprehensive oral language. While many creatures on earth have some ability to communicate using sounds, none come close to having current human speech capabilities.

These human communication capabilities now are genetically *built in* to each of us. However, it still requires years of education and practice for children to actually gain the skills in language use that we adults want them to have. Moreover, some people develop much greater skills than others.

Contrast this with reading and writing. Evolution provided Homo Sapiens with the cognitive capabilities both to invent and to learn to use reading and writing. But it took until about 5,500 years ago for this major development to occur. I like to think of reading and writing as a type of artificial intelligence, one we humans created and have the ability to learn to use. Fluency in reading and writing (that is, in learning to do reading and writing at the level defined as *competent* by contemporary standards) requires a number of years of instruction, study, and practice.

In relatively recent years, we Homo Sapiens have developed a very wide range of tools we can learn to use. These tools take varying amounts of time and innate ability to gain a high level of expertise in their use. Each tool requires some learning on the part of the person wanting to make use of that tool. A great many of us have the capabilities to learn to drive a car, and we spend the time needed to gain a driver's license. Many of us also have the capabilities to learn to fly an airplane safely, but in the United Sates less than a half of one percent do so. The percentage of us with the innate abilities and the drive to become commercial airline pilots is much smaller than this.

I find it interesting that the AI-based flight control systems in modern airplanes are able to fly such planes safely. Nowadays, the majority of the hours spent actually flying commercial

passenger planes is carried out by computers. Perhaps 30 years from now a similar statement will hold about driving cars? Current estimates are that this will cut traffic deaths by 90-percent.

Here is another interesting situation to think about. With commercial airlines, the individual passenger is not the owner of the plane, and the passenger can decide whether to fly in that plane. The airline company can decide whether to make use of an automatic pilot. Perhaps a good analogy is with taxicabs. A taxicab company can make the decision on using driverless cabs, and an individual passenger can decide whether to ride in such a cab. Hmm. Might a state decide to have much more stringent tests for a driver's license, arguing that this would reduce driving accidents? This might force more people to decide not to try to have a driver's license, and instead to make use of driverless cars.

Some History of Human Development and the Use of Tools

The basic goals of school-based education were established long before AI-using computers began to be produced. Today, the capabilities of current AI-based computer systems affect most (perhaps all) of the goals of our schools. The content and processes of schooling have not kept up with these rapidly increasing computer capabilities. This chapter addresses some of what I and many others believe our schools need to be doing about this situation.

Let's begin by looking back many thousands of years. We humans have both physical and cognitive abilities. They served our ancestors well over the millions of years leading up to the evolution of the first Homo Sapiens some 200,000 or more years ago. The evolved physical and cognitive capabilities developed by Homo Sapiens have helped us to survive and prosper, while all of the humanoids coming before us are now extinct.

Prehumans were developing and using tools for millions of years before the first Homo Sapiens were born. The more powerful brains of Homo Sapiens allowed them to become better at developing and using tools than were their predecessors. Now, most of us live in regions of the world where we enjoy the use of a wide variety of machines, many that have physical capabilities far exceeding our own. Most of us are highly dependent on these machine capabilities. But, we certainly do not spent time worrying about the possibility of such machines taking over the world and enslaving humans.

Over the past 80 years, humans have been developing computer-based artificial intelligence (AI), a type of brain tool. Such AI-using computers are often imbedded into the types of machines that have long augmented our physical capabilities. If the resulting machine has mobility, we typically call it a *robot.* Such a robot may well have a combination of physical and cognitive abilities that exceed those of humans in a variety of areas.

But, robots do not need to exceed human capabilities to be very useful. A number of research and development companies are making progress in developing walking, talking robots that can provide help to bedridden residents of a nursing home. A similar robot might eventually be used routinely used as a babysitter.

We humans have long been able to live and work successfully with machines that exceed our physical capabilities. Now we are engaged in the task of learning to live and work with artificially intelligent machines that have a steadily increasing number of intelligence-like capabilities far exceeding some of our human capabilities. Such AI makes it possible for me to write and publish this book, and for you to access it.

Here are two important questions related to education today:

1. How have these AI-using computers changed our world and our lives, and what major changes will they produce in the future?
2. What should we be doing in raising and educating our children to help prepare them for their adult lives during which such AI-based computers will continue to become more and more capable?

Some futurists talk about the *singularity*, a happening (an event) when computers become more intelligent than humans over all types of human intelligences. Predictions about when this might occur range from sometime in the next ten years, to sometime in our current century, or to never. Personally, I am not able to comprehend the possibility of a time when computers will exceed humans in all areas of human intelligence. So, I do not spend time worrying about the singularity.

Human Intelligences

I have found it helpful to learn more about human intelligences as I strive to understand possible roles of AI in education. I became interested in Howard Gardner's theory of multiple intelligences sometime in 1984 after reading his book *Reflections on Multiple Intelligences: Myths and Messages* published in 1983. Gardner has since devoted much of his academic career to expanding on and elucidating his ideas (Gardner, 1995, link).

In brief summary, his work has focused on nine types or aspects of human intelligences. The following is a brief summary of Gardner's nine types or aspects of human intelligences:

- **Bodily-Kinesthetic Intelligence:** The ability to control one's body movements and to handle objects skillfully.
- **Existential Intelligence:** The sensitivity and capacity to tackle deep questions about human existence, such as the meaning of life, why we die and how we got here.
- **Interpersonal Intelligence:** The capacity to detect and respond appropriately to the moods, motivations and desires of others.
- **Intrapersonal Intelligence:** The capacity to be self-aware and in tune with inner feelings, values, beliefs, and thinking processes.
- **Mathematical-Logical Intelligence:** The ability to think conceptually and abstractly, and the capacity to discern logical or numerical patterns.
- **Musical Intelligence:** The ability to produce and appreciate rhythm, pitch, and timbre.
- **Naturalist Intelligence:** The ability to recognize and categorize plants, animals, and other objects in nature.
- **Verbal-Linguistic Intelligence:** Well-developed verbal skills and sensitivity to the sounds, meanings, and rhythms of words.
- **Visual-Spatial Intelligence:** The capacity to think in images and pictures, to visualize accurately and abstractly.

For each of these types of intelligences, researchers can examine the human brain to possibly locate specific regions that are linked to a particular type of intelligence. Also, we can study how each type of intelligence is used by people, and how different types of upbringing and schooling

affect a person's use of that intelligence. We can explore how our culture, schooling, and other aspects of our lives help to train and educate students to enable them to make more effective use of a particular intelligence.

A quick perusal of Gardner's list identifies *Bodily-Kinesthetic, Mathematical-Logical, Musical,* and *Verbal-Linguistic* intelligences as four areas being addressed by our schools providing specific instruction in each. *Interpersonal* intelligence is addressed by the requirements for students to routinely work together as they interact throughout the school day. *Naturalist* intelligence is addressed in biology and other science courses. *Visual-Spatial* intelligence is addressed in art and math instruction, and in the use of multimedia as aids to learning. *Music* is part of our upbringing outside of school and in school curriculum.

The extent to which schools address *Existential* and *Intrapersonal* intelligences varies considerably from school to school. For example, a school sponsored by a particular religious group will likely address certain aspects of existential issues in ways that are consistent with the beliefs of that religious group. All schools and all teachers include some emphasis on knowing yourself, but relatively few schools provide specific courses in this area.

In brief summary, schools provide an environment in which students make use of a wide range of human intelligences. The use of any one specific intelligence improves one's ability to use that intelligence. However, an important aspect of schooling is that instruction typically requires students to use many of their different intelligences. That is, the problems and tasks that students gain skill in addressing in any course they study requires the use of multiple intelligences.

Empathy and Curiosity

A number of people have suggested additions to Gardner's list of human intelligences. Just for the fun of it, as I read the list I thought about what I might want to add. My brain came up with the response of *empathetic intelligence.* This led me to ask the question, "Is *empathy* a type of intelligence?" I went to the Web, and Google provided me with about 47 million results to my enquiry. The answer is certainly **yes**.

> *This is an aside.* Think about Google searching through billions of articles, finding 47 million that seem relevant to my search request, and then sorting out about the 200 articles that it considers to be most relevant to my personal needs. In this final sorting process, Google uses its built-in artificial intelligence to take into consideration what it knows about me as a person, and what it knows about me through its analysis of each search request I make. Google is doing the same thing for its estimated four billion individual users! Wow! Talk about, "Big brother is watching you."

My further Web research led me to a Wikipedia entry titled Artificial Empathy (Wikipedia, 2021b, link). Quoting from this article:

> A broader definition of artificial empathy is "the ability of nonhuman models to predict a person's internal state (e.g., cognitive, affective, physical) given the signals (s)he emits (e.g., facial expression, voice, gesture) or to predict a person's reaction (including, but not limited to internal states) when he or she is exposed to a given set of stimuli (e.g., facial expression, voice, gesture, graphics, music, etc.)".

An empathetic robot would have the knowledge and skills to take appropriate actions based on such perceived information. This is an active area of research, one in which significant progress

is occurring. This makes me realize that we indeed are moving toward a time when the intelligence of a computer may well exceed that of a person over a very broad range of human intelligences and capabilities.

Consider my personal thinking that led to the Web use described above. I, a human being, posed a question that interested me. I made use of the computer facilities in my home and others located in various places to seek answers to my question.

My point is that my curiosity led me to pose an interesting question about *empathy*, one that I am sure other humans may have posed as well. **However, I doubt that any computer has independently posed this or a similar question, and then set out on its own to find an answer.** In that regard, I have and I use a cognitive ability that is quite different from that of the best of current AI-using computers.

