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## The Role Of Simulation In Future Educational Curricula

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INSTITUTE FOR SIMULATION AND TRAINING

## The Role of Simulation in Future Educational Curricula

Patrick Moskal  
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December 14, 1994

University of Central Florida,  
Institute of Simulation and Training  
3280 Progress Drive

**IST**

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## **The Role of Simulation in Future Educational Curricula**

### **EXECUTIVE SUMMARY**

Researchers in the areas of education, psychology, cognitive science, and instructional technology are discovering more about how we learn every day. In addition, advances in computer and multimedia technologies may lead to significant advances and innovations for education. A number of simulation related technologies hold great promise for educational applications.

Two major factors are present in our society that are forcing a change in the educational system. First and foremost is that increasing student populations, increasing student diversity, and decreasing economic resources place an increasing strain on traditional delivery systems. Education must be modified to accommodate these individuals. Simulations can provide varying levels of instructional support for learners at different ability levels.

Second, as the information age becomes reality, business and industry are more dependent upon information retrieval and processing. Thus, the changing workplace is requiring students to be computer literate and to possess basic technical skills such as word-processing and mathematics.

Simulations engage learners and make them active participants in the learning process. They use technology to gather data, solve problems, and prepare products. Simulations provide experiences that capture student attention in a way that is structured to achieve desired learning outcomes.

What is simulation and how should it be used as part of future educational curricula, particularly those using advanced computer-based instruction? By definition, simulations approximate, replicate, or emulate the features of some task, setting, or context. Typically, for instruction or training environments, simulations are used when the costs of alternative teaching systems are prohibitively high, when it is impossible to study the concepts of interest in "real-time," or when the risks are considered sufficiently high to require demonstration of competence in a controlled, relatively risk-free environment. From an educational perspective, simulations may also be used to expose learners to a situation or environment that otherwise may not be possible in their daily lives. In addition, simulations may be useful in teaching real life skills, such as creative thinking, decision-making, problem-solving and visualization, examples of which are outlined in the Secretary's Commission on Achieving Necessary Skills (SCANS) Report (Department of Labor, 1993).

A good simulation presents believable scenarios or task situations, a variety of response choices, and the consequences of those responses. Because the student is able to see the consequences to his or her actions, higher order thinking is stimulated. This higher order thinking leads to the acquisition of real life skills and to the development of a cognitive framework for further learning. According to Brant, Hooper, and Sugrue



(1991), two of the most promising roles of simulation in instruction are to establish a cognitive structure to accommodate the acquisition of knowledge, and to provide an opportunity for reinforcing, integrating, and extending new and previously learned material.

Gagne (1962) summarizes three important characteristics of simulators (and simulation, in general). First, simulators are built to present a situation or scenario that is as close to the real event as possible (at least the components that are being trained). The reason for this objective is typically because using the actual equipment or performing in the real event is either too dangerous or too expensive for training purposes, and simulators are often more readily available than the actual devices. In addition to these very pragmatic reasons, simulators often prove more instructionally effective than the actual equipment.

Second, typical simulators are designed to train one or more specific tasks rather than provide general knowledge about a task domain. Aspects of equipment or the environment that are deemed irrelevant are not simulated. Of critical importance is that simulations provide the trainee with direct, hands-on practice of the required task(s).

Third, a simulation allows the trainee to make multiple responses during the scenario and view the consequences of his or her actions. That is, the educational experience is not presented to occur in some specific, sequential manner.

Simulation to enhance training and education does not have to represent the real world as closely as possible to be effective. Simulations have been developed that possess many different levels of sophistication, depending upon the training need. Some unrealistic features are often necessary to enhance training, such as the addition of instructional features like feedback, freeze and replay modes, and the ability to speed up the simulation so that more trials are possible within a given time frame than would be possible in the actual equipment.

## **SIMULATION WITHIN FUTURE EDUCATIONAL CURRICULA**

Simulations should have a promising role in future educational curricula and they should also be used to train users how to operate various components and functions of a computer-based educational system or electronic performance support system (e.g., Gery, 1991). The future curriculum should consist of mission-driven outcomes which describe a set of basic skills, thinking skills, and personal qualities and competencies that all students should possess.

The role of simulation is derived from overall goals and approaches. The two primary influences are the emphasis on performance-based education and the SCANS report. Both of these influences have the objective to inject relevancy into all phases of the learning environment. Simulation technology is well suited to assisting this task.



A primary emphasis of performance-based education is on real world experience and interacting with others in a cooperative learning environment. Simulation supports the goals of performance-based education by providing an environment that will assist in the acquisition of skills by using a set of authentic appearing tasks and role playing in an environment that can require collaboration. Used in conjunction with cooperative learning environments and context-based experiences, simulations can facilitate learning of job skills.

The thinking skills identified in the SCANS report include creative thinking, decision-making, problem-solving, and reasoning. These skills can be effectively learned through repeated context driven experiences. Simulation technology is an approach through which all students can adequately be provided with these learning experiences. By utilizing realistic scenarios, simulation can be effective at enabling students to acquire these foundational skills and competencies, thereby better preparing them for their adult life roles.

In addition, simulation can be a useful assessment tool for instructors because it will allow students to demonstrate mastery of certain objectives, some of which could not be assessed otherwise. The benefits associated with the use of simulation, such as increased transfer of learning and increased acquisition of real-life skills, are closely aligned with the mission and exit outcomes.

#### **OTHER RELATED BENEFITS OF SIMULATION**

Simulations have been traditionally used when they are less expensive, less dangerous, or more readily available than training with actual equipment. Within this scheme, standardized simulations may be developed or procured and then transferred to each participating learning site. While the initial cost of these simulations may be expensive, when it is divided by the number of learners receiving the benefit, the result should be cost-effective. This approach provides standardized instruction and presumably lower costs since simulations can be procured for all learning sites. When these simulations are applied on a large scale, (e.g., statewide) they become less expensive. Hence, more students across the state can participate in these hands-on learning experiences. The socio-economic status of a school district may no longer be a limiting factor in providing students with this valuable educational experience.

The use of simulation as an instructional tool can provide parity and consistency in the educational opportunities for students in disparate school districts. Moreover, student diversity based on physical challenges, ethnic heritage, and so forth, can be effectively addressed through the proper design of simulation-based instructional technology.

Through the use of a variety of simulations for different curriculum, instruction, and assessment goals, the educational environment will more accurately reflect the future work environment. Simulations can provide learners with engaging problems on



realistic, relevant activities. These experiences will be invaluable when learners enter the workplace.

Another benefit is that the educational system has limited resources to procure elaborate educational materials and to conduct field trips. Many inner city schools and poor rural districts teach children who have had limited contact with the world outside of their own neighborhoods. Wisely selected and developed simulations and networking can bring the world into these kids' hands.

Simulations provide a learning environment that is standardized and unbiased. With performance measurement capabilities incorporated into simulations, student learning and assessment can occur objectively in a setting in which the background of the learner is irrelevant.

Finally, simulations can be developed to act as stand-alone training devices or they can foster cooperative learning. In a networked environment, learners can interact with the same simulations simultaneously. In this approach, learners would be required to work cooperatively to meet the required learning outcomes.

## CONSTRAINTS

Several constraints will have to be handled before incorporating simulations into a future educational system. The primary constraint is determining the goals that simulations will be designed to accomplish. The next constraint is cost. Developing and implementing simulations may be very expensive. One factor that will help is that if the system is truly networked, as proposed, then a smaller number of simulations will need to be procured.

## SIMULATION STRATEGIES FOR INSTRUCTION

There are two primary distinguishing dimensions which can be used to categorize simulation approaches: content oriented simulations versus outcome oriented simulations, and stand-alone (individual) simulations versus group simulations. Current simulations appear to be designed to instruct or provide drill and practice in a specific subject or content area. This type of simulation is generally narrowly focused in a specific area, such as math, chemistry, economics, etc. The educational software industry is heavily invested in developing this class of products. While this type of simulation is relevant and useful, it is only loosely coupled to the learning objectives embodied in SCANS and performance-based education.

The other class of simulations can be envisioned as outcome or performance oriented simulations. This type of simulation integrates multiple subject or content areas into a single context-based simulation. It is generally characterized by role playing, embedded subject content, integrated multi-subject content, and real life situations. Outcome oriented simulations are the primary type of simulation needed to support performance-based learning objectives. Future performance-based educational initiatives

need to focus on stimulating the development of outcome-based simulations to achieve its goals.

The other primary dimension that can be used to classify simulations is based on the number of users which interact with the simulation simultaneously. Most computer-based training is designed for the single user. This reflects individual workstations and the drill and practice instructional strategy. However, an important aspect of future instruction appears to be in collaborative education. Simulations that provide cooperative learning support outcome-based education, because most real life experiences involve cooperative activities.

## **WHEN TO USE SIMULATIONS**

While there has been much research assessing the effectiveness of simulations as instructional tools, these studies have produced a wide variety of results. Thomas and Hooper (1991) classified and analyzed several recent studies on the instructional merit of simulations. Among their findings, the authors determined that simulations are most effective when used before or after formal instruction rather than as a replacement for it. While simulations can be effective instructional aids, it is false to assume that any simulation can be used to augment the learning process. The general conclusions appear to be that simulations chosen for the future educational curricula should possess, at a minimum, the following attributes: interactive, motivational, inherently easy to use, and support one or more of the SCANS competencies.

## **SIMULATIONS FOR TEACHER TRAINING**

Simulations may be used to train instructors how to perform various tasks, such as learning how to use functions of a computer-based educational system, much the same way that learners will use simulations. However, simulations may also be very useful for training teachers how to actually teach.

