Four fictional views of the future of learning

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Abstract

We are at a critical moment in the history of human learning, and in the history of humans. Learning is very important in our future. With 6 billion people on Earth, going to 9 billion by the middle of the century, current educational systems everywhere at all levels have major problems, probably not solvable with present approaches. In many areas, little education is available. We need new learning modes and structures, and we need them quickly and globally. Creating new learning materials and systems will require great imagination. We need approaches that go beyond current situations. Learning should be greatly improved, less expensive, and available lifelong for all in all subjects. We need a society that focuses on learning, where everyone loves to learn. Solving many of the world's problems, including population, water, violence, health, and environmental destruction, will depend on improving learning. One neglected source of future ideas is fictional accounts of the future of learning. I have long found them helpful in my own thinking and have written about them before. I keep finding new sources of this kind. Some, not mentioned here, are negative views. © 2001 Elsevier Science Inc. All rights reserved.

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1. Source

Some of my papers have introduced these fictional accounts. These ideas have been incorporated in a recent book, *Tutorial Distance Learning, Rebuilding Our Educational*

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System, with a friend, Sigrun Gunnarsdottir. The publisher, in 2001, is Kluwer Academic Publishing. It is part of a series of books edited by Karen C. Cohen. This paper differs from the section in the book.

2. Future views

This editorial is based on four accounts, three from science fiction and one from fictional chapters in a nonfiction book. They are not complete accounts of a new learning system, and differ greatly in the amount of details presented. They also project forward different periods in the future. They are discussed in the order of their writing. These views have much to tell us. We will see several learners, including Alvin, Sally, and Nell. There are remarkable similarities in these approaches.

After presenting the four sources, I look at common features. Finally, I discuss current possibilities to realize these visions.

3. Arthur C. Clarke — the city and the stars

Against the Fall of Night was the first Clarke (1956) novel, written from 1937 to 1946. He decided to rewrite it, and the result was *The City and the Stars*, 1954 and 1955. Education does not play a major role; as with many of Clarke's novels and short stories, the central concern is with the traumatic effect on humans of discovering intelligent life elsewhere in the universe.

This novel is much further in the future than anything else discussed here. The city is Diaspar. It is the ultimate example of technical and social engineering. "They had lived in the same city, had walked the same miraculously unchanging streets, while more than a billion years had worn away." Its citizens believe, incorrectly, that it is the only city on Earth.

We see several aspects of the learning system in Diaspar. The first are the sagas, the extension of what today gets called virtual reality, perhaps the forerunner of the Star Trek holodeck. The second is through interactions with the central computer. The third is with tutors. Since learning is not the main subject, we see only glimpses of these learning aspects. We see nothing of early childhood education, unlike the other sources to be discussed. There are no children in our sense in Diaspar.

The hero is Alvin, a unique individual who eventually orchestrates great changes in the society. In the first chapter, we immediately see Alvin involved in a saga. He and his friends are immersed in an adventure where they play an active part in what happens (within limits, which Alvin violates). There are many sagas available from the central computer. "They played upon all the emotions and were of infinitely varying subtlety. Some ... were uncomplicated dramas of adventure and discovery. Others were purely explorations of psychological states, while others again were exercises in logic or mathematics ..." These sagas are an important aspect of learning in Diaspar.

After this, we see another learning example. Alvin is trying to create a work of art, without success, with the computer. An extensive tool is available for his use. Alvin is unhappy with

the results. No assistance is offered, as far we can see. It is worth noting, for future reference, that Alvin ends the session by SAYING "total erasure."

Alvin and every other person of his age (a small number) do have a tutor, but we see little of this interaction, except that he worries about Alvin. Presumably, the tutor is important in learning. We hear that the tutor could not answer all of Alvin's questions! The tutor and his parents (not biological parents — who no longer exist in Diaspar) play a role in the learning system.