This led me ask another question, "Is *curiosity* a type of intelligence?" So, I once again went to the Web where I found two general answers. One is that some researchers consider curiosity to be a type of intelligence. The other is that curiosity is considered to be part of every intelligence.

My Google search of the term *artificial curiosity* produced about 24 million results. Needless to say, I did not read all of these documents. I did, however, spend enough time browsing to be able to satisfy my curiosity. (If I said that to a class I was teaching, I would expect a chuckle, if not outright laughter. Did you chuckle? Hmm. Is humor a type of intelligence?)

I found an article about curiosity written by Jeremy Dean that I want to share with you, A Curious Sign that Your IQ Is High (Dean, 2011, link). Here are several short quotes from the article:

- People who are curious ask lots of questions, look for surprises, seek out sensations, and make time to search out new ideas.
- The results showed that students who are curious do better in their school work.
- Taken together, conscientiousness and curiosity were just as important as intelligence in students' performance.

In brief summary, curiosity is an innate human characteristic that appears to be a component of each type of human intelligence. Whether or not curiosity is classified as a type of intelligence is much less important than the fact that it is a component of many different types of intelligences. Schools can provide an environment that encourages curiosity. Some human teachers are much better at this task than are others.

Computers that Play Games

Consider Go, a popular board game long regarded as being beyond the AI capabilities of computers. In recent years, a computer program was developed by human computer programmers that was able to defeat one of the world's best human Go players. A few years later, **a different computer program *taught itself* to play Go** and then defeated the original computer program 100 times in a row in a match between the two computers (Hutson, 10/18/2017, link).

Notice my emphasis on *taught itself.* How did a computer teach itself to play a game? First, you might want to pause for a minute or so and think about possible areas of human intellectual endeavor where a computer might teach itself to perform better than a human. I am a teacher, so

I reflected on the question, **Might a computer program teach itself to be a very good teacher?** Let's use the game of tic-tac-toe to illustrate how such learning might occur for a human or a computer.

Tic-tac-toe is a very simple game. If we take into consideration symmetries, there are relatively few different games possible. For example, the first player can play in one of three locations—center, corner, middle of an edge. If the first player plays in the center, the second player really has only two choices—play in a corner or in the middle of an edge.

We know that tic-tac-toe games often end in a draw, so as we program the computer to learn to play the game well, we know that we cannot expect the computer to learn to win every game. But, how about programming the computer so it learns to never lose a game? Is this possible?

My point is that if we try to have the computer learn to play so well that it wins every game, we will fail. But, we could have the computer try to learn to play so well that it never loses a game. We could go still further, and have the computer learn to detect when its opponent makes a *bad* move that opens a door for the computer to win the game.

This is not a difficult learning task, and many human toc-tac-toe players gain this knowledge through a combination of trial and error, and careful thinking. This is possible because the game has such a small number of different possible sequences of moves.

Let's examine this situation a little more deeply. Through trial and error or through a modest amount of instruction, the player who goes second can learn that, if the opponent begins by placing an X in the center, then it is a mistake to respond by playing in the center of a side because the first player can always force a win in this case. So, we have a situation in which the learner of a game can (1) be specifically taught a particular strategy, or (2) can learn the strategy through trial and error, by careful analysis, or by a combination of these two approaches.

Next, I want to stretch your imagination a little. You know that in each learning situation a student encounters, the student has unique prior knowledge and skills, unique capabilities, and unique levels of interest or intrinsic motivation. Now, you are beginning to see the challenge faced by a human teacher who is making use any combination of traditional teaching methods and learning aids to meet the needs of each individual student.

You also can see the challenge faced by the developers of CAL. We want students to learn to solve a wide variety of problems and accomplish a wide variety of tasks. Some are as simple as learning to play tic-tac-toe, while others are far more complex. For example, learning to add the integer *two* to another integer is relatively easy to learn how to do if one already has learned how to count by ones. The learner merely needs to learn that adding two to an integer is the same as twice counting up by one. Still, that requires some learning and understanding. This learning and understanding can be extended to adding three, adding four, and so on.

But, notice that this requires first learning to count. Our educational system has had thousands of years of experience (a combination of trial and error and research) with what we call *scope and sequence*. When should students learn to count? In this initial and subsequent learning about counting, how high should they learn to count? How well do they need to be able to count before they move on to another math topic that makes some use of counting?

Next, think about *number sense* or *integer sense*. Memorizing how to count is a modest part of understanding the meaning of integers and their uses in representing objects or things in the world. Imagine a child grappling with the possible meanings of being fives year old, of living in

a family of five people, of waiting to watch a TV program that comes on at five, of having five fingers on one hand, and so on.

In summary, the development of a really good CAL system for use in a particular part of one curriculum area is probably more complex than developing a computer program to be really good at playing a complex game such as Chess or Go. In the game playing learning task, the game is the game, and so does not change from moment to moment or from year to year. In the CAL task, each student is unique, is always changing, and lives in a changing environment.

However, progress is occurring in both the area of game playing and in the area of CAL. The future certainly will bring us steadily improving CAL. Since the effectiveness of CAL will vary from student to student, our educational system faces many years of steady change.

More About Computer as Tutor

Here is another example that I find interesting. Human tutors are a very powerful, individualized aid to student learning. Might we someday have an AI-using robot that could observe human tutors and learn on its own to be a good tutor? While we are at this task, let's make sure that the robot also can work with a specific student and develop the skills needed to be especially successful with that one student. (After all, that is what a good human tutor does.) We can conjecture about how long it may be before we reach a time when every student can have such an AI-based personal tutor.

Perhaps you are imagining a large humanoid-like robot that accompanies his or her student throughout the day? How about just a pair of eyeglasses with a built-in camera and hearing aid that can both see and hear, and thus can provide its human with audio and video input? Might this become commonplace over the next 30 years? I am not trying to make such a forecast. Rather, I want you to think outside the box. Such a small portable device would have connectivity to a larger, more powerful computer that would draw on the collected knowledge of the human race. It would be both a tutor and an aid to its human in solving problems and accomplishing tasks.

However, consider the rather scary idea that this computer tutor would be learning more and more about its human tutee. (Remember my comments above about Google learning more and more about me?) Who will have access to all of this personal information about the tutee?

Let me play with your imagination a little more. AI-based computer systems already can solve a wide range of problems and accomplish a wide range of intellectual tasks. As we move toward providing every student with an AI-using tutor, we will at the same time be providing students with a device that can solve the problems and accomplish the thinking parts of the tasks that the AI-using tutors are designed to handle.

This raises an interesting problem for educators. If a computer can solve a problem or accomplish a task, what do we want humans to learn about how to solve that problem or accomplish that task when the human does not have a computer available as a helper? As a rather mundane example, I wear my wristwatch 24 hours a day, taking it off only when I shower or when its battery needs recharging. It clearly is a more capable time keeper than my brain, no matter how much time I might spend training my brain to be good at telling time without any watch or clock-like aid.

People have been developing, testing, and using computer-assisted learning (CAL) for about 60 years (Suppes, 1988, link). AI-using CAL systems are now commonplace in a steadily growing number of our schools.

Interestingly, it has turned out that developing high-quality effective CAL has proven to be a very difficult task. Humans have considerable inherent physical and cognitive potential (ability) to learn from each other as well as learning by themselves. Human teachers draw on their own inherent human abilities and humanness, and then hone these through their own schooling and work experience to become very good at helping other humans to learn. This makes me realize that good human tutors are apt to be better than the best of CAL for many years to come. Today, however, we are able to mass produce AI-based CAL systems. In a wealthy country such as the United States, it rapidly is becoming feasible to provide every student with a useful AI-based CAL system, and these systems continue to be improved, year after year.

A current challenge is to decide on measurable goals of education, and then to determine how to measure success in achieving these goals. How effective must AI-based CAL need to become before we make it routinely available to all students all day, every day, both at school and at home? What capabilities will it need to have before it begins to take over a significant part of the work currently being performed by human teachers? What changes are we apt to see in the job of being a school teacher?

Suppose we look carefully at the learning outcomes typically achieved by a human teacher working with a class of 25 or so students. We decide to use test scores as our measure of success, with an emphasis on standardized tests developed by persons other than the teacher. In this case, we are not expecting the AI-based CAL system to be as successful as is a good one-on-one human tutor working with an individual student. We are comparing a typical class taught by a human teacher with a similar class whose students also are able to use AI-based CAL systems as a supplement to the human teacher, and we are defining success only on the basis of passing tests.

Notice that this situation is quite different from a computer learning to play a game. In game playing, the same set of rules apply to the game over and over again. When a student is learning content in order to pass a test, the student does not take the same test (play the same *testing game*) over and over again. Also, each student is unique. In conclusion, developing computer programs that are as good at playing games is a much easier task than developing good CAL systems.

But, here is an interesting idea. Suppose that our goal is for a student to learn to drive a car well enough to pass a driver's test. Because the same driving test is being used over and over again, some of the learning a student gains from using a car simulation can indeed be a useful part of a driver education program. This observation also holds for computerized simulators being used to help train airplane and rocket ship pilots. These are profound examples of the successful use of CAL in education for relatively specific types of performance.

But what about the use of CAL in the much more complex task to teaching students to write effectively? I write using a word processor that helps to find and correct errors in my spelling and grammar, and produces printed text that is far more legible than my handwriting. Moreover, when writing, I frequently do Web searches and make use of the contents that I retrieve. So, should a major goal in writing instruction in our schools be to have students learn to write using

an artificially intelligent word processor in an environment that includes ready access to the Web?

