Some Personal Thoughts About Research on Using Games in Education

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During the past year, I have written a book titled *Introduction to Using Games in Education: A Guide for Teachers and Parents.* This 157-page book is available free in electronic format on my Website (Moursund, 2006).

There is a huge amount of literature available on the Web about the topic of games in education. However, most of it is testimonial, rather than solid research. As I was writing my book, I spent a lot of time reading and browsing the available literature, paying special attention to the research. I talked to a large number of teachers and other people who are interested in the field. In addition, I drew upon my many years of experience in the field of education. However, I did not conduct any empirical research in the field of games in education. Thus, this book is based on an analysis and synthesis of research and practitioner knowledge.

Research

The meaning of research varies with the discipline. I have a doctorate in mathematics, so I bring a math researcher point of view to my insights into research. In math, for example, researchers have proven that for a rectangle in a plane, $A = LW$ and $P = 2L + 2W$. In math, much of the research focuses on conjecturing and then proving theorems. For the most part, once a math theorem has been proved, it remains proved. (The mathematical proving and refereeing system is not foolproof. Errors do occur.)

As a college undergraduate, I took four yearlong courses in physics, I can quote Einstein's theory that $E = Mc^2$. I have some understanding about the difference between a proven mathematical theorem and research-supported theories in physics and in other sciences.

I also have some understanding about research in other fields, such as agriculture, medicine, and education. In agriculture, for example, one can do a relatively good job of establishing a treatment group and a control group, and then trying out various treatments and reporting on the results. This is done in a manner that allows others to repeat the experiments to see if they get the same results. For example, one might select a specific type of seed and plant two plots in a greenhouse in which light, temperature, soil, humidity, etc. are carefully controlled and close to the same for each planted plot. One plot might receive a certain treatment (such as a specific type and amount of fertilizer) while the other does not. Rates of growth, yield, and so on can be carefully measured and reported.

The research is more “dicey” in medicine, even when large amounts of money are spent doing research on a single drug or other type of treatment. For example, in medical research, a subject can be given a specific drug or a placebo. The person providing the treatment (handing out the drug or placebo) can do this without knowing which is which and in a manner that is essentially identical for the research and control group. However, one of the troubles in medical research is that no two people are identical. The reaction to drugs and other medical treatments varies with the person. Thus, it has become fairly common to find that a well researched and widely used treatment is killing or seriously damaging some patients.

Educational research is still dicier. It is easy for politicians, educators, and others to say that our educational system must implement research-based improvements. It is quite another thing to determine what constitutes a potential improvement that has appropriate research support, and then to implement it in a manner that will lead to a high level of improvement and will damage very few (if any) students. Indeed, it is even difficult to get agreement as to what constitutes an improvement in education.

I am supportive of research-based attempts to improve our educational system, but I am inherently suspicious of the overall process and the underlying research. It is not immediately evident to me what would constitute appropriate and adequate research to support the theory that increased use of games in education will improve our educational system. There are too many variable involved in such an endeavor.

Games in Education

There are many different types of games. My book explores the board games, card games, puzzles, and other types of non computerized and computerized games that children and adults play. It does not explore various sports games, such as those in the summer and winter Olympics.

The 84-page document by Mitchell and Savill-Smith (2004) is a British government-funded review of the computer game literature. The following quote from this document helps to define the words *play* and *game*.

> First, **play**: something one chooses to do as a source of pleasure, which is intensely and utterly absorbing and promotes the formation of social groupings (Prensky 2001, page 112). **Fun**, in the sense of enjoyment and pleasure, puts us in a relaxed receptive frame of mind for learning. Play, in addition to providing pleasure, increases our involvement, which also helps us learn (Prensky 2001, page 117).
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> …
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> Second, a **game**: seen as a subset of both play and fun (Prensky 2001, page 118). A game is recognised as organised play that gives us enjoyment and pleasure (Prensky 2001). Dempsey et al. (1996, page 2) define a game as: …a set of activities involving one or more players. It has goals, constraints, payoffs, and consequences. A game is rule-guided and *artificial in some respects.*

One characteristic of a game is that it requires active participation. Quoting Greg Costikyan (1994).