4. George Leonard — education and ecstasy

This book, from 1968 (just before the formation of the United Kingdom Open University), is not a novel. It has two fictional chapters that portray a school of the future, about now. Leonard (1968/1987) also presented another fictional view of a learning system in a 1984 article in *Esquire.* Both of these are in the 1987 edition of *Education and Ecstasy.* I have been describing in papers and my talks the Leonard learning structures for many years, as I consider them very valuable in thinking about the future of learning, as with the other examples presented here.

An interesting chapter that precedes the fictional chapters raises the question of why there should be a school at all. Leonard says, "Practically everything that is *presently* being accomplished in the schools can be accomplished more efficiently and with less pain in the average child's home and neighborhood playground." Leonard interprets this to mean that we do not need current schools. He advises parents to visit their children's schools, on an ordinary school day, to see what happens there. But he believes we can do better, leading to the account of a school in 2001. So, unlike other visions here, the school still exists.

The two fictional chapters describe a visit of parents to their children's school. The school in *Education and Ecstasy* separates the knowledge aspects from the affective aspects. The age range is 3–10. The school is very different than today's schools. "While the children are on the school grounds, they are *absolutely* free to go and do *anything* they wish that does not hurt someone else. They are *free learners*." There are no required scheduled activities, unlike our present schools. Learning happens because children enjoy it.

Knowledge learning occurs in the basics dome, one place where students may choose to go. There are neither classrooms nor teachers. Large computer displays are at the walls. As a student approaches, the computer recognizes the student. Stored records of students' learning histories show the computer where learning is to begin, and then, what the student problems are. Both keyboard and voice input are used. Ongoing brain wave analysis is used to find if the student understands or does not understand at each point in learning, so student progress can be rapid. A more elaborate system called Direct Brainwave Manipulation is mentioned, but the 'conservative' Principle Educator at the school does not believe that the evidence for its value is strong enough.

The student–computer interaction in learning, called computer-assisted dialogue, in the basics dome is tutorial, as the situation closely resembles the interaction between a student and a skilled human tutor. It is highly interactive and individualized, as all learning should be.

Students move at individualized pace through the learning experiences. The amount of time for the student at the computer depends on the student background and on the number of waiting students. There is some human interaction, as the learning programs bring neighboring students together occasionally.

The parents find their 3-year-old daughter, Sally, working on language. The 4-year-old girl on one side is "dialoguing about primitive culture," and the 6-year-old on the other side is learning elementary calculus. Note these ages and subjects. We see only a small section of Sally's interaction with the computer.

Here is the beginning of Sally's interaction: "I hear Sally saying 'cat' into her microphone. Almost instantly, a huge grinning cat's face gathers form and the word 'cat' appears at the bottom of the display." In the following dialog, Sally is queried about linguistically possible alternate spellings of 'cat.' After a bit, Sally leaves to find friends, and plays a game. Remember that she is a free learner, even though she is in school.

I will not review the other part of the school. It has some interesting aspects. The hands on way of learning science, literature, and history offer useful suggestions.

As noted, the school is for children from 3 to 10. The content is clearly beyond that of a 10-year-old today, as we learn from the student learning calculus. Leonard says, "after the age of ten they may never again attend a separate, formal, degree-granting educational institution. This is not to say that they will stop learning. On the contrary, they will be free to begin a lifetime of learning in a society dedicated to education." School is a preparation for lifelong learning.

The school described in the *Esquire* article puts greater emphasis on planning student's time and activity. The morning begins with this planning. Students can work partly at home.

5. James Cooke Brown — the Troika incident

This book was published in 1968 and 1970. Unexpected time travel is the mechanism for going to the future, about 2070. The world is not homogeneous, with 400 regions on Earth, so learning activities differ from community to community. Many areas of this future society are discussed.