Typical teacher education involves learning the theory and practice of teaching, but offers little hands-on classroom practice in the types of everyday problems that teachers face and in handling individual differences among learners. Student internships do not offer the diversity of problems and responsibility required of teachers. Simulations of classrooms offer an opportunity to significantly enhance teacher training and readiness, because simulated events and interactions with students can be practiced routinely. Using simulations can help to form a bridge between learning educational theory and actually teaching. Moreover, with reduced educational resources and larger class sizes, getting hands-on practice with real classroom issues through simulation may prove to be invaluable. In addition, as technology continues to grow, the potential to incorporate virtual environments, collaborative simulations, and complex computer simulations into teacher training becomes more realistic.



## **SIMULATION RECOMMENDATIONS**

Current cognitive psychology provides compelling reasons to engage our learners in meaningful, authentic activities, including simulations. A primary recommendation is that future efforts should investigate existing simulations and see how they can be incorporated into an integrated curriculum. One of the weakest components of existing simulations is the instructional overlay or learning support for the user. Most learning is now only weakly supported, and additional materials will have to be developed to help instructors and learners benefit from simulations. However, there is no doubt that simulation will be used in some form to support future educational curricula. The extent to which it will be used, however, requires much careful thought and planning.

The highest priority simulation development appears to be in the area of collaborative, performance-oriented simulations. While considerable effort is being invested in the development of outcome-based curricula, it appears that little research and development is ongoing into the technologies required to support this type of curriculum. Facilitation of the development of this class of simulation should provide the greatest support and benefits for future educational initiatives.

The simulations to be used should be as broad in scope as possible to fulfill the requirement of curriculum design that there be as much overlap as possible between content areas. Therefore, simulations which include instruction on more than one topic should be given priority over those that concentrate strictly in one area.

Simulations that are presently on the market tend to concentrate on the areas of mathematics and science. The reason for this concentration is most likely that they are the easiest to develop, because they have the clearest mathematical models and algorithms. Recent educational reports indicating that students in the United States have sub-standard mathematics and science knowledge when compared to students in other countries may also be a factor. It is unlikely that future educational programs will have to develop their own simulations for these subjects due to the abundance of mathematics and science simulation software currently available. Rather, they should concentrate on developing simulations which support other subject areas, such as history, civics, social science, geography, foreign language, and vocational skills. These subject areas are equally important in performance-based learning environments.

## **PERFORMANCE ORIENTED SIMULATION TEST CASE**

The development of performance oriented simulations represents a new direction in educational simulations. This is especially true when it is embedded in a collaborative learning environment. Since this class of simulation represents a new technology direction, guidelines do not exist for its development. However, a future effort should pursue the development of a selected simulation in order to aid in the development of guidelines and standards that can be applied to other simulation developments, and to serve as a demonstration of this instructional technology and validate its benefits in meeting goals and objectives.

The test case simulation should:

- be outcome oriented according to the SCANS model
- integrate a broad range of subject areas within a real world context
- incorporate a collaborative learning environment using a peer-to-peer computing network
- utilize distributed interactive simulation concepts
- be expandable

Regardless of whether commercial or custom simulations are chosen for use in a specific curriculum, it is imperative that a program be thoroughly evaluated for effective instructional design and support of exit outcomes. Ideally, the simulations chosen should incorporate as many of the learning objectives and subjects as possible. This concept is in accordance with the integrated, systems approach.



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## THE ROLE OF SIMULATION IN FUTURE EDUCATIONAL CURRICULA

### INTRODUCTION

Researchers in the areas of education, psychology, cognitive science, and instructional technology are discovering more about how we learn every day. In addition, advances in computer and multimedia technologies may lead to significant advances and innovations for education. A number of simulation related technologies hold great promise for educational applications.

What is simulation and how should it be used as part of future educational curricula, particularly those using advanced computer-based instruction? By definition, simulations approximate, replicate, or emulate the features of some task, setting, or context. Typically, for instruction or training environments, simulations are used when the costs of alternative teaching systems are prohibitively high, when it is impossible to study the concepts of interest in "real-time," or when the risks are considered sufficiently high to require demonstration of competence in a controlled, relatively risk-free environment (Hannafin and Peck, 1988). "Simulations enhance the transfer of learning by teaching complex tasks in an environment that approximates the real world setting in certain important ways" (Reigeluth and Schwartz, 1989). From an educational perspective, simulations may also be used to expose learners to a situation or environment that otherwise may not be possible in their daily lives. In addition, simulations may be useful in teaching real life skills, such as creative thinking, decision-making, problem-solving and visualization, examples of which are outlined in the Secretary's Commission on Achieving Necessary Skills (SCANS) Report (Department of Labor, 1993).

Effective simulations can be implemented using a wide range of realism, which is known as the fidelity of the simulation. The cost of developing and implementing a simulation is directly related to the level of fidelity. The level of fidelity required for an effective learning aid depends on the specific application. Although instructional simulations require high content fidelity and validity, they are usually aimed at specific skills, which lowers their development cost. For example, a physics simulation for relative motion requires a high fidelity simulation model, but the focus of the application is narrow, making costs more manageable. Large role-playing simulations, on the other hand, can usually be implemented with only low to medium fidelity models because of cost. However, the nature of learning tasks permits a wide variety of cost-effective simulations, which makes them a viable and desirable instructional tool.

A good simulation presents believable scenarios or task situations, a variety of response choices, and the consequences of those responses. Because simulation permits the student to see the consequences of his or her actions, higher order thinking is stimulated. This higher order thinking leads to the acquisition of real life skills and to the development of a cognitive framework for further learning. Cues provided in a well designed simulation should enhance memory recall of the learned information when the student is placed in the real situation (i.e., transfer of training should be positive). Moreover, Pierfy (1977) found evidence that simulations supported the retention of information and changes in attitudes. According to Orlansky and String (1981), this retention of information occurs about 30 percent faster when a training simulation is used instead of conventional training. According to Brant, Hooper, and Sugrue



(1991), two of the most promising roles of simulation in instruction are to establish a cognitive structure to accommodate the acquisition of knowledge, and to provide an opportunity for reinforcing, integrating, and extending new and previously learned material.

Hays and Singer (1989) define a training device as an arrangement of equipment or other materials that simulates the actual task environment and provides functional interaction by the trainer. This "device" can include written materials, equipment, visual aids, video tape, and computer software. Use of such a device provides contrast to an actual simulator or simulation, which attempts to replicate the salient features of a task situation and which provides direct practice (Kincade & Wheaton, 1972). On a training continuum, simulators stand closest to the actual environment, thereby occupying one extreme, while low fidelity training devices such as instruction manuals are at the other extreme.

Gagne (1962) summarizes three important characteristics of simulators (and simulation, in general). First, simulators are built to present a situation or scenario that is as close to the real event as possible (at least the components that are being trained). In this case simulation is preferable because frequently using the actual equipment or performing in the real event is either too dangerous or too expensive for training purposes, and simulators are often more readily available than the actual devices. In addition to these very pragmatic advantages, simulators often prove more instructionally effective than the actual equipment. For example, they provide flexibility of instruction (e.g., scheduling) for both trainees and instructors, they provide performance measurement capabilities that the actual equipment often does not have, and training can often be simplified or broken down into segments, facilitating learning (Hays & Singer, 1989). For instance, it is easier to learn to fly a plane if the task is broken down into segments that are built upon one another, such as initially having the trainee control only the aircraft's heading and altitude, rather than requiring the trainee to concentrate on heading, altitude, throttle, flaps, navigation, and communications all at once.

Second, typical simulators are designed to train one or more specific tasks rather than provide general knowledge about a task domain. Aspects of equipment or the environment that are deemed irrelevant are not simulated. Typically, in military simulations, buttons and knobs that are not important to the task are depicted on the display via a photograph or some other means, but they are inoperative. Of critical importance is that simulations provide the trainee with direct, hands-on practice of the required task(s). However, simulations in education may be developed to teach more general outcomes than do military simulations.

Third, a simulation allows the trainee to make multiple responses during the scenario and view the consequences of his or her actions. That is, the educational experience is not presented to occur in some specific, sequential manner, as are traditional instructional approaches. New multimedia training applications do allow the learner to move through the material at his or her own pace and to take multiple paths, but again, the actual information is static.

Simulation to enhance training and education does not have to represent the real world as closely as possible to be effective. Simulations have been developed that possess many different levels of sophistication, depending upon the training need. Some unrealistic features are often necessary to enhance training, such as the addition of instructional features like feedback, freeze



and replay modes, and the ability to speed up the simulation so that more trials are possible within a given time frame than would be possible in the actual equipment (Hays & Singer, 1989). Choosing the extent of fidelity is one of the key issues in the simulation industry. In this age of reduced budgets, how much realism is necessary to provide satisfactory training at the lowest cost? After years of research, answers to this question are still being sought. As previously discussed, in many educational settings, where general knowledge is more likely being learned than specific task procedures, less fidelity is acceptable and is usually much less expensive.

## HISTORY OF SIMULATION

The use of simulation probably goes back to the beginning of civilization. War games of one sort or another were likely used for training and practice. Tansey and Unwin (1969) write, "chess is the oldest form of war game and those tactical games that involve map maneuvers have evolved from it over a long period."

The earliest "simulators" may have been those used by knights during the Dark Ages. When knights practiced jousting, they often used a training device called a quintain (Blaiwes & Regan, 1986). It was basically a post with a cross arm. On one end of the arm was a target, which was often counterbalanced on the other by a sandbag. When the knight hit the quintain, its "arm" would swing around rapidly toward the rider. Careless or unsuspecting riders could be knocked off their mounts from the force of the blow delivered by the quintain. Thus, this device provided simulated training in both offensive accuracy and defensive maneuvers.