> When you look at a painting, you may imagine things in it, you may see something other than what the artist intended, but your role in constructing the experience is slight: The artist painted. You see. You are passive.
>
> When you go to the movies, or watch TV, or visit the theater, you sit and watch and listen. Again, you do interpret, to a degree; but you are the audience. You are passive.
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> …

> Enter the game. Games provide a set of rules; but the players use them to create their own consequences. It's something like the music of John Cage: he wrote themes about which the musicians were expected to improvise. Games are like that; the designer provides the theme, the players the music.
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> A game is a form of art in which participants, termed players, make decisions in order to manage resources through game tokens in the pursuit of a goal.

The term game is often taken so include puzzles. Thus, for example, my book devotes a chapter to Sudoku puzzles, a chapter to solitaire card games, and a chapter to multi-player games. From a research point of view, we might ask questions such as those given in Figure 1.

1. How might use of games in informal and formal education improve the education of some children?
2. How might the use of games in informal and formal education cause harm to the education of some children?
3. What roles might parents, teachers, game designers, and curriculum designers play to increase the benefits and decrease the harm of use of games in informal and formal education?

Figure 1. Some researchable questions.

I can imagine extensive research being carried out on a single game, such a Monopoly in a non-computer and in a computer environment. I have trouble believing that we will ever have a definitive set of answers to the three questions just for Monopoly. One of the difficulties is that parents and teachers change over time, as do computer implementations of games. Thus, for example, some future computer implementations of Monopoly may contain built-in parents and teachers that are designed to add significantly to a child's total experience and learning while playing the game.

Situated Learning

There are many things that make the researchable questions in Figure 1 very difficult to answer. Here are a few examples:

1. Each child is different, and children change over time. Thus, the effect of a particular game on a particular child varies with the child, and may change in a very short period of time. For example, consider possible game effects of a child playing a handheld computer game shortly before and shortly after being "yelled at" by a parent for playing the game instead of cleaning his or her room.
2. All learning is situated, and there is significant research on situated learning (Brown, et al., 1989). Thus, the situation in which a game is used/played will affect the benefits and harm to each individual player. The game, the players, the location and time of the gaming playing, and so on are part of the situation in a game-based situated learning environment.
3. In a game, each player (there will be one or more players) is both a learner and a teacher. There may be other teachers and mentors involved, such as a parent, school teacher, coach, and other children observing or supervising a child or children playing a game. The participants and their observers and supervisors are part of the situated learning environment.

The recent article by Kirschner et al. (2006) lends another important dimension to research on games in education. In rough summary, the article says that if we want students to learn something, we get the best results by directly teaching what we want students to learn. Thus, if we want children to learn to play Monopoly, we get the best results by directly teaching the children how to play Monopoly. If we want children to learn to count money and make change, we get the best results by directly teaching counting money and making change. We will do better by this direct instruction than we will by children counting their play money and making change while playing Monopoly.

My brief summary is an over simplification. Thus, for example, the claims made in the article are most applicable to novices in a particular domain. As children gain in expertise in a domain, they are more able to learn on their own and to do transfer of learning in situations that involve the domain. If this topic interests you, you will want to read Clarke, 2004).

Remember, the evidence supporting discovery-based learning and its many variations is weak. The following quoted material provides excellent insight into the situation as it applies to games (Conati & Klawe, 2000):

> These results indicate that, although educational computer games can highly engage students in activities involving the targeted educational skills, such engagement, by itself, is often not enough to fulfill the learning and instructional needs of students. This could be due to several reasons.
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> One reason could be that even the most carefully designed game fails to make students reflect on the underlying domain knowledge and constructively react to the learning stimuli provided by the game. Insightful learning requires meta-cognitive skills that foster conscious reflection upon one's problem solving and performance [2, 4, 24], but reflective cognition is hard work. [Bold added for emphasis.]