We already have a variety of examples of successful CAL, and the developers of such systems are confident that they will do still better in the future. So, let me summarize what I see coming. We can expect that the researchers and developers will succeed in producing increasingly better AI-based CAL systems. We also can expect that students will gain increased skill in making use of these systems.

I am confident that this will occur without the aid of any new advanced technological and brain science breakthroughs. But, even now researchers are developing brain implants that facilitate direct communication between a human (or animal) brain and a computer. I find this rather scary, especially as I can think of the possibility of a computer brainwashing a human.

I have a feeling I may now be in *way over my head* in this current discussion, but stay with me. We already have developed computer systems that can:

- Respond to a specific question for information from the Web—which currently contains roughly the equivalent of a thousand billion very long books—in less than a second.
- Teach themselves to be very good at playing a wide variety of board, card, and other types of games.
- Defeat humans in quiz games such as Jeopardy.
- Pass college entrance exams.
- Translate from any one of a hundred different human written languages to any other of these languages.
- Accept oral speech as input in a large number of different languages and produce written text from such input. (Science fiction has long had such voice writers.)
- Solve the various types of math problems that students study up through the first two years of college math.

However, a computer does not have human consciousness and has no understanding of what it is doing. This same statement holds true for other types of machines that humans have developed and now use routinely in their everyday lives.

So, why do we have schools? If we look back 20,000 or so years ago, humans lived in small hunter-gatherer groups. Children learned what they needed to learn by growing up in a community of people who knew how to survive, have children, and pass on the group's collected knowledge and wisdom to their own children. The people occasionally had to deal with disease, changes in climate, or other major natural disasters, and some groups migrated over long distances. This situation persisted for many tens of thousands of years as the communities grew and prospered.

Homo Sapiens began to develop agriculture about 10,000 years ago. Horses and donkeys were domesticated about 5,000 years ago, and camels were domesticated about 3,000 years ago (History of the World, n.d., link). This produced a more stable lifestyle, an increasing population, and larger groups of people living together in villages, towns, and small cities.

The part of this story that I find most interesting is the fact that reading and writing were developed, as well as the schools to teach reading, writing, arithmetic, and history, about 5,500 years ago. This was a very major change agent, and it occurred perhaps 500 years before the domestication of horses and other beasts of burden.

Current Schools Have Many Purposes

Following the development of these earliest schools, it took another 5,200 or so years until the start of the industrial revolution led to the initiation of major efforts toward compulsory schooling of all students. The driving force pushing this change in England was not a belief that all children needed to learn the three R's. Rather, the goal was to keep young children from competing for the jobs that adults needed to have in order to make a living, and also to provide daycare for children whose mothers were working.

PreK-12 schools play many important roles in the education of our children. Some of what schools are trying to achieve can be measured with reasonable accuracy. For example, we want children to learn to read and write. We can measure the reading and writing skills of a child and how they change over years of schooling. Similarly, we want students to have knowledge and skills in mathematics, starting with counting and arithmetic. We also can measure these skills.

We now have had about 5,500 years of experience in helping students to gain skills in reading, writing, and arithmetic. We know that some students are better than others at gaining these skills. We also know there are many aids to learning available to students, e.g., teachers, parents, teaching methods, books, and so on. One or more of these may be better than the others in helping a specific individual student. It is important that we have the ability to match each student with the most appropriate of these aids to learning.

Over thousands of years we have added a variety of content areas to the curriculum. There is considerable difference between gaining basic skills in reading, writing, and arithmetic, and gaining the school-specified knowledge in areas such as history, the sciences, and so on. **An even more challenging problem has been to create schools in which each individual student can learn and grow at the pace best suited to that student .**

We have long known that schooling and education are far more than just having students achieve high scores on tests. We also realized that achieving high scores on tests is an indication that a student might do well in future schooling, quite possibly benefitting by going to college and/or vocational training in preparation for a career and life that requires still more formal schooling.

Computerized machinery and AI-using computers have not changed this overall situation. What is changing are both the aids to using our physical and cognitive capabilities, combined with aids to becoming skilled in functioning well in such a high-tech world.

Many years of research and development, accompanied by substantial decreases in costs and by improvements in the facilities that can be made available to students, have led to significantly increased amounts of the use of CAL. The Covid-19 pandemic has hastened this adoption and use of CAL, both in students' homes and in their schools.

This Covid-driven change to online schooling has not proven to be particularly effective in students' homes for a variety of reasons. One is the fact that students have not been educated to take responsibility for their own learning in a home environment. A second is that students are very accustomed to the set of controls and rules provided by teachers in a classroom and in school. The fact that a typical home does not provide such a structure is another indication that good schooling is far more than just having students achieve high test scores.

A good human tutor has *empathy,* and so is skilled in connecting with a student as a human being to help foster learning. Aha! Perhaps we may need to focus on developing CAL with empathetic

intelligence. **In any case, learning in a CAL-assisted learning environment is now a new basic skill in a modern education.**

Basic Skills

AI makes it necessary for us to reconsider carefully some of the widely accepted goals of education. Let's use Basic Skills as an example. Quoting from the discussion of 14 goals of education in chapter 2 of this book:

> **G6. Basic Skills:** All students gain a working knowledge of speaking and listening, observing (including visual literacy), reading and writing, mathematics, logic, and storing, retrieving, and communicating 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.

The steadily improving capabilities and availability of computers leads to the question of what now constitutes a *basic skill.* Do we still consider reading and writing cursive to be a basic skill? Some schools no longer consider this to be one and are dropping it from their curriculum. Is using a word processor that includes a spelling and grammar checker now a basic skill? How about reading and writing multimedia documents? How about being skilled in learning from CAL systems? These are some of the provocative questions that need to be addressed by our current schools.

A still larger issue is developing and implementing a curriculum when today's AI can solve many of the problems and accomplish many of the tasks that we currently teach students to accomplish without computers. Let's use math as an example. Two goals of math education are:

1. To help students develop number sense and more general math sense. We want students to have good insights into the capabilities and limitations of math to help represent and solve a myriad of problems that they encounter in their everyday lives.
2. To develop skills used in solving certain types of math problems. Here, we now need to consider mental skills, paper and pencil skills, calculator-based tools, and computer-based skills.

We have long had AI-based computer systems that can solve the full range of the types of math problems students currently study in their math courses up through the first two years or so of college. Software to accomplish these problem-solving tasks is available free on the Web, with Wolfram Alpha being an excellent example (Wolfram Alpha, 2021, link).

The challenge that our educational systems now face is to achieve an appropriate balance between the amount of math education school time and effort spent on each of the two general goals listed above. Computers make it possible to spend more time on the first of the two goals, and less time on the second. Within the second category, how much emphasis should be placed on each of the four commonly available approaches that are listed in 2 above?

This same type of analysis can be done for the entire Prek-12 curriculum. In each subject area currently being taught, we need to help students learn to make effective use of computers to help solve the problems and accomplish the tasks that make up the discipline. We also need to help students gain the knowledge and skills to be responsible, productive adults in a world that is increasingly becoming computerized.

Final Remarks

The next chapter will explore some of the dangers inherent to the world's growing dependence on computers. I do not fear the possibility that AI-based computers will take over the world. What I do fear is that a small number of human users of AI-based computers might take over the world or parts of the world. Consider a despot running a group, an organization, a company, part of a government, or the government of an entire nation. AI-based technology can be a powerful aid to such a person or group of people.

Chapter 6
A Gift to Humanity

> Never look a gift horse in the mouth. (Ancient wisdom, perhaps growing out of the Trojan Horse which harbored Greek soldiers during the Trojan war more than 3,000 years ago.)
>
> Always look a gift horse in the mouth. (*Neigh sayers* David Moursund and many others.)

Introduction

I view computers and AI as a type of gift that humanity has given to itself. This reminds me of the quotations given above. (Did you catch my pun in attributing the second quote about *naysayers*?)

This and the next chapter explore some of the current and rapidly increasing uses of AI in our schools. Although I am a strong proponent of using computers and AI in education, I have some concerns that I want to share with you.

In talking about possible futures, I like to start with the past. Life on earth has existed for billions of years (Marshall, 7/14/2009, link):

> (3.8 billion years ago) is our current "best guess" for the beginning of life on Earth. It is distinctly possible that this date will change as more evidence comes to light. The first life may have developed in undersea alkaline vents, and was probably based on RNA rather than DNA. [The article by Marshall includes a photograph of a large tortoise with a statement, "Galapagos tortoises are the product of over 3 billion years of evolution."]

More recent publications suggest a still earlier beginning of life on earth (Wikipedia, 2021e, link). During these billions of years, some life forms prospered and survived for very long periods of time, while others became extinct. Homo Sapiens have only been on earth for perhaps 200,000 years or so. During this time, we have developed many new technologies together with the lifestyles that make routine use of this technology. We have populated the earth, and our activities have significantly changed the world. In the past few hundred years, our technology and life styles have led to our current global warming crisis, and also contributed to many species moving toward extinction.

We can examine the various technologies we routinely use, and think about how they are changing us Homo Sapiens as well as other life forms on earth. We might want to think of each technological development as a gift we accept, and not consider what effects it is having on us and on all other life on earth.

Or, we can question what we are doing, and consider more carefully how we educate ourselves (and especially our children) to make wise use of each new technology. We can set goals for ourselves such as improving the quality of life of Homo Sapiens while at the same time preserving nature with its many life forms and beauty.