Jones (1980) believes that the first use of organized simulation may have been by the Prussian Army in the 1800's, who created "simulations to test behavior" in their selection of officers. This use of simulation was incorporated and expanded by the British and later used by other countries including the United States. Using simulations for selection then expanded into business and industry. Simulations are now widely used in recruitment, selection, and training for any positions that involve behavioral components (Jones, 1980).

According to Hays and Singer (1989), the use of modern simulation and training devices can be traced to three factors: 1) early teaching devices created in the 1920's and 1930's, 2) the military trainers developed during World Wars I and II, and 3) programmed learning developed by the behaviorists beginning in the 1950's. Of course, modern simulation would not be where it is without ongoing research and development and technological advances in computer hardware and software.

The first patents for educational devices were obtained in the early 1800's (Hays & Singer, 1989). Motion pictures and photographic projectors were used in teaching by the 1880's (Branson, 1977). By the mid-1930's, there were between 600 and 700 patented teaching devices of one sort or another (Hays & Singer, 1989).

As is often the case, the greatest innovations and technology advances occur as a result of war or the threat of war. The next big push in educational devices and simulation occurred through advances arising during World War I. The first flight trainers (quasi-simulators) were developed to train military pilots. Specific trainers were created to teach ground operations (e.g.,



basic aircraft controls, taxiing) and aircraft control responses, such as limited pitch, roll, and yaw responses to pilot inputs (e.g., Blaiwes & Regan, 1986; Hays & Singer, 1989; Miller, 1976).

The first modern teaching machine, originally an automated testing device, was developed in 1915 by S. L. Pressey during this same period (Hays & Singer, 1989). Pressey later observed that his device could be used to present instruction since it would not advance to the next question until the user obtained the correct answer on the prior question.

During World War II, the next advances in simulation occurred because of the demand to train large numbers of soldiers in a limited span of time. Operational equipment was not readily available for training, at least at the start of the war, and instructors soon found that training could be enhanced through the use of "synthetic" trainers (Hays & Singer, 1989). For example, the Link Flight Trainer successfully trained many pilots to perform instrument flying. Simple by today's standards, it provided a replication of the actual aircraft cockpit controls and limited motion base (Hays & Singer, 1989). This device, based on the successful training that it provided, led the way to future simulators in many domains, not simply flight (e.g., navigation, maintenance, propulsion). Instructors knew how valuable these devices were as a result of using them during the war, but this value was not empirically corroborated until later when experiments in transfer of training and cost-effectiveness were conducted.

The military has researched, developed, and used many forms of simulation technology since World War II. The most common forms are flight simulations and command and control training centers. These applications have led to significant advances in computer and simulation technologies, especially visual system technologies to generate realistic visual scenes. Advances in this field have led to other high fidelity simulators, such as submarine, maritime, and driving simulators. The military continues to conduct simulation research to improve simulator effectiveness and to incorporate the many computer hardware and software advances that have recently exploded onto the market, such as advances in virtual environments and networking.

In another development during the 1950's, the behaviorist movement led by Skinner created programmed learning devices that utilized principles of operant conditioning (Hays & Singer, 1989). These devices provided feedback after the student answered the questions that were presented, and they also allowed self-paced learning. Programmed learning has been used substantially to this day.

Early simulator designers and researchers followed prescriptions from learning theorists, who postulated that to transfer learning from one domain to another, the learning elements or situations must be as similar to each other as possible (e.g., Hays & Singer, 1989; Thorndike, 1903; Wolfe, 1951). Due to learning theory and to technological advances that allow simulation to more closely represent the real world, there has been and still is a drive to make simulations as realistic as possible. However, more realism does not necessarily mean better training, nor is it more cost-effective, except in certain specialized environments. Many researchers are now trying to improve training effectiveness by focusing on teaching essential skills and knowledge rather than making the complete training task as similar to the operational task as possible (e.g., Gagne, 1954).



Thus, technological advances, reduced budgets, and hazardous operational conditions have led to increased reliance on the use of simulation in the military. This type of instructional technology has been repeatedly shown to be effective. The application of the simulation-based instructional technology in education should produce similar benefits because of the parallel in the learning requirements. Early research and simulation-based instructional products are clearly demonstrating this conclusion.

Simulations have also been used for a long time in some aspects of education. Whereas simulations in military applications have been heavily influenced by advances in computer technology, simulations in education have not been computer-based until recently. For example, in primary schools, the idea of learning through a game (such as playing "store") is common. The idea of computer-based simulations is only recently being used in secondary and post-secondary education. In technical training, simulated "on the job" training simulators have been used to train psychomotor skills. Simulations have also been developed for secondary education to help students improve social skills through job interviews, classroom discipline situations, and situations which require students' interaction with others (e.g., Romiszowski, 1988; McLellan, 1991, 1994a).

Simulations which help students understand real world problems are becoming more common in education as well. The Jasper Woodbury videodiscs are a good example; *The Tacoma Narrows Bridge* and *The Physics of Sport* provide physics instruction. In addition, *The Mystery of the Disappearing Ducks* is a very good multimedia package from Apple Computer and LucasFilms. *Sell Bicycles* is a program for intermediate grades which provides a simulation of running a store. Similarly, *The Factory* simulates a factory allowing the player to select up to three different types of machines to produce a product (Saettler, 1990). Problem-solving simulations have also been used in chemistry and physics to provide simulations of experiments which might otherwise not be performed in the classroom due to hazards or impeding cost. While off-the-shelf simulations are becoming more prevalent for the classroom, much research still needs to be done to determine when they are most effective and how they can be appropriately used to improve instruction. Moreover, most of these applications are geared for intermediate to upper level students. Attention also must be placed on simulations for younger learners.

## THE NEED FOR SIMULATION IN EDUCATION

Two major factors are present in our society that are forcing a change in the educational system. First and foremost is that increasing student populations, increasing student diversity, and decreasing economic resources place an increasing strain on traditional delivery systems. Education must be modified to accommodate increasing numbers and an increasing diversity of students. Simulations can provide varying levels of instructional support for learners at different ability levels. A significant amount of money will be required to implement most aspects of a simulation. However, when compared against the potential expenditures resulting from an uneducated society (e.g., dropouts, low-skilled, non-English speakers), the costs do not seem so high. Industry and the taxpayers will have to take over the burden of educating these people if the school system cannot do it. For example, Medin (1990) reports that in 1987, federal, state, and local governments spent approximately \$99.6 million for public welfare and \$3.5 billion for



housing for unemployable and low-skilled people. Moreover, cash and non-cash benefits paid to persons with limited income approached \$115 billion. A significant savings should occur if some of these expenditures are reduced through improved education.

Second, as the information age becomes reality, business and industry are more dependent upon information retrieval and processing. Thus, the changing workplace is requiring students to be computer literate and to possess basic technical skills such as word-processing and mathematics. Future jobs will be technology-based and emphasize teamwork (collaboration), and companies will compete through efficiency, effectiveness, and productivity. Future curricula can utilize computers and simulations to provide valuable real-life experiences with workplace technology.

Simulations engage learners and make them active participants in the learning process. They use technology to gather data, solve problems, and prepare products. Simulations provide experiences that capture student attention in a way that is structured to achieve desired learning objectives. For example, Science Vision's Geo Explorer allows students to become involved in the search for a rare mineral, and Carmen San Diego provides students with geography education as they chase criminals around the world.

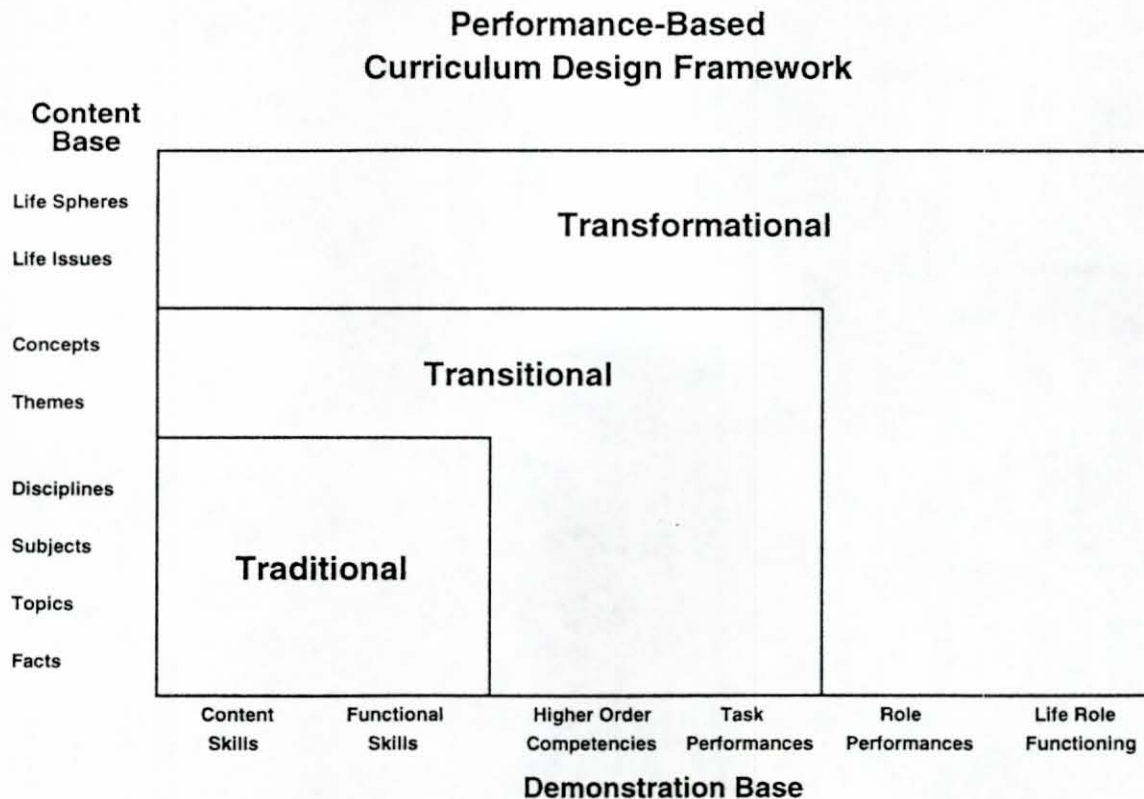
In addition, technology is permeating the home environment through television, computers, and other electronic devices. Students now come from an environment in which information and images are presented in a vibrant, interactive manner. These individuals frequently do not accept the traditional, non-dynamic instructional model in which a teacher lectures to a class. In some cases, students are bringing technology into the classrooms, such as pagers and personal digital assistants. This influx in advanced communications technology may force a change in education in and of itself, much the way electronic calculators changed math and science education.