Thus, as we think about roles of games in improving education, we need to think carefully about goals of education and what constitutes an improvement in achieving some of these goals. For example, suppose that one of the goals of informal and formal education is to preserve and pass on the culture of the family, and community closely related to the family. A particular family has a tradition (history, culture) of learning and playing certain games. The adults and children of all ages participate in the games. The players may include near relatives and neighbors.

This culture is preserved and passed on by some combination of direct and discover-based learning as children grow up in their home-centered, family-based culture. The overall process is a very important aspect of a child's education. A school might provide formal instruction on the same games, but cannot capture the situated learning aspects of the home/family environment.

Incidental Learning

The term *incidental learning* is used when discussing unintentional or unplanned learning that occurs in a particular situation. However, unintentional is easily changed to intentional. Suppose that I observe that in a particular situation, some desirable unintended or unplanned learning occurs. I then repeat this teaching/learning situation with other students, with a specific intent that they learn what was previously considered unintentional. I make the unintentional learning intentional learning.

Let me give an example. We know that many children find electronic games to be attention grabbing and attention holding. We know that in hand-eye coordination games such as Tetris, that the game is increased in speed to increase its difficulty level. We know that with practice, a player learns to recognize patterns more rapidly and to react more rapidly. Indeed, quite a bit of one's increasing expertise in an area comes from building an increasingly large repertoire of patterns in one's long term memory—patterns that are quickly recognized and retrieved for use by one's short term (working) memory.

Notice how a little bit of brain theory entered into the analysis. Playing the game changes the brain. Brain science is a rapidly growing field. Educational research that ignores our current understanding of brain science may well be suspect because it is out of date.

Now, take these game and brain ideas, and apply them to a child who is severe speech delayed because the phoneme processors in his or her head function too slowly. After careful testing, it is determined that the child has normal hearing. Create a game-like environment that requires the child to recognize and respond to orally presented phonemes and words containing a sequence of phonemes. Start the child playing the game at a speed level where significant success occurs. At this level, phonemes and words are pronounced very slowly in a manner that does not overload the brain's processing capabilities. Slowly speed up the game. The goal of this "game" is nothing less than to cure the severe speech delay developmental problem—to rewire the brain.

Amazingly (but not unexpectedly), the child's phoneme pattern recognition and processing speeds increase. There are observable changes in brain structure and activity. A brain developmental problem is attacked and, in many cases, is cured. Research and implementation of products in this area provide some of the best examples of highly interactive intelligent computer-assisted learning. See, for example, products and their supporting research from Scientific Learning Corporation (n.d.).

Somewhat similar research and implementation is now going on in treatment of ADHD. In addition, the hand-eye coordination that children gain through use of joystick, mouse, and buttons in a variety of fast paced computer games carries over to the somewhat similar situations of controlling robotic-types devices in surgery and in many other robotic-assisted problem-solving situations (Dobnik, 2004).

While all of these examples involve game or game-like environments, research in these specific areas is a far cry from research that helps answer the questions given in Figure 1.

Flow, Addiction, and Intrinsic Motivation

Mihaly Csikszentmihalyi is a world expert and leader in Flow Theory. Quoting from Csikszentmihalyi (n.d.):

> Mr. Csikszentmihalyi (pronounced chick-sent-me-high-ee) is chiefly renowned as the architect of the notion of flow in creativity; people enter a flow state when they are fully absorbed in activity during which they lose their sense of time and have feelings of great satisfaction. Mr. Csikszentmihalyi describes flow as "being completely involved in an activity for its own sake. The ego falls away. Time flies. Every action, movement, and thought follows inevitably from the previous one, like playing jazz. Your whole being is involved, and you're using your skills to the utmost."

I have experienced flow while writing computer programs, developing spreadsheets, writing books, and playing games. In all of these situations, my mind/brain is highly engaged and I shut out the outside world. I feel good—my dopamine and other "feel good" endorphins are flowing. I am intrinsically motivated to continue activities that can take me into a flow state. The flow state is, in some sense, addictive.

Many people have observed that games can be addictive. I have seen this type of addictive behavior in myself, and in some of my children and friends. Many people have trouble getting started in the morning with out their cup of coffee (caffeine is addictive) and their crossword puzzle. Many people are compulsive gamblers. One of my friends flunked out of a doctoral program because of two-deck solitaire games that were far more attention grabbing and attention holding than the courses he was taking.