Broadening Our View of AI

Most people tend to think about AI as something quite new. They think in terms of the current and still increasing capabilities of computers to solve problems and accomplish tasks that require human intelligence. For a long time, I have thought of this definition as being too limited.

Abhijit Naskar presents a much broader view of AI. He was born in Calcutta, India, and now is one of the world's most famous neuroscientists and an untiring advocate of global harmony and peace. He became a beloved best-selling author all over the world with his very first book, *The Art of Neuroscience in Everything.* In a recent *TEDx* talk, Naskar states, "Every machine has artificial intelligence" (Naskar, 5/20/2019, link). He argues that the more advanced a machine becomes, the more advanced its artificial intelligence becomes as well. In his writings and talks, Naskar emphasizes that **a machine cannot feel what it is doing and this is a fundamental difference between human intelligence and machine intelligence.**

I agree and even expand on what he is saying about AI. For example, I think of the human development of written language as a tremendous step forward in AI. This was followed almost immediately by the creation of schools to teach people (including children) reading, writing, and arithmetic. It was recognized how such knowledge and skills empowered its users—and also empowered the people who owned or could hire readers and writers to work for them. Such education was limited initially to a small number of people. Wealthy people paid for the education of the people they selected. Cuneiform clay tablets from these early years of schools indicate that it took up to twelve years for students to achieve the competency levels deemed desirable in these three subject areas.

Over the past 5,500 years, we have decided that a multi-year opportunity to attend schools teaching reading, writing, and arithmetic is an inalienable right of children throughout the world. It is encouraging to realize that a high percentage of today's children now have this opportunity.

As an aside, the development of the mind tool called *writing* and the development of schools to teach children the 3 R's were not based on careful long-term research that studied whether or not this was a good thing for the future quality of life of the students or for humanity.

Here is another example. While you were in school, you learned to do paper-and-pencil long division of decimal numbers. Well, at one time number systems had not yet been invented, and even after these systems were developed it took people about 5,000 years to reach our currently used paper-and-pencil algorithms for long division (Pat's blog, 11/17/2019, link). I think of long division as a human-developed capability that might well be considered to be a type of AI.

Over thousands of years, some people began to encounter arithmetic problems that required a great deal of calculation. Researchers worked on developing machines that could aid in this task, with the resulting wide-scale availability and use of mechanical calculators. This proved to be a difficult challenge (SchoolMart, 3/29/2017, link).

> The first tool created specifically for use in mathematical computations was the abacus, likely invented in Sumeria around 2500 B.C. The abacus was a table of successive columns with beads or stones representing a single unit, which could be used for addition or subtraction.
>
> …
>
> In 1642, the first true "calculator" was invented: one that performed calculations through a clockwork-type of mechanism. The Pascal calculator, invented by French inventor and

mathematician Blaise Pascal, was lauded for attempting arithmetic calculations previously thought impossible.

Here is another important example of a machine-based (but not a computer) type of AI. A number of years ago I spent quite a bit of time visiting a third-grade classroom. One day I was talking with two boys in the class, and I asked them if they could tell me the time. They each looked at the analog clock on the wall, and told me the correct time. A clock is one of the great inventions of humanity, an important example of artificial intelligence that was developed and routinely used long before we had computers.

Next, I asked the boys to tell me how long it would be until morning recess, or lunch, or until school let out. They thought, but could not provide me with answers. Aha! They could tell time, but they still lacked an understanding of time, or *time sense.* They had learned to use a clock, but their education in both the use and the understanding of their time-knowledge was quite low. As a responsible adult, your understanding and use of time are essential to functioning well in our society. A clock has a very low and limited amount of AI. But, you can use a clock, watch, or other timepiece to make a team that working together is able to accomplish many things that neither of you can do alone.

We want children to learn to understand and deal with the types of problems and tasks adults encounter that require not only knowledge of how to *tell* time, but also to be able to deal effectively with the time-related problems and tasks that are a routine part of adult life. This observation applies to other technologies, such as AI-using computers.

AI and Computers in Schools

In the remainder of this chapter and in the following one, I discuss some education-changing aspects of the many different types of AI being developed for use by electronic digital computers. I raise some questions that apply to all such uses of AI in our schools.

To begin, let us consider a very simple example. The least expensive electronic calculators have a type of AI that people can easily learn to use, one that provides them with arithmetic calculation capabilities that often far exceed those of people using paper-and-pencil algorithms. Moreover, it takes very little time to learn to use such a calculator.

These calculators provide an excellent example of a specific *non-human type of AI.* One underlying goal of math education is for students to develop *number sense* and *math sense.* We know how to help children learn to count and to do simple arithmetic. We know how to teach them to do paper-and-pencil addition, subtraction, multiplication, and division. We can look at adult uses and understanding of math, and explore the level of number sense and math sense routinely demonstrated by adults.

Math education in early grades includes a major focus on learning about numbers and on learning paper-and-pencil algorithms to do arithmetic. So, here are two basic questions:

1. To what extent does having students develop speed, skill, and accuracy in doing paper-and-pencil arithmetic contribute to their development of number sense and math sense?
2. If we partially substitute electronic calculators for paper-and-pencil arithmetic skills, to what extent does this result in students developing less number sense and math sense?

These two questions are illustrative of the questions that we educators face as we deal with the steadily increasing capabilities of AI in our schools. Many educators and others fear that

allowing students to make use of calculators will significantly decrease their level of number sense and math sense. They often give examples of today's high school graduates who lack number sense in dealing with money and in other situations requiring number sense.

But, such testimonials do not constitute proof. I, personally, can examine a widely accepted set of goals of education, and examine how AI-using computers might affect each goal. My analysis draws on my long career in the field of computers in education. Based on this analysis, I can provide you with my own personal thoughts about some of the possibly good and bad effects of such uses.

I also read a lot, and from time to time I encounter research that is relevant to these two questions. But mainly I find articles describing individual teachers who have experimented with various uses of the technology, and then telling stories about the results they observed. I enjoy reading such stories. **However, they do not constitute the type of research needed to justify major changes in our schools.**

This lack of long-term research to support changes in schooling has been going on for thousands of years. During this time, we have made a number of changes based on perceived needs and goals at a particular time and in a particular location. For example, a country might decide that all children should attend school and learn reading writing, and arithmetic. It may be many years later that evidence begins to emerge that this has proven to be both good for the economy and for the health and well-being of the children as they grow toward being responsible adults.

I think it is fun to consider some of the technological progress that contributed to what goes on in our schools. For example, we initially did not have paper and pens for writing. Hmmm. What research did we have to show that moving from writing on clay or wax tablets to the use of paper and pens actually improved student learning, retention, and use of what they were learning in school? This same type of question can be asked about the myriad of other technology-based aids that have come (and, in some cases, gone) being used as aids in teaching and learning.

Our school leaders are beginning to believe that providing every student with good access to high quality CAL materials at home and at school will be good for the education of our children. At the current time, however, we have sparse evidence of long term benefits that may come from this change. Still, I strongly support such a move.

Summary of the Overall Issue

We have long had electric calculators. We also have long debated the extent that they should be used in schools and in tests, and this still remains an issue in schools. Now we have computers, and the same issues arise. In each subject area that we teach in our schools, we want students to learn to think and to solve the problems and accomplish the tasks they are encountering or are likely to encounter. Thus, it is my belief that a modern education includes learning to make effective use of the AI-based computer tools that now are routinely used tools in the various disciplines that students are studying.

The usefulness of a specific AI-based computer tool can vary widely from subject to subject, and likely cuts across many disciplines. The Web, Internet, and search engines provide an excellent example of ubiquitous AI-based computer tools whose usefulness spans all disciplines. Unfortunately, many students still lack the necessary connectivity, computer resources, and instruction needed to integrate the effective use of these tools into the various subjects they study.

You might think that the *powers that be* in a country such as the U.S. would understand this situation, and therefore would have taken the steps necessary to provide all students with effective access to these AI-based computer tools. Prior to the Covid-19 pandemic, the U.S certainly had taken some steps to address this issue. However, the amount of progress occurring over the years has proved to be quite inadequate. Now, the Federal Government and a number of state governments are beginning to move on the task of providing every student with good Internet connectivity and suitable computers for use both in their homes and in their schools.

I believe this to be an excellent first step. But, what about the needed training of the children's parents, guardians, caregivers, and teachers? What about the development of curriculum and instructional materials that make effective use of such facilities? What about ongoing research designed to determine the effectiveness and the flaws in this overall major change in education?

Here is just one example of the challenge we face. For years, educators have talked about *authentic assessment.* Now, we need to be talking about authentic assessment in an education where students are making extensive use of connectivity and Web-based materials, both as aids to learning and as aids to using their learning (Shaw, 3/26/2019, link):

> **Authentic assessment** is the idea of using creative learning experiences to test students' skills and knowledge in realistic situations. Authentic assessment measures students' success in a way that's relevant to the skills required of them once they've finished your course or degree program

It now has become routine for people to make use of the Web as an aid in many different aspects of their everyday lives. Thus, as students make more and more use of AI-using computers in their schooling, we certainly must assess this use in the coursework they are doing. Doing so would be a huge change in the way we currently assess students that now is based primarily on the use of closed book, closed notes tests. A small step away from this was a change in the SAT (Scholastic Aptitude Test) that often is used as an aid to determining college admission. The SAT math test has allowed the use of certain types of electronic calculators since 1994. The level of capabilities of these calculators has been increased gradually over the years, but the currently allowed calculators are far from being state of the art.