## **SIMULATION WITHIN FUTURE EDUCATIONAL CURRICULA**

Simulations should have a promising role in future educational curricula, and they should also be used to help train users how to operate various components and functions of a computer-based educational system or electronic performance support system. The future curricula should consist of mission-driven criteria which describe a set of basic skills, thinking skills, and personal qualities and competencies needed for employment and successful performance in the life roles encountered by students immediately after they graduate (i.e., real-life skills). The role of simulation is derived from overall goals and approaches. The two primary influences are the emphasis on performance-based education and the SCANS report. Both of these influences have the objective to add relevancy into all phases of the learning environment (i.e., make learning relevant to real-life requirements). Simulation technology is well suited to assisting this task.

Performance-based education emphasizes the design and organization of all curriculum and instructional planning, teaching, and assessing, with the goal of advancing students around successful learning experiences (see Figure 1). A primary emphasis is on real world experience and interacting with others in a cooperative learning environment. Simulation supports the goals of performance-based education by providing an environment that will assist in the acquisition of

skills by using a set of authentic appearing tasks and role playing in an environment that can require collaboration. Used in conjunction with cooperative learning environments and context-based experiences, simulations can facilitate learning of job skills.



**Figure 1.** Performance-based curriculum design framework (Spady, 1991).

The SCANS report identifies the foundation skills and competencies that America's labor force will need to be effective and competitive in the next century. Several categories of these skills and competencies parallel the objectives of performance-based education (e.g., interpersonal and information competencies). The thinking skills identified in the SCANS report include creative thinking, decision-making, problem-solving, and reasoning. Each of these skills has been addressed through simulation technology. These skills can be effectively learned through repeated context driven experiences. Simulation technology can be an effective instructional tool for this class of problems. It is an approach through which all students can be provided with these learning experiences. The resources required to provide these experiences to all students by other means are cost prohibitive. By utilizing realistic scenarios, simulation can be effective at enabling students to acquire these foundational skills and competencies, thereby better preparing them for their adult life roles.

In addition, simulation can be a useful assessment tool for instructors because it will allow students to demonstrate mastery of certain objectives, some of which could not be assessed otherwise. The benefits associated with the use of simulation, such as increased transfer of



learning and increased acquisition of real-life skills, are closely aligned with the mission and exit criteria.

The use of simulation could lead to a wide variety of instructional applications. For example, students would be able to:

- conduct elaborate chemistry, biology and physics experiments through interactive simulations.
- reenact battles in history via computer simulations and intelligent simulated forces, in order to actually see how battles were fought, and play "what if" games.
- participate from different sites in problem-solving exercises such as hurricane preparedness.

*The Great Solar System Rescue* and *The Great Ocean Rescue Mission* are excellent multimedia packages that promote cooperative learning and problem-solving. They can be used as a sample for a design model.

## PRAGMATIC BENEFITS

Several benefits of simulation are more pragmatic than pedagogical. Traditionally, simulations have been used when they are less expensive, less dangerous, or more readily available than training with actual equipment. For future educational curricula, standardized simulations may be developed or procured and then transferred to each participating learning site. While the initial cost of these simulations may be expensive, when it is divided by the number of learners receiving the benefit, the result may be cost-effective. This approach provides standardized instruction and presumably lower costs since one simulation can be procured for all learning sites. Off-the-shelf simulations may be used if they are determined to be adequate for the learner-centered approach.

The use of simulations for conducting experiments in science classes provides a prime example of the cost and benefits of simulation. Science projects in chemistry and biology can require considerable expendable resources (e.g., chemicals, animals, equipment). These consumable resources can represent a significant budget expenditure for these classes. In addition, these expenditures are repeated year after year. While simulations cannot be used to replace all necessary experiments, they can be used to provide students an equivalent experience, and there is only a one-time cost. Other types of experiments in chemistry and physics can involve safety issues, both during the conduct of the experiments and the disposal of hazardous waste. Potential savings in insurance, hazardous materials handling, and other related expenses can offset the development or procurement of simulations which can provide equivalent experience without the safety risk.

A side benefit is that when these simulations are applied on a large scale, (e.g., statewide) they become less expensive. Hence, more students across the state can participate in these hands-on learning experiences. If simulations are developed and implemented well, the socio-



economic status of a school district may no longer be a limiting factor in providing students with a valuable educational experience.

Another benefit is that through the use of a variety of simulations for different curriculum, instruction, and assessment goals, the educational environment will more accurately reflect the future work environment. Simulations can provide learners with engaging problems on realistic, relevant activities. This practical experience will be invaluable when learners enter the workplace.

Moreover, by using simulations and other instructional tools through an electronic learning support interface, more students can be handled by the instructors and with the available resources. Students can spend more time working on learning activities, allowing the instructors to act as facilitators, and freeing up time to provide assistance to learners who need it.

Using standardized instructional approaches and software (including simulations) will foster cohesiveness within and across learning sites. This arrangement should improve communications and information management throughout the system, and hence, provide a cost-effective educational experience. The use of simulation as an instructional tool can help to provide parity and consistency in the educational opportunities for students in disparate school districts. Moreover, student diversity based on physical challenges, ethnic heritage, and so forth, can be effectively addressed through the proper design of simulation-based instructional technology. However, the learning environment must be modifiable in an unbiased manner to meet individual learners' needs. Examples with different frames of reference are needed to help them understand. For example, Jetter (1993) describes how a highly successful math education program had to be adapted from the urban Boston area, where it began, to meet the needs of students in rural Mississippi.

## **PEDAGOGICAL BENEFITS**

There are many pedagogical benefits associated with the use of simulations that are mentioned below. However, many of these benefits will have to be addressed in terms of how simulations will be implemented into the curricula and how they will be used.

One important benefit is that most educational systems have limited resources with which to procure elaborate educational materials and to conduct field trips. Many inner city schools and poor rural districts teach children who have had limited contact with the world outside of their own neighborhoods. Wisely selected and developed simulations and networking can bring the world into these students' hands.

Second, the entire curricula can be enhanced through the use of standardized simulations that are available at all learning sites. This approach also fosters multidisciplinary education at all sites and curricula that reflects relevance to the expectations of society. For example, in the present Florida education system, some schools cannot provide courses on certain topics because of a lack of resources or student interest. With a standardized instructional approach and system, students anywhere within the learning sites can have access to the same education. Thus,



advanced materials can be made available to more students. Along a similar vein, students who require diverse instructional materials can obtain them, regardless of the location of their school.

Simulations can provide a learning environment that is standardized and unbiased. If appropriate performance measurement capabilities are incorporated into simulations, student learning and assessment can occur objectively in a setting in which the student's background does not affect the assessment.

When used as an instructional activity, simulations can enhance motivation, reveal misconceptions that could inhibit learning, provide an organizing cognitive structure for receiving new material, and serve as concrete examples of complex, abstract concepts. This influence is greatest for meaningful learning where existing knowledge often serves as an anchoring point for evaluating and subsuming new pieces of information (Brant, Hooper & Sugrue, 1991).

Simulations inject feelings of realism and relevance to the learning task, which should help to enhance motivation. With greater motivation, learners will spend more time on task, hence reducing the need for instructor supervision. Instructors can spend more time helping learners and less time attending to administrative and disciplinary tasks.

Furthermore, simulations enable complex problems to be made simpler and more easily understood. Simulations allow the learner to visualize the situation and gain an initial qualitative perspective that may help them organize the information better, increasing the likelihood that they can solve the problem. This also applies to using simulations to teach users to operate components of a computer-based educational program.

Simulations may also help learners become adaptable problem-solvers who discover and explore problems and find solutions from a variety of perspectives, continually adapting based on new knowledge. Simulations can help learners analyze and interpret verbal and numeric data to generate and evaluate potential solutions to problems and evaluate their effectiveness.

In problem-solving, it is important that the learner be able to relate the components of the problem in a meaningful manner (e.g., Greeno, 1978; Brown, Collins, & Duguid, 1989). A study on the solving of physics problems by both experts and novices illustrated that the difference between the two groups was not in the quality of their reasoning, but rather in the quantity of knowledge which experts can bring to bear upon a problem and its interpretation (Larkin, McDermott, Simon, & Simon, 1980). This knowledge is lacking in novices, and as a result they tend to deal with one narrow conception after another, abandoning each when a solution is not achieved. Using appropriate simulations can help learners bridge this gap between novice and expert reasoning.