One of the arguments for making use of games in education is their attention grabbing and attention holding characteristics. Game developers are aided by a steadily growing accumulation of research and practitioner knowledge on the design and implementation of games that will attract and hold players. They are being greatly aided by the steadily growing computing power available for use in games.

One might facetiously claim that a goal of computer game makers is to design and implement games that are addictive. I read a lot of science fiction, and I have read a number of books and stories in which the bulk of the human population becomes addicted to combinations of games and drugs. If I were a “doom and gloom” futurist, I would project from our current situation into a steadily growing proportion of the population becoming entrapped in the addictive world of games.

Instead of going in that direction, think about possible roles of games in education as an aid to students learning about flow and addiction. That’s an interesting research and curriculum development project! Imagine the public uproar if schools began to offer such a course. On the other hand, consider the fact that addiction is a major problem throughout the world, and that education is a viable approach to helping prevent addiction and in helping people deal with addictions.

Problem Solving

My games book has a strong focus on problem solving. This section provides some of the background ideas that I draw upon. More information is available in Moursund (2004).

The school curriculum draws from many different academic domains. In general terms, each domain of research, practice, and study can be defined by its unique combination of:

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

A person’s expertise in a domain consists of some combination of knowledge, understanding, and skills in the areas listed above. Problem solving and other higher-order cognitive processes can be thought of as a unifying, underlying theme in a person’s expertise in a domain or part of a domain. Many of the goals of education focus on helping students achieve certain levels of expertise in domains (such as language arts, math, science, and social science) that are considered particularly important.

The term *problem* means different things to different people and its meaning differs somewhat from domain to domain. Here is a definition that has served me well in teaching preservice and inservice teachers. You (personally) have a problem if the following four conditions are satisfied (Moursund, 2004):

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

The problems that we want students to solve in the situated learning environments of the classes they are taking often fail to satisfy this four-part definition. Specifically, the fourth criterion is often not satisfied. We often want a student to learn things and apply what they learn to solve problems and accomplish tasks—when the student couldn't care less. We try to ameliorate the situation by extrinsic rewards and threats of punishments.

A key idea in problem solving is domain specificity versus domain independence. When solving a problem, a person draws upon specific knowledge and skills within the domain of the problem. However, a person also draws upon domain independent knowledge, skills, and personal characteristics. Examples of personal characteristics include self-reliance, self-confidence, and perseverance.

Educators understand the importance of transfer of learning. It is essential that a student's knowledge and skills learned in a school setting transfer to other school and non-school settings. Reading, writing, and math are core content areas in education because they are useful in addressing problems in many different domains—even domains that a student might not encounter until many years in the future. We want students to learn and use reading, writing, and math "across the curriculum" and outside of school settings. Personal characteristics such as self-reliance, self-confidence, and perseverance tend to help a student deal with problems in any discipline and in varying situations. To learn more about transfer of learning, see the excellent article by Perkins and Solomon (1992).

A good educational system is designed to help students both to increase their levels of expertise in a number of domains, and to learn how to increase their levels of expertise. Our education system "talks the talk" in terms of wanting students to learn to learn and to become independent, self-sufficient, lifelong learners. However, for many students the level of success is less than is considered desirable.

Problem Solving in a Game Environment

Sometimes the goal in using a game in education is specifically to have students learn to play the game. For example, in some sense chess is the national game in Russia. I can imagine chess being part of the required curriculum in some schools in Russia.

However. Solving problems, accomplishing tasks, and making decisions lie at the heart of any game. Games provide a type of learning environment that can help to foster general learning applicable in a wide range of problem-solving situations This is one of the unifying ideas in my book on games in education.