The community we see in greatest of detail is Loma Verde, of about 400 people on the California coast, where the four astronaut/time travelers initially land. "The real business of the people of Loma Verde is not raising artichokes, or grapes, or even feeding themselves. It is raising children ... there is no formal school, no teachers, no grades to pass, no marks. The Companions (citizens of Loma Verde) do their own teaching in small study groups, or in tutorial relations with individual children ... But mostly the children simply range for themselves over the cultural landscape the adults' activities create ... in the free but stimulating atmosphere there Loma Verdias seem to have created for their children, they *all* love to learn ..."

> ... the key to this autonomous learning ... [is that] Their children teach themselves how to
> read ... when they are between two and four years old ... the language in which they learn

is Panlan ... spelled phonetically ... [and] very simple grammatically ... Once a child has learned to read in this simple international tongue, books, ideas, the regional language and its literature, all seem to come pouring in ... reading never loses its each grace for them. And the generalization of this early attitude — that all learning will be joy — seems to infuse their lives.

The community has a Children's House with "private studies, labs, and workshops for them all." Reading is learned in the Children's House.

"The two-year-olds were racing back and forth between two large toys that looked a little like typewriters. Only no keys — as they shouted in Panlan at these toys their words would immediately appear all neatly typed out on a large screen — they called this writing — they could either write these words for themselves — or they could send messages to each other."

The key importance of reading and writing is critical in this society. It happens with a computer, although that word is not used, beginning at two.

A common device in this future society globally is the reader, "a light flat, plastic box with a glass screen ... [with] an alphanumeric keyboard." The search mechanism is familiar today. "Every book that has ever been written ... is waiting to materialize in this little box sitting on you lap." The description sounds like the Internet. But it goes far beyond today's Internet, with no commercial component. "You can learn anything, find anything out, look up anything, simply by fiddling with a little plastic box sitting in your lap." The storage area is the Australian desert. This device plays a major role in adult learning.

There are still universities in this society without schools. We do not hear much about them. Generally, people do not attend them until they are finished raising their children.

6. Neal Stephenson — the diamond age

This is the most recent of the four sources considered in this paper, published in 1995. Learning, central to the novel, is described in detail (150 years from now?).

A wealthy and powerful man is worried about the education of his granddaughter, Elizabeth. He talks to a wonderful engineer about the problem. "... to raise a generation of children who can reach their full potential, we must find a way to make their lives interesting ... Do you think that our schools accomplish this? Or are they like the schools that Wordsworth complained of?"

The answer is that the schools are not adequate. With support of the powerful person, the engineer develops *The Young Ladies Illustrated Primer*. Two copies of this book are produced initially, one illegally. One falls into the hands of a poor 4-year-old girl, Nell, living in very unhappy circumstances. Another is later produced for the engineer's daughter, Fiona. Later, hundreds of thousands are produced, again all for girls. We see in some detail how Nell learns from this book, throughout the novel; we do not encounter the other two young ladies until later, and we do not view them using the book in any detail.

The first time Nell opens the book, it begins with a story about Elizabeth, the grand-daughter of the wealthy person. But the book quickly learns that this is not Elizabeth, but

Nell. The engineer says, "It is unlikely to do anything interesting just now. It won't really activate itself until it bonds . . . it's looking for a small female. As soon as a little girl picks it up and opens the front cover for the first time, it will imprint that child's face and voice into its memory." The device has a camera.

The book bonds with Nell. The first learning session is portrayed in a marvelous passage.

"The book spoke in a lovely contralto . . . Once upon a time there was a little princess named Nell, who was imprisoned in a tall dark castle on an island in the middle of a great sea, with a little boy named Harv, who was her friend and protector. She also had four special friends named Dinosaur, Duck, Peter Rabbit, and Purple.

Princess Nell and Harv could not leave the castle. But from time-to-time, a raven would come to visit them.

'What's a raven,' Nell says?

The illustration was a colorful painting of the island seen from up in the sky. The island rotated downward and out of the picture, becoming a view toward the ocean horizon. In the middle was a black dot, and it turned out to be a bird. Big letters appeared beneath. 'R A V E N,' the book said. 'Raven.' Now say it with me.

'Raven.'