Final Remarks

Humanity has long made use of aids to our physical capabilities. As individuals, we have all grown up learning to make use of many machines whose physical capabilities exceed our own in a variety of endeavors. We routinely find it to be both convenient and expedient to make full use of these machines as supplements to our own physical capabilities.

We now have AI-using computers whose capabilities exceed our own cognitive capabilities in solving a wide range of problems and accomplishing a wide range of tasks. The capabilities of these AI-using computer systems are increasing steadily. Whether such computer systems eventually will have capabilities that exceed human intelligence across all areas in which we make use of our intelligence is a fun question to debate, but is not particularly relevant to the discussion in this and the next chapter.

Our school systems must deal more effectively with the situation of computers becoming increasingly more capable than are people in many of the problem-solving tasks that humans historically have used their human intelligence to solve or attempt to solve. The number and importance of these situations will continue to increase. Thus, our schools need to be providing

students with an education for adult life in a world that routinely makes effective use of both human brainpower and AI.

Chapter 7

Concerns About the Uses of AI in Education

> "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; 1928-2016.)
>
> "As more and more artificial intelligence is entering into the world, more and more emotional intelligence must enter into leadership." (Amit Ray; Indian author and spiritual master known for his teachings on meditation, yoga, peace, and compassion; 1960-.)
>
> "… we have a lot of children in each class, sometimes up to thirty. There's no way a teacher can manage them all. It's too overwhelming, as there are too many children, and too many places a teacher needs to be all at once. A human just can't do that. An AI [AI-using computer assisted instruction system] on the other hand could. It could be everywhere in the classroom at once, managing every child at once. This would result in every kid getting as much attention as they needed." (Parker Heintz, 5th grade student in a Portland, Oregon public school.)

Introduction

Notice that the third quotation comes from a fifth grade student. *The world, it is a-changing.*

In the previous chapters, we have noted that AI-using computers already are firmly entrenched in our schools and in our everyday lives. These chapters emphasize that such technology is a major change agent in our world, and that its high pace of success in research and development will continue for many years to come.

AI already surpasses human intellectual capabilities in a number of areas, and this will continue to increase rapidly. However, you may be relieved by my current belief that the development of walking talking robots that can mingle with and pass themselves off as human beings will not occur in the next decade. (Pretty sneaky, right?) My forecast hints that I believe this eventually will occur, but likely not during my lifetime. Also, it is not just *walking*, talking robots that we need to be concerned about. Consider, for example, an AI designed specifically to make an individualized sales pitch on a phone. Advertisers look forward to having such technology, one that will be more effective than just providing a standard recorded message to a potential customer.

I have tended to become philosophical as I write and ponder the ideas in this book. Right now, although I am focusing specifically on AI-using computers in schools, I cannot help but think about the fact that education is a continuing lifelong endeavor, with much of a person's learning occurring outside of formal schooling. We all know that schools provide an important part of a person's lifelong education, but this time is limited in hours per day, days per week, weeks in a school year, and years of formal schooling. Thus, we must pay careful attention to how this precious time for formal schooling is used, and we must align this special time with each person's hugely more hours of learning that is occurring outside of the school hours. I will explore this topic more in the next chapter.

An Expanded List of Concerns

My list of AI-related concerns presented in this chapter includes an enhanced version of items from the previous chapter, as well as additional items. For each concern in my current list, educators who are developing and implementing the curriculum need to consider whether the current use of such AI-using computer technology in our schools is providing students with an education that better prepares them for responsible adulthood in our current and changing world.

This list is by no means exhaustive. My intention is to provide a representative sample of ideas that have occurred to me. I am sure that you can add to the list and quite possibly may not agree with some of my concerns. I have not attempted to order my list in what I might consider to be increasing importance. As they say, *beauty is in the eye of the beholder*.

All items on my list, and others that will occur to you, need to be analyzed in terms of whether they would represent *progress* in education. But, progress is a hard word to define, So, we will never have complete agreement on lists of suggestions on how to improve our schools.

1. An Overall Problem

People in the U.S. today have a great deal of mobility in terms of where they live. Thus, a significant percentage of students experience living in two or often more school districts during their K-12 school years. This always has posed somewhat of a problem, despite the fact that there a considerable amount of uniformity of content in the primary school curriculum and in much of the secondary school curriculum throughout the country.

We damage that uniformity when we provide varying levels of computer capabilities and varying types of usage of these computer facilities from one school district to another school district. This problem is exacerbated as schools provide varying levels of computer capabilities for students to use in their homes, and varying levels of amounts and types of uses of the at-home computers for school purposes. A related problem that will persist for many years is the varying levels of computer knowledge and skills of teachers at all grade levels, and those of the students' parents/guardians.

Perhaps even more important to the future of schooling is the continuing rapid pace of change in the many AI capabilities that are relevant to K-12 education today. This represents an ongoing challenge to curriculum developers, schools, and parents of school-age children.

2. The Use of Electronic Calculators in the Math Curriculum

What is gained and what is lost in math education as we decrease the emphasis on paper-and-pencil by-hand calculations, and increase the emphasis on using calculators and computers? It currently takes considerable school time for a student to develop paper-and-pencil skills in doing arithmetic calculations. Might the use of calculators and computers allow us to spend less school math education time on this topic, and more on other aspects of math such as mental calculations and estimations, number sense, math sense, math modeling, and problem solving? This is an important research question.

It also is a course content question to be asked across all curriculum areas as computers with powerful problem-solving capabilities become more and more available not only to students, but to adults who need to solve such problems. From quite early on, this question has been a challenge to our math educational system, as we have long had computer systems that could solve essentially all of the types of math problems that students encounter up through the first

year or two of college math. Which of these math problems must they still learn to solve by hand, and which should they now be learning to solve with the use of computers instead?

My doctorate was in mathematics, and I have long been interested in these types of questions. Very early on, I wondered whether the use of electronic calculators in grade school might eventually lead to a substantial decrease in the number of students who take the more advanced math courses in high school and college. Or might the opposite outcome occur as students find the math they are encountering in more advanced courses to be so much more interesting and fun that they happily will pursue advanced coursework in math and in college degree areas that make extensive use of such math? Neither of my conjectures has proven to be a problem.

3. An Extension of the Item 2 Idea to Other Curriculum Areas

I see two aspects of this question, the first one from a math point of view. Math is a useful tool in most academic areas of study. Many teachers are loath to make such use of math in their courses because of the large variations in students' calculation and other math skills, and because the teachers themselves do not want to spend their valuable class time helping their students learn to do math.

The second aspect consists of considering other computer tools that are useful in many different curriculum areas. For example, the use of computer graphics has become a routine part of the graphic arts, and graphic arts now are used routinely in the creation of multimedia documents. Therefore, learning to make use of such tools has become an accepted part of learning to develop and write multimedia documents. To what extent do we want students to be dependent on computers for completing graphic arts activities that formerly were done only by hand?

More broadly, we certainly want students to learn to read in an interactive multimedia environment. Do we want them to learn to write in this environment? Students can learn to do this, even at the elementary school level. But, think about the challenge to teachers in all curriculum areas that currently expect their students to produce written documents.

Here is a simpler example. Some students develop good keyboarding skills. Should such students be allowed to use a word processor when taking written tests that require students to do some writing? Or, do we decide it is unfair to allow such students the advantage of being able to use a computer to write faster and produce more legible text?

The point is that, because computer applications in computer graphics, spreadsheets, and databases have become skills so important and widely used by adults, perhaps all students should begin learning to use these tools while still in elementary school. A similar statement holds for learning to use a word processor. And, what about using a voice input word processor? Can you imagine a teacher trying to give a test to a classroom full of students who are talking to their word processors? Aha! A technological solution would be for all students to wear earphones that cut out all outside sound, and the teacher to be able to electronically talk to any individual student or to the whole class via the electronic communication system.

Suppose only some elementary schools decide to do this. Then teachers in all of the schools that receive graduates from these elementary schools will be faced by students who have these skills and who also have an expectation of routinely making use of them in the upper grades.

4. The Decrease in Emphasis on Cursive Reading and Writing

I see two aspects of this decrease in emphasis on cursive reading and writing that some schools are implementing. First, students are growing up in a world that predominately still makes use of cursive writing. So, an elementary school's decision not to teach cursive reading and writing can ill prepare students to deal with this mode of written communication that may well be expected by their teachers at higher grade levels, and a skill that is still a routine part of the adult world.

The second aspect consists of the benefits students gain by learning to make effective use of the grammar, spelling, and other writing aids that a word processor provides. A downside it that students may come to depend on such writing aids, and will be disadvantaged when they are not allowed to use them when taking tests.

As an old timer, I am somewhat disturbed by seeing some of my grandchildren struggle with reading cursive. This example illustrates some of the challenges that schools face as they consider increasing the use of computers in writing. However, there is much more to this issue. A good word processor has AI-based spelling and grammar checkers. This is a type of built-in Computer-assisted Learning. Such a system also provides good access to a list of synonyms and to a thesaurus.

5. Our Current Slow Progress in Developing Authentic Assessment of Computer-using Students

This is both a local and a national problem. In the adult world, employees who have need of computer access to do their job will have such access and are expected to use it. In addition, many adults with computer knowledge and skills make routine use of these skills in their day-to-day lives. Thus, as students gain increased computer knowledge and skills, we need to assess their progress to determine how well they are doing—because such knowledge and skills will be very important to these students in their adult lives.

We already have come to expect students to make use of the Web as they complete assignments, but currently most teachers do not allow such access when students are taking tests. Traditional schools have a severe lack of making use of open computer, open connectivity in student assessments. National, state, and regional tests also lack this authenticity. These are all problems that face our educational systems.