A number of different games are analyzed from the point of the game-specific and game-independent problem-solving strategies involved in playing the game. An extensive analysis of Sudoku (a puzzle) identifies some Sudoku-independent and some Sudoku-specific strategies. The details of high-road transfer of learning are taught, and then applied to helping the reader do high-road transfer of these domain-independent problem-solving strategies. Here is a short section on transfer of learning quoted from Moursund (2006):

> Low-road transfer is associated with a particular narrow situation, environment, or pattern. The human brain functions by recognizing patterns and then acting upon these patterns. Consider the situation of students learning the single digit multiplication facts. This might be done via work sheets, flash cards, computer drill and practice, a game or competition, and so on. For most students, one-trial learning does not occur. Rather, a lot of drill and practice over an extended period, along with subsequent frequent use of the memorized facts, is necessary.
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> Moreover, many students find that they have difficulty transferring their arithmetic fact knowledge and skills from the learning environment to the "using" environment. One of the difficulties is recognizing when to make use of the memorized number facts. In school, the computational tasks are clearly stated; outside of school, this is often not the case.
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> This helps to explain why rote memory is useful in problem solving, but critical thinking and understanding are essential in dealing with novel and challenging problems. It also supports the need for broad-based practice even in low-road transfer. We want students to recognize a wide range of situations in which some particular low-road transfer knowledge and skills is applicable.
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> High-road transfer for improving problem solving is based on learning some general-purpose strategies and how to apply these strategies in a reflective manner. The *build on previous work strategy* is an excellent candidate to use to begin (or, expand) your repertoire of high-road transferable problem-solving strategies. To do this, think of a number of personal examples in which you have used this strategy as an aid to problem solving. Mentally practice what you did in each case. In the near future, each time you make use of this strategy, consciously think about its name and the fact that you are using it. Also, in the future when you encounter a challenging problem, consciously think through your repertoire of high-road transferable problem-solving strategies. Your goal is to increase your ability to draw upon this repertoire of aids to use when faced by a challenging problem.

Research suggests that the typical person has only a modest repertoire of general-purpose problem-solving strategies. Thus, adding even a half dozen new strategies to a person's repertoire of such strategies can make a significant contribution to the person's ability to deal with novel, challenging problems. Appendix 1 of Moursund (2006) contains a long list, with brief discussions, of high-road general-purpose problem-solving strategies identified in the book.

Expertise

There has been considerable research on how long it takes a person to achieve a high level of expertise in a limited area. The statement "a minimum of 10,000 hours" is often asserted. A combination of natural ability, good teaching/coaching—and 10,000 to 15,000 hours or so of hard work—will move a person reasonably close to being as good as the person can become in many different athletic and academic areas.

Of course, this regimen needs to be consistent with a child's maturing physical and cognitive development. Ten thousand hours of instruction and practice in swimming, starting at age six and spread out over five years, does not produce an Olympic swimmer. The 11 year old does not yet have the physical maturity to compete with adults at a world-class level.

Games such as bridge and chess, where there are world championship competitions, tend to have a 10,000 hours or more learning curve. For example, chess players ranked in the top 10 in the world are likely have put in 15,000 to 30,000 hours or more gaining their chess skills. In 2006, the average age of the top ten chess players in the world was about 30 years. People who play chess at a world-class level usually put in well over 2,000 hours a year developing, honing, and maintaining their chess skills.

Of course, the average child is not going to become a world-class competitor or champion. Our educational system is much more interested in the level of expertise that a typical student might achieve in one or two thousand hours or a few hundred hours of study and practice in a particular discipline.

A school year is about 180 days in length. Suppose that a student has a 50-minute math class every school day for 12 years. This amounts to about 1,800 hours of instruction and practice. If the school system requires quite a bit of math homework, this might well push the student's total to 2,200 hours or more. Think of this amount of study and effort as being about 1/6 to 1/4 of what it would take for the child to achieve his or her potential in math.

For a student with average math ability, the quality of math instruction, the student interest and intrinsic motivation, and the 2,200hours or so does not produce very good results. A significant fraction of students entering college place for "bonehead math" in their placement tests. Moreover, many people "hate" math and claim "I can't do math." This mathematics education experience tends not to build self-confidence and interest in being a lifelong learner of mathematics. It does not build the mathematical habits of mind of a person with a high level of expertise in math.