Very good! Nell, you are a clever girl, and you have much talent with words. Can you spell raven?

Nell hesitated [the book sees that she cannot read] . . . after a few seconds, the first of the letters began to blink . . .

The letter grew larger until it pushed all the other letters and pictures off the edges of paper. The loop on the top shrank and became a head, while the lines sticking out the bottom began to scissor. 'R is for Run,' the book said. The picture kept changing until it was a picture of Nell. Then something fuzzy and red appeared beneath her feet. 'Nell Runs on the Red Rug,' the book said, and as it spoke, new words appeared."

This passage continues in this interactive way. The reader can find the original beginning on page 94 in the paperback edition.

Several things are important. The book already knows quite a bit about Nell! Her brother Harv and her toys are mentioned immediately, within a fanciful story, told to her with pictures in the book. Her mother and her mother's horrible boyfriends also are incorporated in the legend.

This information is not programmed in the device; it was not known that Nell would be the user. Nell has not used the book before, but it has been listening to her and to what has been happening around her! It has a picture of her. It has begun storing a record of her situation and interests, soon to be augmented with information about Nell as a learner when she uses the book.

The basic story of Princess Nell (or another person) is programmed. At Nell's next session, there is a summary of the entire fantasy, including a happy ending. So Nell knows from the beginning how the story will end.

As with *Education and Ecstasy* and the *Troika Incident*, learning to read is the basis of further learning, and again it occurs at a very young age. The book remembers what progress Nell makes, and what her learning problems are. When the story speaks of a raven, Nell,

living in a slum, ASKS what a raven is. The book hears her. Not only does the book tell her, with a picture, but it also starts to spell raven. It quickly determines that she cannot read, and begins to help with the alphabet, highly interactively.

The book has other skills that we see later. It can record and illustrate things that Nell tells it (writing). It teaches Nell the art of self-defense, and helps Havr and Nell escape when their situation becomes life-threatening. It can defend itself against those who try to steal it. Nell learns to cook healthy foods. The book contains an encyclopedia. It displays books, like the machine in *The Troika Incident*.

It has game-like situations that encourage problem-solving. Nell seems to participate in these situations, as Princess Nell, as with Clarke's sagas. "As she climbed the switchbacks, she forded those delightful current of air over and over ... the little shrubs that clutched rock and cowered in crack became bigger and more numerous... 'Nell looked for a safe way down,' Nell essayed ... 'No, wait!' she said." These situations become more important as Nell approaches the end of her education. They even include learning to program 'Turing machines.'

The book (a computer without keyboard) gets outside help for voice output. It seeks humans who can work with Nell. They are paid for this. We see one person, a ractor Miranda, who is willing to do this; perhaps there are others. We assume it was her lovely contralto voice Nell heard when he first opened the book, and continues to hear. A ractor is a new technology-based actor. Nell has no contact with Miranda, as it all happens through the computer. Miranda works from a script. They do meet, at the very end of *The Diamond Age*.

The engineer regards this need for a human voice for speech output as a design problem. He is unsatisfied with the quality of computer-generated voice. When he must generate hundreds of thousands of copies of the book, and so the ractors are no longer practical, he uses computer-generated voice. These users of the book become Nell's 'mouse army.'

Nell does eventually go to a fancy school, Miss Matheson's Academy, one that would not normally be available to someone of her background. She continues to work with the computer. The other two ladies with the book, Elizabeth and Fiona, are also at this school, and they are the three brightest students.

But Nell is the best, perhaps because of the real-life problems she encountered because of her poor environment. The wealthy person attributes this difference to the ractors. In Elizabeth's case, many ractors were involved. For Fiona, it was mostly her father, the engineer. Nell develops a mother–daughter relation with Miranda, not by personal contact but through the book.

It is curious that no boys learn with the book. Different programming would be needed, since the fundamental story is oriented toward girls. The possibility that this could be the educational system for all is not considered, except possibly by implication in the comment about schools by the wealthy person. But this is a novel, not a treatise on learning, so it is unfair to this novel to complain about such things. If the wealthy man had a grandson instead of a granddaughter, the novel would have been plotted differently.