6. The Replacement of "Conventional" Library Materials by Online Library Materials

There is considerable difference between the knowledge and skills used as one searches in a card catalogue and browses the library stacks, versus searching on the Web. Conversations with a skilled school librarian, and formulating search strategies based on such conversations, is a valuable part of education that is disappearing rapidly from our schools. Classroom teachers in each subject area must now teach the research skills related to accessing and using the types of content relevant to the subjects they are teaching. These skills must cover searching both online and in printed materials found in libraries and at home.

Teachers have an added concern of more widespread plagiarism resulting from sudents having easy access to the Web. Of course, many teachers now make use of the online AI-based software that searches a student's paper for signs of plagiarism.

Certainly there is a difference between learning to *browse the library stacks* and learning to carry out a Web search. Personally, I like to make an analogy between browsing library stacks and

browsing in a retail store, where I often stumble upon a product that grabs my attention. When I do a Web search, in essence I am using a computer to search though billions of documents and bring to my attention a few that its AI determines might interest me. While this is an increase in efficiency and also searches a great many more documents than would be available in a local library, I miss the opportunity to browse the library shelves for unexpected discoveries.

The placement of items in a store is designed to increase sales. A search engine such as Google makes its decisions of what to display to me based on its knowledge about my previous searches and also about usage patterns from other people who have done somewhat similar searches. Many people are concerned by the collection and use of such information about their searches by the computer in its decision making, and of the subsequent sale of such information.

7. An Increased Risk of Students Being Presented With and Using Fake News

Fake news is defined quite broadly as content that is heavily biased or deliberately falsified. Here we are mainly concerned about fake news on the Web and in other resources readily available for students to read, listen to, or view. In the past, the materials in schools and classrooms were screened very carefully by librarians and teachers. Even then, of course, children received (and nowadays continue to receive) considerable information from family and friends that may be strongly biased and/or just plain incorrect.

This presents an interesting challenge to teachers and all other people who interact with children. It is part of being a child and growing up to have to deal with inconsistent stories (fake and strongly biased news) coming to them throughout the day. Personally, I classify much of the advertising I encounter as falling into that category. I believe this is a topic that needs to be addressed openly in schools. Certainly, as the reading skills of students reach a level at which they can access and read Web documents, they should be learning about *fact checker websites.* They should learn that it is perfectly appropriate for people to have differing beliefs, but it is important to pay attention to factual information that is based on careful data gathering, analysis, and peer review (Farmer, 5/31/2018).

8. AI Is Now Routinely Used in (Very Addictive) Computer Games

Some of the earliest computer games were designed to be both entertaining and educational, and the number of these games continues to grow. Many of these are very useful educational activities often presented as simulations or in other game formats. For example, consider an airplane flight simulator designed to help a person learn to fly a plane. It is fun to learn some of the aspects of flying a real airplane, even if one decides to not become a pilot. And, of course, flight simulators are an important aid to training the pilots of airplanes and rocket ships. Or, consider a computer simulation of a scanning electron microscope. Since the human interface to such a machine is a computer program, a user cannot readily differentiate between using a simulator and using the actual microscope. Simulations of this type are used routinely in training radar operators, air traffic controllers, and so on.

However, many of today's so-called educational games are very short on educational value and very long on entertainment value. Years of research on designing these *edutainment* games has produced games that are potentially addictive. This type of addiction is different from addictive drugs, but tends to have some of the same ill effects.

I personally have experienced this form of addiction in my own life, and I have learned to deal with it in a variety of ways. One of my observations is that my brain's pleasure center (or, the

part of my brain that gains satisfaction with what I am doing and accomplishing) does not differentiate between the pleasure that it gets from my playing a game and pleasure from my writing insightful paragraphs such as the ones I am currently writing.

Students now are routinely exposed to and play such games, many of which are in some sense brainwashing devices. What do we want students to learn about this type of addiction? Researchers and developers will continue to improve the entertainment and addictiveness capabilities of such games. I strongly believe that schools should provide students with explicit instruction about this topic, and what to do if gaming becomes a personal problem for them. Free professional counseling should be made available to students who need help in dealing with such an addiction.

9. Learning to Learn in Highly Interactive Intelligent Computer-assisted Learning environments (HIICAL).

I have used the term *HIICAL* in a number of previous writings, but it is not yet widely used by other people (Moursund, 2002). For me, the term emphasizes the role of AI in modern Computer-assisted Learning (CAL).

My concern is that we will underestimate the magnitude of this learning challenge faced by students and schools as the availability and use of such instructional materials continues to grow. We certainly have seen this as millions of children began to be home-schooled because of the Covid-19 pandemic. Most students, teachers, and parents/guardians were ill prepared for such a sudden and massive change in teaching and learning.

HIICAL researchers and developers have had more than fifty years to hone their skills and learn to market their products. We have long known the value of providing students with individual, well-qualified tutors (Bloom, 2021, link). Now we have HIICAL that can do much of this same tutorial work with students, and so we face the challenge of integrating the effective use of both human tutors and HIICAL.

The future will bring us more and better multimedia HIICAL materials designed for use by individual students at specific grade levels and in specific subject areas. And, of course, when it is useful to the learning task at hand, the materials will include virtual reality. We are used to the idea of having different reading groups in a class. With sufficient high-quality HIICAL, it will become possible to provide individualized HIICAL across the curriculum and across the grades. In the years to come, our schools will need to decide the extent to which it wants to incorporate this level of individualization offered by HIICAL.

While the financial challenge of providing the needed equipment, connectivity, and multimedia HIICAL materials is large, it is clear that these barriers can and will be overcome. We face other, more daunting challenges. For example, we certainly want students to have access to and also learn to make effective use of these materials facilities and aids to learning both at home and at school. But, such a learning environment is alien to most parents. This is in contrast to reading and writing literacy in at least one natural language, which is common in U.S. homes. Teacher education will be a related and ongoing challenge as significant improvements in the capability of HIICAL and other uses of AI continue to occur from year to year.

10. Brain Implants and Genetic Engineering of Humans

> "We'll never have true AI without first understanding the brain." (Will Douglass Heaven, currently senior editor for AI at *MIT Technology Review.*)

Humans have had thousands of years of experience in the genetic engineering of agricultural plants and animals, a growing field for scientific research. AI now plays a major role in both the research and in the implementation of this research. It now has become is likely that our schools may soon be faced with learning to deal with an increasing number of genetically engineered children.

A somewhat related, but likely much larger problem, is that of brain implants. We are used to the idea of physical implants as replacements for various parts of a person's body. But, the direct implant of an electronic human-to-computer interface is new. Research on proof-of-concept has been occurring during the past few years, and a highly computerized robot has been built that can actually carry out such implants (Kay, 2/2/2021, link). Of course, direct interfaces between computers and a person's brain have been part of science fiction for many years. In such stories, computers can download a natural language into a person's brain in a modest number of hours. That idea is still wild-eyed speculation!

Final Remarks

Since the initial development of reading and writing, and of arithmetic that makes use of reading and writing, education as a whole and our schools have never faced a challenge as daunting as that posed by current progress in ICT, AI, and technology based on their rapidly increasing capabilities. Continuing *business as usual*, with its glacial rate of change in our schools, does not suffice.

We know that business, industry, medicine, politics, and other major aspects of our world are making large and concerted efforts to adjust to and take full advantage of these advances in technology. **It is imperative that our educational systems do the same.**

Chapter 8

Major Changes Are on the Horizon

> "It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change." (Charles Darwin; English scientist and naturalist; 1809-1882.)
>
> "Any genuine teaching will result, if successful, in someone's knowing how to bring about a better condition of things than existed earlier." (John Dewey; American philosopher, psychologist, and educational reformer; 1859-1952.)
>
> "The aim [of education] must be the training of independently acting and thinking individuals who, however, can see in the service to the community their highest life achievement." (Albert Einstein; German-born theoretical physicist and 1921 Nobel Prize winner; 1879-1955.)

Introduction

My goal in this book and many of my previous writings is to help to improve the lives of people and other life on earth. The quotations given above reflect some of my beliefs.

It is clear that AI is a powerful change agent, one that already has produced a number of changes in our schools. Each of us has our own opinions as to which of these and other proposed AI-related changes may prove to be desirable, and which may prove to be undesirable.

Our schools have made some progress in making effective use of AI, but for the most part our schools might best be described as *same-o same-o*. The computer-based changes and more specific AI-based changes in our K-12 schools pale to insignificance when compared with changes in the business world. Amazon, for example, began its original retail book sale business based on emerging capabilities of computers, and now has expanded into a HUGELY large and successful business that is quite different from what large retail businesses were like before Amazon was established. A similar statement holds for Google.

Brief Summary of Key Ideas from the Previous Chapters

AI-using computers present us with new opportunities in both informal and formal education. This final chapter explores some of my ideas of what I think K-12 education can and should be doing.

We Homo Sapiens have a combination of physical and cognitive abilities that set us apart from all other creatures on earth. Using these capabilities, we have developed superior abilities to preserve and pass on information from one generation to the next.

Eventually our human brains evolved to made it possible to develop our current levels of oral fluency. This was a huge step forward. We don't know precisely when oral fluency developed. But, estimates are that this was likely more than 200,000 years prior to the time when we developed written language.

It seems clear that we had the intelligence and physical capabilities to develop reading and writing for many tens of thousands of years before we actually made that great cognitive leap. It was only about 5,500 ago that we invented reading and writing, together with arithmetic based

on using reading and writing. We developed books and printing presses to allow us to make still more effective use of our reading and writing skills.