Moreover, for most students their rate of progress in learning math is slow, so they are not easily motivated by the progress they are making as they study math.

In contrast, games provide an environment in which a learner can gain a significant level of expertise fairly quickly. For example, quoting Young et al. (2006):

> Yes, video games are mainly for play and fun. But video games are educative as well as interesting and engaging—something that we all hope that more classrooms could be. Many of today's students spend more time playing video games than they do watching television, reading books, or watching films**. Massively multiplayer online games (MMOGs)—long and surprisingly complex gaming environments that normally require over forty hours to get beyond novice levels (Squire 2004)—represent the latest development in the history of video game technology.** [Bold added for emphasis.]

The "over forty hours" figure in the quoted material suggests that 40 hours of study and learning effort is a long time. Squire is impressed that many children will spend that much time and effort learning to play a MMOG.

In games, a novice can "see" the progress he or she is making. With some direct instruction by a teacher or parent, this provides an excellent opportunity for a student to learn about learning and to learn about increasing expertise that comes from study and practice. In some games, as person can go from, "I had never even heard of the game." to "I am pretty good at that game." in just a few hours. A learner can learn about game-specific strategies and can observe his or her steadily increasing speed and confidence in following the game rules and making good moves.

John Bransford, in the book Bransford et al. (1999) discusses the idea of how gaining a high level of expertise in one domain is applicable to self-assessment and self-guidance in learning in another domain. The idea is simple enough. If I have gained a high level of expertise in one domain, I know what it means to be highly competent in the domain. As I study another domain, I have a basis for judging how well I am learning and how it contributes to my goal of gaining a significant level of expertise.

In my opinion, this constitutes one of the most important reasons for using games in education. I want students to learn to self assess, to develop understanding of their own learning strengths and weakness, to develop confidence in their ability to learn, and to take increased responsibility for their own learning. Clearly, this is an area where more research and research-based curriculum development are needed.

Computational Thinking and Artificial Intelligence

Jeannette Wing is chair of the Computer Science Department at Carnegie Mellon. This department is known for its overall strength as well is its major contributions in artificial intelligence. In a recent short article in Communications of the ACM, Jeannette Wing discusses the importance of *Computational Thinking* (Wing, 2006). Quoting from her article:

> Computational thinking builds on the power and limits of computing processes, whether they are executed by a human or by a machine. Computational methods and models give us the courage to solve problems and design systems that no one of us would be capable of tackling alone. Computational thinking confronts the riddle of machine intelligence: What can humans do better than computers, and What can computers do better than humans? Most fundamentally it addresses the question: What is computable? Today, we know only parts of the answer to such questions.
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> **Computational thinking is a fundamental skill for everybody, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child's analytical ability.** [Bold added for emphasis.]

Computational thinking combines ideas from procedural thinking, algorithmic thinking, heuristic thinking, modeling and simulation, and much of the thrust of research in both brain science and artificial intelligence. The last sentence in the quote from Wing summarizes a potential new goal for our educational system. In my opinion, this is a very important goal.

Computational thinking as one of its unifying themes in my book Moursund (2006). Obviously, there is need for substantial research and research-based curriculum development in computational thinking. This research and development needs to be done throughout our current curriculum, instruction, and assessment, in all subject areas.

Games—especially ones that are available both on and off the computer—provide an excellent environment for studying capabilities and limitations of humans and computers, working collaboratively and independently. There has been a substantial amount of artificial intelligence research in the area of games and devoted to developing "intelligent" interactive environments in which humans can play and work.

Final Remarks

I have been a Star Trek fan for many years. On a Holodeck (a virtual reality, entertainment room), human participants interact with computer-generated participants. One can carry on conversations with people from the past. One can have great teachers as individual tutors. One can be a part of reenacted history events.

Slow but steady progress is occurring in developing computer simulations with Holodeck-like properties. Research on *highly interactive intelligent computer-assisted learning* is providing an increasing number of examples of when HIICAL produces better learning results than are obtained in a typical classroom environment. In some sense, Holodeck and HIICAL can be considered as game-like applications of computers to education. The best is yet to come!

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