7. Aspects of these views of learning

We see many interesting features in these fictional accounts of learning that can offer guidance for the future. There are some remarkable similarities in these sources.

Here are some of the learning aspects in these books.

7.1. Love of learning

These accounts stress that learning should be enjoyable, that everyone should like to learn. This encourages lifelong learning, essential for our changing world. This is in sharp contrast to our situation today, where many children describe schools as prisons.

Perhaps one reason is the flexible schedules. Children are not *required* to do anything. They make the decisions, engaging in learning activities when they want to. They do not sit for long periods in assigned seats, not talking. The learning activities are enjoyable, not boring, as is often the case now. Learning is successful for all, as we will discuss later, another factor encouraging love of learning.

7.2. Learning to read and write at an early age

Learning to read occurs between 2 and 4 years old, and with NO human teachers! Everyone learns to read; no one is illiterate. We do not see this period of Alvin's education, but the process was possible with the Central Computer. But Alvin was never a child. Learning to read closely follows learning to speak, a natural progression in language learning. Reading is critical to later learning, along with love of learning.

Writing comes next in several of these accounts, but with little detail. With Brown (1970), the two happen together. Writing is not done by handwriting or typing, but by talking to the computer. The purpose is communication with others.

It has been suggested that the computer may eventually eliminate the need to read because the computer can do all the reading. But this is not the present situation.

7.3. Tutorial learning

Much of the learning in these visions is tutorial, in that the interactions with the student are close to that between a student and a skilled human tutor, with frequent high-quality interaction in both directions. We see this most clearly with Leonard and Stephenson (1995). The interaction is fully conversational. To distinguish it from other interactions, we can call it HIGHLY interactive, or dialog. Only in Clarke is the tutor a human, but not many people need to learn in Diaspar.

Like human–tutor interactions, these interactions use the most powerful learning tool humans possess — our native languages. The examples we see are in English or Panlan, but other languages could be involved. Pointing, a limited form of interaction, is not used, in contrast to modern Web learning material. The student replies to questions, or asks questions,

with no restrictions on the form of the reply. This use of our natural languages is a very critical aspect of tutorial learning.

7.4. Computers as critical in learning

All these educational systems are computer-based. The computer is the tutor, in most cases.

The examples we see go beyond the current use of the computer in learning. But as we will discuss, they are mostly possible today.

7.5. Communication with voice

As we have pointed out, communication with the computer is through voice. People talk to the computers, and the computer talks to them. Voice input is accepted as standard, but with Stephenson, the quality of computer-generated voice output is questioned; the voice Nell hears is that of Miranda, but computer voice is sufficient for the 'mouse army.'

Science fiction has long recognized that voice is a natural way for humans to communicate. But in spite of adequate inexpensive speech recognition software, very little learning software uses voice input, and little empirical evidence exists about the effectiveness of voice input in learning.

7.6. Adaptive learning

Learning in these sources continuously adapts to the needs of each individual learner, offering a unique learning path for each person. This is in contrast to what often happens today in schools, universities, and other formal learning environments. We see this most clearly with Sally in Leonard and Nell in Stephenson. When the computer determines that Nell cannot read, it proceeds accordingly. Records are stored frequently and the computer programs use these records to adapt to the student needs.

7.7. Accelerated learning

In some of these examples, learning occurs much faster than today. One of Leonard's students is learning calculus in a school where the maximum age is 10. This is a consequence of adaptive learning. Learning is tailored to the needs of the student, so progress is rapid. No students spend time 'learning' what they already know, and each receives just the help needed.

7.8. Mastery learning

We all learn to speak and listen to our native languages well in our first few years. That is mastery in learning. There are some evidence that the learning systems in the four books insist on mastery learning, although we do not see much learning material. In mastery learning, everyone succeeds.