Every tool inherently contains a certain level of intelligence. Computers now bring us AI, the most powerful aid to intelligence we have ever developed. We do not yet know the likely limits of AI or what changes it will lead to in our lives and world. As mentioned in the Preface, a number of people have written about achieving a *singularity,* a time when computer-based AI exceeds human intelligence across the full range of human cognitive capabilities. Current predictions as to when this might occur range from sometime in the next ten years, to sometime in our current century, or to never.

Overriding Goal: To Make Progress in Improving Education

I assume that all of my readers are interested in improving education, a task that I have been working on for the past fifty years or so. It is a formidable challenge.

AI has the potential to help to improve education—both education through our schools and education outside of our formal schools. Two questions we all need to address are:

1. What would constitute an *improvement* in education?
2. How does one define and measure *progress* in improving education?

As I was browsing through possibly relevant literature, I encountered a recent article by Amy Nordrum in the *MIT Technology Review*, What Does Progress Mean to You? It contains brief responses from ten activists, entrepreneurs, historians, and economists who were asked to define the deceptively simple term *progress* and to respond to the question, "What does it mean to make progress?" I found the responses interesting and enlightening. She begins her article with this statement (Nordrum, 2/24/2021, link):

> What do we mean when we talk about progress? In general terms, to make progress means to move toward something and away from something else. But where we're headed and what we're leaving behind are key questions that drive political movements, shape international treaties, and define our own sense of personal growth.

The definitions provided by the interviewees gave me some insights into the challenge of achieving widespread agreement on defining what might constitute *progress in improving education*. The following are short quotations from six of the people interviewed for the Nordstrum article. Each person is from a different country.

> "The bottom line: progress isn't about closing a gap. It's about opening a door." (Shivani Siroya, Founder and CEO, Tala.)
>
> "Progress, to me, is not found in the growth of companies or even the development of new technologies, but in justice and equality and human rights." (Jillian York, Electronic Frontier Foundation.)
>
> "Meaningful progress is about using our abilities and resources to create a world where anyone can thrive." (Bárbara Paes, Activist and Cofounder, Minas Programam.)
>
> "Progress means actively fostering innovation." (Yariv Bash, Cofounder, SpaceIL and Flytrex.)

> "Progress is often measured as economic growth only. But real progress would involve growth that doesn't externalize social or environmental costs." (Farhana Sultana, Associate Professor of Geography, Syracuse University, U.S.)
>
> "Progress for me is about what actually matters most in life: health, job satisfaction, housing quality, living standards, and real education." (Danny Dorling, Professor of Geography, University of Oxford, United Kingdom.)

For me, this range of definitions highlights the challenges that educational leaders face as they work to improve education. We need to think broadly as we help to prepare the future adult citizens of the world. Quoting again from Hugh Evan's 2016 *TED talk*, What Does It Mean to be a Citizen of the World? That was mentioned in chapter, "I'm convinced that if we had more global citizens active in our world, then every single one of the major problems we face — poverty, climate change, gender inequality—become solvable." (Evans, 4/11/2016, link).

You might want to reread the previous sentence about the need to have more global citizens active in our world. I believe that every person on earth already is a *citizen of the world,* and that we need an educational system to foster and support this belief. This global perspective has been strengthened greatly by the current availability of about one smart phone for every two people on earth, together with global connectivity that makes it possible for them to communicate with each other. In addition, this global ability to communicate is helped by ongoing AI-based developments in language translation, including the ability for voice input in one language to be translated quickly into voice output in another language.

Over the past century, leaders throughout the world gradually have come to believe in and support the idea that schooling at least through the sixth grade, and much further in many countries, is an inalienable right of all children in the world. Considerable progress has occurred in implementing this idea, and the global literacy of current 15 year-olds is now approaching 90% (Wikipedia, 2021h, link).

In essence, there is global agreement that one goal of education is to help all children to become reading and writing literate. We have thousands of years of experience in how schools can accomplish this task. We have made considerable progress in improving both our teaching and the related instructional materials that help us to move toward universal reading and writing literacy. We also have achieved relatively good worldwide agreement on what constitutes reading and writing literacy, an agreement that can help us to measure progress both in individual countries and throughout the world.

Personally, I would like for our schools also to include a focus on having all students gain a useful level of understanding of the concept of *quality of life*. What is it, how does one measure it, and how does one measure progress in improving the *quality of life* of all people, people in a specific country, and each individual person? Notice the parallel with the goal of achieving global reading and writing literacy.

Is it an alienable right for all people to have an adequate quality of life? The United Nations addressed some basic quality of life issues in its December 10, 1948, Universal Declaration of Human Rights. The U.S is a signator and a strong supporter of this document. Quoting from this document (United Nations, 1948, link):

> Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and

> necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control.
>
> …
>
> 1. Everyone has the right to education. Education shall be free, at least in the elementary and fundamental stages. Elementary education shall be compulsory. Technical and professional education shall be made generally available and higher education shall be equally accessible to all on the basis of merit.
>
> 2. Education shall be directed to the full development of the human personality and to the strengthening of respect for human rights and fundamental freedoms. It shall promote understanding, tolerance and friendship among all nations, racial or religious groups, and shall further the activities of the United Nations for the maintenance of peace.
>
> 3. Parents have a prior right to choose the kind of education that shall be given to their children.

That seems to me that the item #1 in this list needs to be updated. At a minimum, should free and compulsory elementary education be defined as education through the eighth grade? Education through the eighth grade would appear to be a very conservative goal for our current world. We also need some general worldwide agreement about what constitutes an education to this level. I would modify item #3 so that it clearly fits with a modified version of item #1. There are many ways to achieve a given level of education, and parental choice is an important idea to uphold. It is important to remember, however, that every person is a citizen of the world who therefore needs to learn to function both locally and in a much larger world.

AI can and is making contributions to the overall quality of life of people in our country and in the rest of the world. My vision of the future of schooling in the U.S. is that it will include a substantially increased emphasis on helping all students to understand what constitutes an adequate quality of life.

As noted above, the United Nations Declaration of Human Rights stresses the need for a basic education as one part of an adequate quality of life. Educators throughout the world agree that reading and writing are essential components of the early grades. I believe that a *modern* basic education includes learning about the capabilities and limitations of the aids to our physical and cognitive abilities that now are a routine part of the current world, together with insights into what is likely to become available in the next decade or so. AI lies at the heart of many of the changes that are occurring and will occur.

An Opportunity for Major Change in School Curriculum

Here is an overly simplistic description of the content of a typical school's curriculum. The curriculum consists of some content that is strongly vertically structured and some content that has little or only modest vertical structure. This difference between strongly vertically structured versus moderately vertically structured presents a major challenge to our schools. This is because of the huge differences among students, both in their natural abilities and in the depth of their interest in learning any specific subject area.

We tend to group students in grade school based on their age. To a certain extent this continues in middle and high school. This grouping is considered to be important in the social education and development of students.

> *This is an aside:* The education of infants and children up until they start in a preschool or kindergarten program is highly individualized. A certain amount of intervention by our social welfare systems provides instruction to some parents and guardians designed to benefit very young needy children. This is a type of educational individualization for the adults and their children.

Math education provides an excellent example of a vertical structure. If a student earns a grade of D in third grade math, and the student is then moved on into traditional fourth grade math, the chances are that the student will do very poorly because the fourth grade math builds heavily on the math knowledge and skills taught in the third grade. The student likely will continue to fall even further behind throughout the subsequent grade levels, and is likely to stop taking math coursework as early as the school system allows. Indeed, some students fail to graduate from high school just because they have had major difficulties in learning the required math.

I have a doctorate in math, and I certainly believe it to be an important academic area. But, I cannot believe that we should use an inability or unwillingness to learn math above the level of basic arithmetic to be a reason for preventing a student from graduating from high school.

Contrast this with a school that decided every student should have a half-year or a year-long course in keyboarding, a stand-alone skill rather than one that is structured vertically in successive years. Some students will perform much better than others in learning this skill, but all will gain by having a useful skill that will serve them well in the future.

For another example of a course not structured vertically, many states in the U.S. provide fourth grade students with a year of instruction about their own state. This course contains considerable content about the history of one's state, and also some instruction about learning about history. The latter knowledge and skill can be used by students in their subsequent studies of history. However, substantial differences in how well the students learn their state's history are likely to have little impact of their future years of pre-college education.

AI-based HIICAL provides schools with the opportunity for each student to move at his or her own pace in a course. We know that some students will be able to progress at two or more times the pace of average students in a particular subject area, and some will progress at half or less the rate of average students. This is important in any course area, but I believe it to be particularly important in the vertically structured courses.

> *This is an aside:* This situation reminds me of a time when I had an office in the Computer Center at Michigan State University. As a university faculty member, I generally kept my office door open. When I heard two young students talking while sitting outside my door, I went out and talked with them. It turned out that both were twelve years old. One was the son of a janitor at the university, and one was the son of two Ph.D. research mathematicians who were on the faculty. Both of these young students were being allowed to audit Advanced Calculus—a course for juniors and seniors who were majoring in mathematics at the university. Both students had been provided with this opportunity to proceed in their math studies at a rate that suited their interests and abilities, and both were succeeding. Essentially, from perhaps age four or

five, both had learned math at about twice the rate of the average student. So, by age twelve they were seven or more years ahead of their age group in math.

Our schools certainly understand that students vary considerably in how fast and how well they can learn the various subjects the school offers. At the elementary school level, for example, it is common to divide students into reading groups that progress at different paces. In secondary school, we now offer different sequences of math courses, e.g., a calculus course or at least a course that is designed to prepare students to take a calculus course.