Another research finding relevant to simulation is the value of using qualitative information to help students solve quantitative problems. The availability of qualitative information plays a significant role in developing reasoning and problem-solving skills (Forbus, 1983). For example, research in problem-solving demonstrates that experts solve problems by qualitative reasoning before attempting a quantitative solution (Larkin, 1979, 1983). To



effectively use qualitative information, the problem-solver must have formed a "knowledge base" of rules (Holland et al., 1986). This knowledge base allows the thinker to recognize perceptual events and possible changes in the environment which may result in problems that must be solved. Thus, simulations can provide a qualitative perspective to the information being presented.

Moreover, simulations can help teach learners the outcomes of their actions, and they can also be used to assess how well the learner has attained the required knowledge and skills. For example, simulations may help learners become capable workers who apply knowledge, skills, and technology to implement plans, procedures, and solutions. Simulations support approach to the discovery of rules and relationships by posing questions and problems. Learners can look for concepts, procedures, or facts that will elaborate on the simulation content. This information can then be used to form hypotheses that can be tested through further interaction with the simulation. The discovery approach should help learners become creative thinkers who address challenges and problems in new ways. For example, Bricken (1991) speculates that the computer is an ideal tool for manipulating symbolic abstractions. She suggests that instead of teaching the abstraction, the learner can be taught how to use a virtual reality tool to provide a natural interface between the physical world and the logical-mathematical abstractions that we use to understand various processes and interactions. Virtual environments permit reality to be modeled and they allow us to escape the bounds of reality to help us understand principles, processes, and interactions, such as in physics and chemistry applications. Lantz (1992) suggests that with virtual environments, highly technical concepts and information can be presented intuitively, allowing the learner to go beyond "book knowledge" and actually develop a sense for advanced concepts and relationships.

Finally, simulations can be developed to act as stand-alone training devices or they can foster cooperative learning (e.g., Biegel, 1989; Gibb & Biegel, 1989). In a networked environment such as recommended here, learners can interact with the same simulations simultaneously. In this approach, learners would be required to work cooperatively to meet the required learning objectives.

If a cooperative learning approach is used for working with some simulations, then learners can use these experiences to help them become responsible collaborators. The cooperative approach will teach learners to work successfully with one another and to share responsibilities with individuals and groups in diverse work, community, and family settings to complete tasks.

Simulations that require cooperative learning to solve a specified problem may also be helpful in reducing racial intolerance if they are designed to: a) require cooperation and interdependence among learners of different cultural backgrounds, b) require the participants to have equal social status during the simulation, c) produce a positive outcome for the group, and d) require that the participants from different backgrounds get to know one another and be seen as typical members of their cultural group and not exceptions (e.g., Aronson, et al., 1978; Bernstein, et al., 1991).



## CONSTRAINTS

Several constraints will have to be handled before incorporating simulations into a future, performance-based educational system that utilizes advanced technologies. The primary constraint is determining the goals that simulations will be designed to accomplish. The next constraint is cost, which is highly dependent on the goals. Developing and implementing simulations may be very expensive. Unfortunately, at this time there is no way to make accurate predictions about what those costs may be, because there are several factors that must be addressed, and each will have an impact on the cost. Some of the important cost factors include:

- type and extent of simulations developed (e.g., non computer-based vs. computer-based, standalone vs. networked, simple vs. complex).
- type and extent of the network structure (e.g., type of network selected, available bandwidths).
- who will design, develop, and implement the simulations.
- multiple simulations developed from an initial prototype vs. many different simulations developed independently.

Thus, depending on the direction that a future effort takes, costs could vary a great deal. One factor that could help is that if the system is truly networked, then a smaller number of simulations may need to be procured, because they could be accessed over the network by each learning site.

Developing simulations for an entire educational system will require significant planning and strategic implementation. A needs analysis should be conducted to determine what types of simulations are needed to meet the curriculum, instruction, and assessment goals. Off-the-shelf simulation packages should be investigated as well, but it is doubtful that many will meet the criterion-based requirements. Other issues will also need to be addressed, such as who will ultimately determine which simulations are developed or procured, who will develop them, and how will they be implemented?

A fundamental constraint on the effective use of simulation in future efforts is the need for hardware and software standards. These standards are needed on a national and global basis if the entire spectrum of benefits offered by educational simulations is to be realized. New hardware and software standards need to open the delivery environment for simulations, and not simply choose one platform over another. Current hardware and software for computing and networking will be adequate for short-term needs, but future requirements may be different.

One of the primary areas of hardware and software standards that is needed to support educational simulation environments is in the networking and communication area. New standards in this area must address several concerns. The first concern is network architecture. Educational networks for the future must support peer-to-peer computing environments as well as the standard client-server architecture. Peer-to-peer computing is needed to facilitate collaborative learning environments and real-time distributed learning simulations. These requirements are fundamental to the learning objectives.



Another important concern is the bandwidth of the network. Current network bandwidth is designed to accommodate non real-time data transfer. Simulations that use animated graphics, advanced instructional tools, or video require large memory for storage and need significantly higher bandwidths. The bandwidth must be adequate to transmit simulations over the network and operate them in real-time. The demand on bandwidth will also be driven by usage. The number of users on the available networks is increasing dramatically. Given that the network should be a cornerstone of the future educational system's design, bandwidth will be a limiting factor in successfully implementing learning objectives.

Similarly, current Transmission Control Protocol/Internet Protocols (TCP/IP) cannot support distributed simulation environments. The restriction to host simulations at local workstations or local area network (LAN) levels restricts the potential benefits of simulation. New protocol standards are needed to support open simulation applications at any point in the network. These new standards should incorporate protocols being developed by the military for interoperability of simulators and distributed interactive simulation. The research by the military on standards for simulator and simulation interoperability provide a significant leverage for new network protocols for educational environments.

The other hardware/software standard issue that needs to be addressed is the computer platform(s) for the learning environment. In this area, the standard should not be hardware oriented, rather, it should focus on open software operating systems. Too often, the current debate pits IBM (or its PC clones) versus Apple. School districts have significant investments in equipment and it varies from district to district. The standard in this area should make the hardware platform irrelevant. The need is for open software standards which support a variety of hardware platforms, including heterogeneous hardware environments. Application software should be available for either hardware platform, and it should be consistent across platforms. Microsoft has made major steps in this direction. Their new line of application software is compatible with Windows and MacIntosh environments and provides total file transportability between platforms. This represents the model for future hardware/software standards.

Industry standards have always tended to favor the strongest competitor. This is not compatible with future educational initiatives. An open computing environment is necessary to implement simulation-based learning environments cost-effectively.

## **SIMULATION STRATEGIES FOR INSTRUCTION**

There are two primary distinguishing dimensions which can be used to categorize simulation approaches: content-oriented simulations versus criterion-oriented simulations, and stand-alone (individual) simulations versus group simulations. Each of these distinctions are discussed below.

### **CONTENT-ORIENTED SIMULATIONS VERSUS CRITERION-ORIENTED SIMULATIONS**

One of the major distinctions that can be used to classify educational simulations is based on focus. A majority of current simulations appear to be designed to instruct or provide drill and



practice in a specific subject or content area. This type of simulation is generally narrowly focused in a specific area, such as math, chemistry, economics, etc. These types of simulations may take many forms and utilize a variety of the basic simulation technologies described earlier (e.g., simulations, animations and games). The educational software industry is heavily invested in developing this class of products. While this class of educational simulation is relevant and useful, it is only loosely coupled to the learning objectives embodied in SCANS and performance or criterion-based education.

The other class of simulations can be envisioned as performance-oriented. This type integrates multiple subject or content areas into a single context-based simulation. This type of simulation is generally characterized by role playing, embedded subject content, integrated multi-subject content, and real life situations. While there are a few board-based games that use this approach, there are currently few computer-based examples of this type of simulation (SimCity and SimEarth are two examples). This type of simulation is closely coupled to the learning objectives associated with future performance-based educational curricula. However, the educational software industry is not responding to this need. This may be in part due to the simpler nature of content oriented simulations and their applicability to conventional curricula. Performance-oriented simulations, by definition, are larger and more complex, and consequently more expensive to develop. In addition, the technology infrastructure to support this class of simulations is only now emerging. Future performance-based educational initiatives need to focus on stimulating the development of performance-based simulations to achieve their goals.

## **STAND-ALONE SIMULATIONS VERSUS GROUP SIMULATIONS**

The other primary dimension that can be used to classify simulations is based on the number of users who interact with the simulation simultaneously. Most current computer-based training is designed for the single user. This reflects the drill and practice instructional strategy and individual workstations. However, an important aspect of future instruction appears to be in collaborative education. Simulations that provide cooperative learning support criterion-based education. Most real life experiences can be provided effectively only to students in group settings. As mentioned earlier, the learning group may be geographically distributed. The educational software industry is primarily focused on stand-alone simulations, with only a few group learning environments that appear to be under development.

## **WHEN TO USE SIMULATIONS**

Research studies regarding the effectiveness of simulations as instructional tools have produced a wide variety of results. Thomas and Hooper (1991) classified and analyzed several recent studies on the instructional merit of simulations. The authors determined that simulations are most effective when used before or after formal instruction rather than as a replacement for it. When used as a pre-instructional activity, simulations can provide motivation, reveal misconceptions that would inhibit learning, provide an organizing cognitive structure for receiving new material, and serve as concrete examples of complex, abstract concepts (Brant, Hooper & Sugrue, 1991). The use of a simulation prior to formal instruction initiates thinking on the part of the student and makes the student a contributing member of the instructional process.



Although pre-instruction use of simulations is less widely accepted than post-usage, students who used a simulation prior to formal instruction performed better on a post-test than both students who did not use the simulation at all and students who used the simulation after formal instruction. With regard to post-instructional use of simulations, they facilitate the integration and application of recently acquired knowledge (Brant, Hooper & Sugrue, 1991).