7.9. No schools

Some assume that schools and universities will last forever. But in the examples we have looked at, schools are not prominent, although some still exist. Even when we see a 'school,' as in Leonard, it is very different than a current school, and he explicitly raised the possibility of no schools. Having people gather at a central location for learning is no longer necessary.

We see little of university education, except to hear that it exists in the society Brown describes.

7.10. Distance learning

If we do not have schools, where does learning take place? Alvin and Nell learn in their homes. In Brown, learning to read and write takes place in a special building for children, not a school, and other learning is at home. Such learning is called distance learning.

8. Technology today for learning

Although these accounts are located in the future, current hardware is adequate for almost all of the tasks needed for these future learning systems. We do not need much new technology to create most of what we have seen in these books.

8.1. Technology

Programs we developed at Irvine 30 years ago already had the interactive tutorial capabilities seen in these examples. So hardware much more primitive than today's hardware was adequate to the task. Early personal computers we used had 64K memory, no hard disk, much slower processors than today, and no network connections.

We developed the Scientific Reasoning Series in this environment about 15 years ago.

A brief example from one of the programs, Heat and Temperature, illustrates the high level of interaction. After the title page, the first message to the student asks, 'How do you take your body temperature?' If the student does not reply, the program prompts she or he further. A student might type 'use a thermometer.' If so, the program asks if an accurate result would be obtained if the thermometer is kept in the mouth for only a few seconds. If the student types no, the program asks what should be done to obtain a more accurate result. The program proceeds in this conversational way for about an hour with a typical student, allowing the student to develop the concept of heat.

Today, this example could use voice input, rather than typing. The one piece of new software needed after 30 years is voice input. Commercial speech recognition is now adequate for the stories we have examined.

The limited brain wave analysis in Leonard is beyond current capabilities, but seems possible soon in a limited form. The major activity where our current capabilities are

inadequate is Clarke's Sagas, and perhaps some similar things in Stephenson. We cannot construct sagas today, and it would seem to be a long time in the future, although not a billion years if we survive as a species! Some simulations and Internet environments are primitive forerunners of the sagas. Presumably, brain wave input and output for many people at the same time are required for this activity. The programs to generate sagas are far beyond the complexity of those we can develop today.

8.2. Adaptation and mastery

To achieve mastery with well-designed learning units using the computer is not difficult. The program needs to be looking frequently at what learning problems the student has, and addressing these problems with new learning material. Tutorial interaction makes this possible. This implies a new role for student assessment to determine what learning material is to be presented next to the student. These elements come from the very good teachers who do the design.

A key feature in achieving mastery with computer-based tutorial learning is Vygotsky's concept of the zone of proximal development. At any moment in learning, the students stands at the frontier of what can be learned next. Learning efforts should be in this zone. Again, this is the role of the designers, good teachers in the area. The computer makes this approach practical for large numbers of students.

Grades do not exist in a mastery environment. With mastery approaches, learning and assessment are woven together into one seamless product.

How can computer-based tutorial learning be highly adaptable and achieve mastery? Feedback from the student is critical. This includes both recent feedback, and the storage and use within the programs of information about past student performances. Decisions on how to use this information are made by skilled teachers who design the units, working in groups of about four in our design activities at Irvine. Eventually techniques from artificial intelligence may be useful.

Each learner is unique, and should be treated this way at all times. Different learning approaches may be best for different students. Learning time may vary from learner to learner. Each individual embarks on a new topic at a time that is different from that of other learners.

8.3. Distance learning

The computer makes large-scale distance learning possible. Interactive learning can now be made available in homes, libraries, shopping centers, children's buildings, and other informal environments, for all ages and everywhere.

Further, with distance learning, we can, with the aid of the stored records, do a better job than in Leonard's school of matching together students who can learn from peers; this matching can change with time. Physical proximity is not what is needed, but rather students involved in peer learning should be in the same learning situation.

I stress again that most of what we have seen can be done now. The technology is not the determining factor in creating new learning environments.