> *This is an aside:* My father was chair of the Mathematics Department at the University of Oregon. When was a young child, calculus was a second year course for math majors. By the time I started at the university, it had become the second and third quarters of a freshman course for math majors. Today, some students take a year of calculus in high school. This change over the years reflects our increased understanding of the math-learning capabilities of students who are interested in and also gifted in mathematics. In essence, our precollege math education system has implemented a type of grouping system. This is not a complete individualization system, but is a step in that direction.

Progress in developing AI-based HIICAL eventually will provide schools with an opportunity to individualize vertically structured coursework in all of K-12 education. This individualization of education can be helpful in most if not all content areas, but will be especially helpful in vertically structured curriculum areas where students currently move upward in lockstep year after year.

A Glimpse into a Possible Future That Is Not Too Far Away

Here and in the following section, I describe a relatively near future and a slightly further away future that I believe should and likely will occur in the United States. We now are in the process of providing every student in the U.S. with home and school access to computers that have good connectivity. Students also will have access to a wide range of computer-assisted learning materials. Of course, the nature and extent of these materials will vary from state to state, and from school district to school district within a state. Our schools will support the use of such materials as part of their students' home and school education.

These materials will be improving steadily as AI-based Highly Interactive Intelligent Computer-assisted Learning (HIICAL) becomes the standard that developers of CAL materials strive to achieve. The Covid-19 crisis has shown us that it is not easy for students to *learn to learn* in a CAL or HIICAL environment. Thus, I believe that one of the goals of education should be helping all students to become comfortable and competent in learning in this new environment. This is a very important idea. We want students to *learn to read* in order to be able to *read to learn.* Part of reading to learn today is *learning to read interactive multimedia* designed to help people learn.

HIICAL materials gradually will become available to cover the entire K-12 academic curriculum and a large number of content areas that are not (yet) part of the regular curriculum. Thus, if a student becomes interested in a subject area not being covered in a school's regular course offerings, that student will be able to access HIICAL materials designed to meet those individual needs. All of this is possible with current technology—no new technological breakthroughs are needed.

Another important aspect of HIICAL is the fact that we can integrate instruction on the use of computer tools within this framework of learning. Students can *learn to learn* in such an environment, and also learn to use the computer tools that now are routinely available to people who make use of the knowledge and skills they are learning in a course. This integration of the routine use of computer-based tools is a major step forward in education.

If you are a teacher or have other involvements in our schooling system, pause for a moment and think about the necessary changes to preservice and inservice teacher education that will be an important ongoing need amid the many other challenges to our current schooling system. Think about helping students learn to be effective users of this new HIICAL school environment, and what parents will need to learn in order to provide effective help.

In summary, my glimpse into the near future forecasts that all students will have rapidly expanding access to HIICAL that covers a very wide range of areas of study, both areas in the required school curriculum and other areas that a student might want to study. The motivation to make routine use of HIICAL outside of the required school curriculum might come from a student, from a teacher, from a parent or guardian, or from other sources. I personally believe that this will be an improvement in our schools. In addition, it will open up an opportunity for other very major changes in our schools.

A Glimpse Further into the Future

In this section, I gaze further into the future. The future I envision here can be achieved with only modest improvements in the technologies that already have been developed. It requires that we develop and then mass produce some quite sophisticated ICT hardware. It also will require a major change in the way we currently implement the results from very high quality refereed educational research. Right now, we do a poor job of making effective use of much of this research.

To begin, I want to mention a very difficult issue. As we raise and educate our children, we attempt to prepare them with knowledge and skills that will serve them well, both at the time they are receiving the education and then throughout their lives. At the same time, we also attempt to shelter them from harmful information. Decisions about each of these general types of goals are made by people with varying insights into what is important information and also what is correct information. For one example, I imagine that it may be confusing to students who learn differing stories about evolution at home, perhaps in their church, and at school.

In my vision of the future of education, all students will routinely learn to make use of both HIICAL and the Web in each area they study. This means that most students will gain an education based on content coming from multiple sources. A goal of education will be to help students learn to evaluate and learn from these multiple resources, and also to deal with conflicts in both content and teaching methodologies in their education.

Providing students with access to the Web and with connectivity to other people near and far opens up learning opportunities and experiences different from those they formerly received from their home, community, and school experiences. It also exposes them to fake and/or heavily biased content in their schoolwork (Farmer, 5/31/2018).

This is not a new problem. The new problem is one of carefully crafted fake and/or heavily biased information being presented to students as part of their everyday lives, both in and outside of school. What do we want students to learn about fake news, such as how to detect it and how

to deal with it? In the past, each school had a library and textbooks with contents carefully chosen to reflect the insights and biases of the schools, school district, state, and country. Now, we are providing students access to the Web, with content that is not carefully screened for correctness and bias. This creates the situation of having students who can read well enough to make use of the Web are very likely to routinely encounter fake or strongly biased information that has not been screened by their teachers, school, and so on. This is certainly a challenge to teachers, schools, and parents.

Suppose that a country has a national school curriculum in which all students develop the knowledge and skills needed to access information independently. Some of this information often may be contradictory to what they have previously learned and/or are being taught at school and/or at home. It is difficult enough to challenge statements in one's school materials and content presented by a teacher. For many, it is even more difficult to challenge information that is coming from one's parents and other authority figures outside the school.

Now, for a glimpse into the future. Imagine providing every student with an easily portable personal digital assistant (PDA) that has the following types of capabilities.

1. The PDA has varying types of input capabilities such as video, audio, and GPS. Sensors will allow the PDA to know where "its" student is and what is in that student's current environment. The PDA will be able to recognize many of the objects it sees. It is fun to point my Smartphone at a flowering plant and have my phone identify the name of the flower and give me other information about it. A feature that I personally look forward to having readily available is face recognition. I have face blindness, which often can make it quite difficult for me to recognize people I know.
2. The PDA uses HIICAL as a personal tutor and learning aid for "its" student. It learns the physical and cognitive capabilities and limitations of "its" student as a learner. Thus, the PDA will routinely compensate for a student not having the prerequisite knowledge and skills that are assumed for students being taught a specific subject at a particular grade/age level.
3. The PDA provides access to the curriculum instructional content as well as to instruction on the computer-based tools our school system believes students should be learning to use. Of course, this still leaves open the issue of the extent to which students will be provided access to computer-based tools that they, personally, decide they want to learn to use, what their parents want them to learn and use, what their friends are learning and using, and so on.
4. The PDA will be available to students at home, at school, and in other locations deemed appropriate by schools and parents/guardians. This leaves open the issue of access when schools and/or parents do not want a student to have and use such access. Quoting from the UN Universal Declaration of Human Rights: "Parents have a prior right to choose the kind of education that shall be given to their children." This means that schools must develop an appropriate response to a parent who says, "I don't want my child to learn from or have access to the HIICAL or the Web." Or, a parent might want a child to have unlimited access to the HIICAL or the Web claiming that this is essential to preparing their child for life as an adult.

Here is analogy that just occurred to me. Parents decide that they do not want their children to get the vaccinations a school district requires of all of its students. The school district might respond by providing home schooling via free HIICAL, one free hour of a human teacher's

online help per week, and whatever other help the parents want to pay for. If a child gains the knowledge and skills that the district is expecting for its school-attending students, then the child would receive a diploma. This child might not get the same student-to-student social upbringing as do the students who attend school, but that is a different issue to consider.

The technology to implement all of the above can be mass produced and mass distributed. In the wealthy nations such as the U.S., it will be economically feasible to develop and to provide such facilities and content to all students at the K-12 level. In the U.S., our Federal government will help to pay for some of this, but it mainly will be up to the individual states to decide the extent to which this set of possibilities will be implemented and to pay for them over the long term.

The second item in my list of PDA capabilities is particularly important. We have long known that providing a student with an individual human tutor makes a huge difference in that student's education. Benjamin Bloom's work in this area has been seminal. In essence, his research indicates that, with the aid of a human tutor, an average "C" student in a course can earn an "A" in the course (Wikipedia, 2021c, link). We are making significant progress in developing computer-based tutors that have many of the capabilities of a good human tutor.

Progress in educational research and in AI will lead to the development of much better versions of the currently available *computer tutors*. Increasingly, we will have HIICAL that is more successful in many different aspects of teaching than is a human teacher who is working today with a classroom of 20 to 30 students. And, as noted earlier in the chapter, this HIICAL will facilitate a much higher level of individualization of instruction. Such courseware will be valuable to many students, and eventually will facilitate a major change in how teachers spend their time in working with students.

Final Remarks

AI-based computer technology is being implemented widely and quite rapidly throughout the world of business, industry, education, medicine, research, and many other areas. Each such area has its own measures of success or progress.

Let's use business and industry as an example, and compare it with PreK-12 education. Successes and failures in business and industry are much easier to measure than successes and failures in our attempts to use AI to improve education. Business and industry use measures such as market share, profit, and loss. A business or industry failure results in a loss of money by the owners, and a loss of jobs by employees.

All of these measures are rather concrete. They are quite different than measures of how well our schools are doing. For example, a major goal in schools is to help children grow up to be responsible, law abiding adults who have knowledge and skills in a variety of areas. We want them to develop both a learning ethic and a work ethic. Some of this learning ethic, knowledge, skill, and work ethic is applicable to getting and holding a job, while other is applicable to being a good parent, having knowledge and skills to be a lifetime learner, and so.

This is an exciting time to be a teacher. I wish each of my readers a happy future.

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