While simulations can be effective instructional aids, it is false to assume that any simulation can be used to augment the learning process. Simulations chosen for future educational curricula should possess, at a minimum, the following attributes:

- interactive.
- motivational.
- inherently easy to use.
- support one or more of the SCANS competencies.
- support performance-based criteria.

### **Simulations as Instructional Tools**

While the list of commercially produced simulations grows at a steady pace, we suggest that a panel of curriculum experts be formed to evaluate these commercially produced packages based on their instructional effectiveness and the application of learning criteria. While commercially produced simulations (e.g., games, animated programs, simulated environments) may be effective for some applications, there is much to be said for custom packages.

Many parallels have been drawn between military and educational simulations. Over the last two decades, the United States military has developed an impressive array of simulation and training systems. These programs and devices have been very successful at teaching members of the armed forces to do their jobs as individuals or as members of small teams. However, the ability to perform certain tasks as an individual does not guarantee the ability to perform as a member of a team. As our societal concerns continue to become more global in scope, our students will need to have the knowledge to function in other environments. The students of today will need to work as members of teams and communicate with people from other geographic locations. As such, the system used to educate these students must take these realities into account. Working in teams is now an important part of every corporation, no matter what the field. Thus, students must learn how to work with others and to contribute as a productive member of a team. Computerized simulations can provide a means for practicing team activities, especially with presently increasing networking capabilities available to the schools.

### **Simulations for Teacher Training**

Simulations may be used to train teachers how to perform various tasks, such as learning how to use functions of a computer-based educational system, much the same way that learners will use simulations. However, simulations may also be very useful for training teachers how to actually teach the curricula.



Typical teacher education involves learning the theory and practice of teaching, but offers little hands-on classroom practice in the types of everyday problems that teachers face and in handling individual differences among learners. Student internships do not offer the diversity of problems and responsibility required of teachers. Simulations of classrooms offer an opportunity to significantly enhance teacher training and readiness, because they can routinely experience simulated events and interactions with students.

According to Tansey and Unwin (1969), simulation in teacher training has taken two directions: role-playing and the 'in-basket technique.' In role-playing, the teacher-in-training is provided with much information regarding a particular situation (e.g., background information on the school, class, community). The teacher-in-training is then required to play the 'teacher' of this simulated class. An example of this type of simulation for teacher training that is still in use today is "Tenure" (Gaede, 1975). This package was developed in 1975 for the "Plato" system. A second simulation possibility is to have the teacher-in-training practice with a simulated student's case study.

The 'in-basket technique' refers to a methodology in which the teacher-in-training receives a set of scenarios that might occur during the normal classroom day of a teacher. Usually about 20 items make up the in-basket, and the simulation is finished when all items in the basket have been handled (Tansey & Unwin, 1969). Typically, in a non-computer simulated environment, each item is often completed in writing. However, using computer-based simulation, the teacher-in-training may interact with the simulation to complete many or all of the tasks. Some of the tasks may require role playing to be completed.

Today's students bring a variety of experiences to the classroom that teachers must handle on a daily basis. In addition, beginning teachers must know how to handle unusual situations. While the effective handling of these situations comes with experience, the use of a simulation can provide the inexperienced teacher with ideas for handling difficult situations when they arise.

Using simulations for beginning teachers can also give them exposure to problems they might not encounter in the classroom for some time. By practicing the handling of these situations without the fear of criticism in a simulated environment, the teacher will have a better chance of dealing with the situation successfully when it does arise. Simulations also allow teachers to view students as individuals. Instead of learning about children in general, as in lectures, the student teacher can react to students as individuals in a simulated environment.

Thus, there are several means by which simulation may be used to train teachers in classroom practices before they actually get in front of a real class. Using simulations can help to form a bridge between learning educational theory and actually teaching. Moreover, with reduced educational resources and larger class sizes, getting hands-on practice with real classroom issues through simulation may prove to be invaluable.

As technology continues to grow, the potential to incorporate virtual environments, collaborative simulations, and complex computer simulations into teacher training becomes more realistic.



## SIMULATION TECHNOLOGIES

A number of simulation related technologies hold great promise for educational applications. These technologies include anchored instruction; interactive, dynamic simulations; gaming; networking; collaborative learning, distributed interactive simulation; intelligent simulated entities; and virtual reality. Medin (1990) describes several of the resulting instructional approaches which will ease the transition of education into a performance-based approach:

- intelligent tutoring systems that provide expert knowledge at the touch of a button;
- ready access to high fidelity video and audio information, animations, and simulations that will increase the quality of education and which will bring to the students a rich knowledge of, and hands on experience with, the world (this is especially important to underprivileged children who may have little experience with the world outside of their neighborhoods);
- electronic performance support that will allow learners and instructors to easily handle routine tasks, thus enabling them to focus on more complicated problems;
- assessment techniques that will allow instructors to track learning, diagnose learner understanding, correct deficiencies, and evaluate attainment of learning objectives;
- tools to help instructors (and learners) create and modify their own lessons and instructional materials.

Several computer technologies are, or may be, associated with simulation, including graphics, animation, feedback, gaming, networking, intelligent simulated entities, and virtual reality. Each of these technologies, and some associated research, will be below.

## ANIMATIONS AND SIMULATIONS

Interactive, dynamic animation and simulation technology can greatly enhance the discovery learning process. A range of research indicates potential advantages to using these instructional technologies. For example, the availability of qualitative information plays a significant role in developing reasoning and problem-solving skills (Forbus, 1983). Research in problem-solving demonstrates that experts solve problems by qualitative reasoning before attempting a quantitative solution (Larkin, 1979, 1983). The use of animations and simulations provides a qualitative perspective to information being presented to the learner and thus can aid in developing skills in problem-solving and reasoning.

Animation and simulation support a discovery approach to learning by allowing learners to explore basic concepts in applied situations at multiple levels of analysis. When used for individual computer-based training, learners should be able to access other animations, simulations, text, and graphic frames to look for concepts, procedures, or facts that will elaborate



on the simulation content. This information can then be used to form hypotheses that can be tested through further interaction with the instructional activity. A listing of specific tactics that can be used in inquiry-based teaching are provided by Collins and Stevens (1983).

In computer-based training and simulation, graphics are used extensively to allow the learner to visualize the problem or task environment. Graphics may be still images or animated images. Their purpose is to provide a visual, qualitative representation of the actual environment. Visualization appears to be very important in helping learners grasp material and solve problems. However, the optimal form of the representation is inconclusive (e.g., line drawings, photographs, animation, video), and the selection is often made based on level of detail required, type of task being trained, personal preference, and cost.

Animation has been applied in a limited way to learning complex information in prototype tutoring systems (e.g., Holland, et al., 1986), and in computer-aided instruction lessons and games (e.g., White, 1984). Applications of animation are becoming widespread in scientific research as an interface for visualization of the dynamic behavior of complex systems and as a means of providing students with a qualitative understanding of those complex systems and processes. Animation and simulation also incorporate many of the characteristics that have been found to aid intrinsic motivation (Malone, 1980), which in turn affects primary learning skills (Driskell & Dwyer, 1984). Increased motivation to actively engage in the learning process has been shown to lead to greater elaboration and depth of processing and consequently better retention of the material (Lepper, 1988). The simulation environment engages the learner by making it intrinsically motivating through the use of realism, challenge, feedback, and/or interaction.

## FEEDBACK

Another important feature for increasing intrinsic motivation and task performance in learning environments may be the presence of explicit short-term goals in which the learner is challenged to achieve those goals (Malone, 1980). The concept of challenge has been emphasized as an important element in intrinsic motivation (Malone, 1980). Challenge can be increased by introducing uncertainty of goal attainment, difficulty levels, and hidden or incomplete information. One way to add challenge to a simulation is through gaming. Often, attempting to attain a certain goal is the main source of interest in a task. To be challenging, the outcome must be uncertain (Malone, 1980; Driskell & Dwyer, 1984). If the goal is always attained, or is never attained, there is no challenge because the outcome is assumed to be fixed. These tasks should provide the student with feedback as to their competency and level of effort (Frederikson, et al., 1982). Some challenging features which may be incorporated into computer games are variable difficulty levels, multiple level goals, cumulative score keeping, informational feedback, and an unlimited ceiling on performance (Driskell & Dwyer, 1984). A student will become bored or frustrated if the problems presented are too easy or too difficult. As the student's abilities increase, so should the difficulty level that he or she finds most challenging. Based on this information, the student must be provided with varying levels of difficulty to keep motivated.



Feedback in response to an individual's performance on a simulation is another important factor in improving subsequent goal attainment. It is important to provide opportunities for success in the initial stages of learning (e.g., Malone & Lepper, 1987a). These motivational characteristics should be incorporated at different levels throughout the simulations. Continuous feedback should be available through the use of cues and questions that prompt the student about the relationship between a basic concept and the simulation.

## GAMING

The premise behind most of the research on gaming has been that if students are intrinsically motivated to learn, then they are likely to spend more time and effort learning the topic. Many students entering schools today have grown up with video games and MTV, and it is no surprise that traditional methods of instruction do not provide the visual and mental stimulation that students receive outside the classroom. Given this situation, computerized learning environments must be made to be intrinsically motivating. Through studies where motivational performance measures were applied, Malone (1980) and Malone and Lepper (1987) found that computer game formats were highly motivational when used in instructional environments.

While research to support a direct effect of computer games on learning is equivocal, the research is clear on their effect on motivation. Recent research (e.g., Lepper & Hodell, 1989) has found that game characteristics can have positive effects on learning. The benefits are also reflected in subsequent learning or retention of the instructional material. Research indicates that students have a strong preference for a simulation with game characteristics over the simulation alone, especially among those students who were less interested in learning science concepts (Shresta, 1991). These findings imply that incorporating game characteristics in the design of instruction will help to increase motivational appeal for the activity and thereby enhance learning and retention (Malone, 1980; Lepper & Hodell, 1989). A key factor in assuring that a motivating game enhances rather than distracts from learning is to design the game goals to be congruent with the learning objectives (Lepper & Hodell, 1989).