9. Why is such learning not available now

If technology is not the problem, why do we not have such learning today? The reasons are complex, many social, political, and economic. I will not discuss these fully. The reader is referred to the book mentioned at the beginning of this material.

Institutions resist change. Schools, universities, and other institutions are imbedded in our society, and are difficult to change. Many current decision-makers come from these institutions, and so reflect limited points of view.

Technology, and the relentless pursuit of new things, may also be preventing us from realizing the learning power of what we already have. A major villain is the mouse and other pointing devices. They have dragged us away from interacting with our wonderful natural languages. The current World Wide Web, with its emphasis on pointing, is another problem, but tutorial material on the Web, with interaction through our languages, seems close at hand.

Most of the forms of distance learning seen so far are too weak to support the new learning structures we need. The distance learning programs of most universities in the US are similar to the campus classes they imitate, with very small numbers of students in a class. Current imitative distance learning has little of the spirit of the examples in these fictional accounts.

A major problem for creating these environments is the lack of funds for developing tutorial highly interactive units. We cannot have Nell's book without developing and testing extensive learning material, and few at present are funding such programs, even initial experiments to gain some insight into the problems that will arise.

10. Planning new learning systems

But these restraining factors for improving learning can change. Two factors suggest there may soon be major changes in our learning systems, perhaps along the lines we have seen in these fictional accounts.

10.1. The need for better learning

There is growing belief that many of the major problems of the country and the world cannot be cured without much better learning than we have now. So there are strong and increasing pressures to improve learning. Almost every politician today claims to be in favor of improving learning.

A striking affirmation of the value of learning comes in a recent statement from the Secretary-General of the United Nations, Kofi Annan:

> Education is an essential human right, a force for social change — and the single most vital element in combating poverty, empowering women, safeguarding children from exploitative and hazardous labour and sexual exploitation, promoting human rights and democracy, protecting the environment and controlling population growth. Education is a path toward international peace and security.

If we are to achieve Kofi Annan's vision for education, we need Nell's book, and the other features we have examined! International organizations, such as the World Bank and UNESCO, are beginning to understand this, I believe.

10.2. The potential market

A second factor that portends major changes in our learning system is different, but complementary. We spend in the US about US$1 trillion dollars each year on all aspects of education, and large amounts are spent in the rest of the world. Technology plays a very small part in that labor-intensive market. So an extremely large potential market is available for a new generation of highly effective computer-based learning material, a market larger than most others involving computers.

We can see many signs that commercial forces are beginning to look at this huge market, and wondering how they can develop the market. Most of the efforts so far are at the higher education level, but all levels are likely to be investigated. Many of these efforts are not as imaginative as our four sources in this paper. They are often aiming at only small parts of the eventual market. Often they are based on today's paradigm for learning, as reflected in current institutions, rather than on tutorial learning.

Many exploring this new market do not spend enough money developing the learning units to achieve Nell's book, or other forms of highly interactive tutorial learning. Spending money will not assure effective learning units, but success is more likely with carefully developed well-tested modules.

This may become the largest of all software markets.

11. Conclusions

The view of learning in these four references appeals to me. I see tutorial learning as a new paradigm for learning, superior to almost all of what happens today. Highly interactive adaptive software could be a major step to the future.

Although the learning in our four sources is mostly possible today, we have very few examples of the type of learning software suggested. An early need is to develop and test such examples, gaining more information about effective types of learning materials and about the marketing possibilities. Governments, foundations, and nonprofit organizations, as well as commercial sources, should support major efforts in this direction, particularly aimed at material that is scalable to very large numbers of learners, eventually the 6 billion people on this planet.

After this experimental work, we can begin the process of producing the very large amounts of learning material that will be needed to provide lifelong learning for everyone, at any place and at any time.

In my papers, I have looked further into these problems. Several papers are in the references that follow. These and others can be found at ⟨http://www.ics.uci.edu/~bork⟩.

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