## NETWORKING

Networking is another important technology that will have a significant impact on the use of simulations within education. Networking within schools is taking place at an increasing pace. This phenomenon is being driven by the efforts to reform our educational system. A key requirement of the National Educational Goals and the SCANS competencies is to introduce real-life experiences into schools and introduce a learning environment which reflects the workplace. Given the transition to an information management environment in almost every aspect of our society, networking within schools is a fundamental aspect of future education. Educational networks will serve an increasing user population characterized by its diversity. These networks will start within the classroom and should provide seamless access to knowledge and applications around the world.

The breadth of the user population for educational networks poses a unique problem. Most user systems have had a restricted user population, or involved relatively limited



functionality. The future user population will include people with diverse skills, educational levels, cognitive skills, and so forth. The human interface must be able to accommodate students, teachers, administrators, and parents. It must also be able to accommodate normal and challenged populations. This diversity will require the system to adapt to the individual user and incorporate a broad range of functions. The adaptive interface will be an essential component to the friendliness of the system and thereby determine user acceptance. These educational networks will access an extraordinary mass and variety of information. Without a well-defined interface, it cannot achieve its full potential. The adaptive interface will need to intelligently change based on the age, knowledge, special characteristics, and other needs of the user.

Networking will impact two components of simulations in education: 1) it will allow simulations (and other software packages) to be distributed and used within and across learning sites, and 2) it will allow multiple learners to simultaneously interact, individually or cooperatively with specially designed simulations. Using a networked simulation in this way can improve learning and cooperation because of the information that is obtained and shared. An important aspect of distributed interactive simulation (DIS) is that the simulations can be run on hardware manufactured by different vendors.

Simulators of different kinds are quite readily networked. An example of a networked system is presented by Gibb and Biegel (1989). They describe how a physical simulator (an airplane cockpit simulator), a computer flight simulator on a CRT, and an intelligent simulation training system (ISTS) were networked for team training of airways personnel. A student at the ISTS air traffic controller simulator sees a simulation of an air traffic control radar screen, which is interactively updated in real-time. The student has the capability of directing student pilots in other simulators.

## COLLABORATIVE LEARNING

One of the emerging technologies for education is collaborative learning. Collaborative learning environments are group learning environments. Education has historically emphasized individual learning. However, as the SCANS report identified, real life work experience is based on team or group performance. People have to work with other people, reflecting all branches of diversity, to accomplish goals. It has recently been recognized that learning environments need to impart this critical skill. It is unrealistic to believe that students who are taught in an individual mode of learning can flawlessly take a productive role in the workplace that requires cooperation. Collaborative learning environments provide the opportunity for students to learn to work as groups to form hypotheses, to gather and analyze data, and to formulate solutions. This is the basis for teaching students how to access and utilize data from remote locations and how to work in group or team environments.

Computer Supported Intentional Learning Environments (CSILE) is an example of a current computer-based collaborative learning environment (Scardamalia & Bereiter, 1993). This approach to collaborative learning focuses on group knowledge-base development. CSILE is a software package that incorporates a multi-user data base, text and graphics capabilities, and feedback routines. Its approach is to provide groups of students with the capability to ask



questions, develop hypotheses, access and store data, interpret data, and provide peer feedback. This type of collaborative learning environment has proven highly successful.

The newest approaches to implementing collaborative learning environments are being facilitated by a new architecture: peer-to-peer networks. While current collaborative learning environments focus on data utilization, the logical next step is to provide access to, and interaction with, simulations within a collaborative learning environment. When simulation is introduced as a tool within a peer-to-peer computer-based collaborative learning environment, this learning environment parallels the topology and function of DIS under development by the military. Hence, this type of network architecture provides an educational parallel to DIS.

## **DISTRIBUTED INTERACTIVE SIMULATION**

The military has recently been pursuing an innovative integration of simulators and command and control training technology. DIS integrates traditional simulator technologies with computer communication technologies to create a system which provides a common 'playing field' on which simulators can interact in real-time, action-requiring situations (Loper, Thompson, & Williams, 1991). This type of networked simulator environment can integrate individual simulators and command and control trainers to provide a total simulated battlefield. By creating environments which allow various types of interactive simulators to communicate, effective training can be accomplished at a variety of levels, from operational team training to force-on-force combined arms training. In order for DIS to take advantage of currently installed and future simulations manufactured by different organizations, a means must be found for assuring interoperability between these dissimilar simulations. One step in achieving this interoperability is to develop a communications protocol. There must be an agreed-upon set of messages that allow host computers to communicate information about the vehicles or entities that they represent in the simulated world. Interactions between these entities must also be communicated.

Obviously, future educational efforts are not interested in military simulations. However, advances in this area are likely to strongly impact the overall networking structure of the educational system, and specifically, the ability to conduct networked educational simulations and distance learning. This type of networked learning environment should provide an effective basis for teaching group problem-solving skills and teamwork. These networked learning environments may link students within a classroom, between classrooms, or between schools. Furthermore, the link between schools is not restricted to a single community. It may involve schools across the state, nation, or worldwide. DIS provides the vehicle for implementing a global learning environment. This type of networking environment provides the technology to support role-playing exercises that permit students to learn through simulations of real-world events. For example, students can play the roles of municipal leaders during a crisis, such as a hurricane. Through these simulated experiences, students can gain insight into real-world problems, and thereby become better prepared and more active citizens in their communities.



## INTELLIGENT SIMULATED ENTITIES

One of the interesting technologies that is under development as part of the military's DIS effort is intelligent simulated entities. Intelligent simulated entities are computer generated behavioral representations based on expert system technology. In the military setting, the behavioral representations are designed to act like real people or objects so that these simulated people can replace real people in large scale simulated events. For example, the opposing force may be completely computer generated, yet each entity of that opposing force would act and respond as if it were operated by a human. This permits large-scale events to be experienced and practiced when there are only a limited number of human participants. This technology provides the capability to experience large-scale events at a relatively low cost.

The evolving technology of intelligent simulated entities has several potential applications within the educational simulation environment. Intelligent simulated entities can be directly used in support of the simulation-based collaborative learning environments described earlier. Just as in a military exercise, students learning in a simulated community situation need intelligent simulated entities to represent the people of the community and provide a realistic event simulation.

In addition, intelligent simulated entities offer a unique potential to the study of history. Instead of reading about history and looking at static maps, pictures, etc., one could watch a historic event unfold in a dynamic simulation. For example, students could watch a recreation of the battle of Gettysburg. Perhaps more importantly, when combined with DIS technology, students could watch the battle unfold from any perspective, and even change conditions to see what might have happened. The military is developing this technology, but it has applications to historical events other than battles. While this technology still requires significant advances, the long-term possibilities offer an exciting potential to education.

## INTELLIGENT SIMULATORS

For references on intelligent simulation, National Aeronautics and Space Administration (NASA) holds an annual conference on Intelligent Computer Aided Training (ICAT) at the Johnson Space Center in Houston, Texas. The presentations during these conferences have been published as Proceedings (e.g., *Proceedings of the Contributed Sessions, 1992 Conference on Intelligent Computer-Aided Training*). Many of these papers address the issue of intelligent simulations being used in education and training.

## VIRTUAL REALITY

Finally, a rapidly advancing technology that will undoubtedly have a major impact on education is the virtual environment (VE). A VE is a multi-sensory, shareable, real-time graphical computer simulation which immerses the user in a three-dimensional geometric space. A VE requires three aspects to be effective: *autonomy*, *interaction*, and *presence*. A simulation with *autonomy* has components that possess behaviors (e.g., water flows, objects fall). *Interaction* basically means that the user can manipulate what happens. Objects may be touched, grasped, moved, and so forth. Finally, *presence* implies that the users believe that they are



actually immersed in a real place, and that they can move and look around freely. The greater the extent that each of these components is present, the more realistic the virtual environment appears to be. VE builders will cause the creation of the most intense and involving simulations ever imagined.

At present, realistic computer games including SimCity, SimEarth, and various adventure games are very popular. They are two-dimensional, but are still highly involving for students and they call for creativity, thought, and problem-solving. In 1995, Nintendo plans on introducing three-dimensional educational software. The Massachusetts Institute of Technology (MIT) received \$2 million from Nintendo to study educational applications. When this software becomes available, it may be the first real challenge to television. By 1997, VE educational applications should be fairly common. However, high bandwidth networking will be required.

Virtual environments were introduced in the 1980s with the multimillion dollar flight simulators of the military and airlines. Today, virtual worlds can be created for around \$50,000, which allows colleges and technical users to have access to them. By the end of this decade, three-dimensional interfaces should cost less than \$1,000, which means they have the potential to become universal information tools. Eventually, VE may be a critical component of the information and educational systems. It can act as an operating system or interface, offering the user presence in other environments, interaction with them, and autonomous behaviors and simulations, as needed.

What one might see in an educational setting, for example, is a student workspace. It could be a cubicle, a table, or simply a location where the learner can plug his or her personal computing device and accessories into the network. The accessories would likely include small video display glasses that would look much like sunglasses (presently these would be eyephones or helmet-mounted displays). Also included would be ultralight (Walkman-like) earphones, a microphone, a video camera directed at the learner, a pointing device, sensored-glove(s), and a keyboard. All major educational activities could be performed with the use of these devices. For example, teleconferences with instructors, classes, and meetings with friends could all take place, in which each person appears to be in the same room with another. Communication would be direct through spoken word. Similarly, accessing specially designed knowledge bases would allow a visual immersion into some scenes.

The virtual environment has the potential to allow the instructor to present information in a manner which is compatible with a learner's preference or need in terms of learning style, physical needs, or task requirements (Bricken, 1991). Interactivity options can be selected to match the learner's performance. Bricken (1991) further comments, "Virtual reality offers teachers and students unique experiences that are consistent with successful instructional strategies: hands-on learning, group projects and discussions, field trips, simulations, and concept visualization. Within the limits of system functionality, we can create anything imaginable and then become part of it. The virtual reality learning environment is experiential and intuitive; it is shared information context that offers unique interactivity and can be configured for individual learning and performance styles" (p. 24).



In a virtual environment, the learner has the advantage of providing a spatial orientation toward problems. This can be beneficial in a problem solving capacity. Jacobson (1993) discussed this advantage of virtual reality and pointed out that virtual reality allows us to look at data in space in detail. We can obtain a visual image of each element and the spatial orientation of each element as opposed to being presented with data in numeric or written form. With this technology, the learner can examine different perspectives and spatial relationships between elements.

Furthermore, the learner can also be provided with an environment in which he or she can practice motor skills which may be difficult or expensive to create in the real world. Because the scenario is computer-driven, precise data can be collected regarding the learner's performance in the virtual environment. VEs can also be used as a powerful tool for nontraditional learners with physical disabilities, and for those undergoing rehabilitation of psychomotor skills.

Some examples currently exist of this powerful technology in use. Researchers at the University of Houston and NASA's Johnson Space Center have created an experiential learning environment called the Virtual Physics laboratory. In this virtual environment, students can change the force of gravity and observe the effects on objects and their behavior. In another application, the JASON Project (EDS, 1991) allows telepresence field trips by allowing students to become hands-on participants in oceanic scientific exploration by transporting them via satellite to remote sites. Students are able to see the exploration through three large video monitors. JASON Jr. is a 200-pound remotely operated vehicle used to explore thousands of feet underwater. Through this environment, students can interact with scientists and exchange questions and answers collectively.

In order for virtual environments to be used effectively in educational scenarios, researchers must determine how this technology can utilize instructional strategies and techniques. Bricken (1991) suggested that VE can even be used to study the process of learning itself. Educators can guide the growth of this technology by participating in its development, thus influencing its impact on education (McClellan, 1994).

### **A MULTIMEDIA-BASED SIMULATION EXAMPLE**

A sample simulation will now be described. It incorporates the technologies just described, although the VE is presented on standard two-dimensional computer displays rather than through a three-dimensional display system. This approach is taken solely because of cost.

In the near future, learners may be able to participate in a cooperative learning activity involving a crisis simulation that demonstrates the exit criteria. This example simulation would enable a learner to integrate and apply knowledge in the area of social studies (i.e., current events, political science) and assist in the development of specific skill areas. Students would solve problems related to a real-world crisis situation in government, research possible solutions, collaborate in decision-making teams and implement a solution based on new knowledge. In this context, learners would achieve curricular objectives by demonstrating this idea in the form of a multimedia presentation at the end of the learning activity.



This crisis simulation was designed with a particular example in mind; however, it may be changed to represent any current event or crisis situation utilizing the same skill areas and knowledge applications.

### Part One: Crisis Simulation

You are a member of the President's Cabinet. A crisis concerning the issue of sovereignty for the Panama Canal has occurred and you and your team members must decide what the United States' role in the crisis will be. Your team must also decide how to handle the situation.

Although American control of the canal and the Canal Zone was guaranteed by treaty, the early 1980s had been marked by growing agitation within Panama for change. The Panamanian government, headed by General Jose Canugi, was essentially pro-western but very nationalistic. Canugi's government had also been very cooperative although they had some demands which needed to be addressed. Specifically, they demanded the canal treaty be revised so that the canal would be fully turned over to Panamanian ownership no later than January 30, 2000.

This had not been a problem for the past eight years. Peaceful talks had occurred, although no promises had been made. However, this morning, you and your team members received news of a successful coup (takeover) by the Anti-American Take the Canal Back revolutionary forces who were demanding that America revise the treaty and release control of the canal to Panama.

You and your team members must come up with a solution. First, based on what you already know, identify pros and cons of possible actions and look at the consequences of each. Second, prepare a report describing your decision and the rationale for your decision. You will present this decision to the President and other members of his staff (role players) who will ask you questions about your decision. (HINT: pay close attention to the questions asked).

*Note to instructors: This part will not actually be assessed. It is a pretest on how much the student already knows. It will also set up a cognitive framework for part two and indicate to the students what to look for in the next part. Please take notes on the behaviors exhibited by students. Keep in mind the overall objectives and the exit objectives associated with the assignment.*

### Part Two: Assessment

Using the information you already have, you will contact an expert in Panama using the network to obtain more information. You may also refer to any reference materials. Also, please obtain historical information about the country and information about how past presidents have handled similar situations. After you have obtained more information, meet with your team to discuss what you would do differently. Write a presentation outline on this information, including the pros and cons of possible actions, consequences, and rationale. Finally, you will present your decision using the new information, and based on the questions asked in part one.



*Note to instructors: In order to assess what has been learned, you will need to take careful notes on behaviors exhibited. Keep in mind the overall objective and the exit criteria associated with this assignment. Students will be assessed on the basis of performance on this objective only. After the presentation, you should compare the notes of the pretest to this second part, noting any improvements.*

As the example demonstrates, the use of simulation is compatible with a performance-based curriculum. Further, electronic system capabilities, such as networking to an expert, having multiple users networked for role-playing, and having access to a general knowledge base, enhance the effectiveness of simulation by making it more informative and realistic.

### SIMULATION RECOMMENDATIONS

Current research in cognitive psychology provides compelling reasons to engage our learners in meaningful, authentic activities, including simulations. A primary recommendation is that future efforts should investigate existing simulations and see how they can be incorporated into an integrated curriculum. One of the weakest components of existing simulations is the instructional overlay or learning support for the user. Most learning is now only weakly supported, and additional materials will have to be developed to help instructors and learners benefit from simulations.

Another important issue is computer equity. Learning activities and simulations, whether for individual or cooperative situations, must be designed that appeal to both girls and boys, and all students must have an equal opportunity to participate. Moreover, these activities must be designed to present the points of view of students possessing different cultural backgrounds, or at least so that they do not offend any groups. For example, the "Oregon Trail" simulation developed by MECC was changed at one point to eliminate the goal of shooting Indians.

There is no doubt that simulation will be used in some form to support future educational curricula. The extent to which it will be used, however, requires much careful thought and planning. One possible approach to assist staff in making these decisions is to create a simulation prototype; that is, to formulate a trial implementation whereby a learning site is designated to test the simulation as well as evaluate the entire implementation process. The first step will be to create and evaluate a simulation prototype plan that includes an estimate of the resources necessary, a designated curriculum where the simulation will be infused, the instructional design and software development requirements for the simulation, instructor training, cost/benefit analysis, etc. This plan will provide management with an estimate of the time and effort required to complete the simulation development and implementation process. The evaluation should provide hard facts concerning the scope and potential benefits of the simulation, and a positive evaluation would serve to justify additional funding to actually develop a working simulation prototype at the selected learning site.

The next section provides a general discussion of the application of simulation . It will center on the following points:

- Type of Simulations
- Commercial vs. Custom Simulations
- Content Areas
- Co-Developers
- Software Evaluation
- Impact on a computer-based educational system

### TYPE OF SIMULATION

As discussed earlier, two dimensions that can be used to categorize simulations are content versus criterion-oriented and stand-alone versus group. Table 1 summarizes the recommended simulation emphasis for future efforts based on goals, objectives, and current technology trends. These recommendations also take into account the current educational software development trend. It is recommended that the management team of a future educational initiative take a leadership role in fostering and sponsoring required simulation development in those areas which the educational software industry is not actively pursuing.

The highest priority simulation development is in the area of collaborative, criterion-oriented simulations. While considerable effort is being invested in the development of criterion-based curricula, little research and development is ongoing in the technologies required to support this type of curriculum. Facilitation of the development of this class of simulation should provide the greatest support and benefits for future initiatives.

**Table 1.** Recommended simulation emphasis, from highest priority (1) to lowest priority (5).

| <u>Recommended Simulation Priorities</u> |                     |                     |
|--|---------------------|---------------------|
|  | Content<br>Oriented | Outcome<br>Oriented |
| Stand-alone                              | 3 - long-term       | 2                   |
|  | 5 - short-term      |                     |
| Group                                    | 4                   | 1                   |



The second highest priority should be placed on individual, criterion-oriented simulations. Criterion-based learning principles will be a future effort's distinguishing characteristics. The development of any type of criterion-oriented simulation is necessary to ensure effective accomplishment of program goals. The importance of support in the development of criterion-oriented simulations is critical because the educational software industry is not currently focusing on this area.

The third highest priority class of simulations is content oriented stand-alone (individual simulations). A wide variety of high quality software is emerging to meet this need. However, future efforts must place a priority on this class of software for the long-term in order to stimulate the development of simulations which incorporate more advanced technology such as virtual reality.

The lowest priority development emphasis would be in the area of group content-oriented simulations. These will essentially be multi-user versions of stand-alone packages which will require little specialized development.

## **COMMERCIAL VS. CUSTOM SIMULATIONS**

Cost and development time will impede efforts to develop all of the simulations necessary to support future educational curricula, instruction, and assessment needs. The priorities presented above provide recommendations on where the future programs should invest their efforts, and hence, provide guidance on the mixture of commercial and custom simulations.

### **Custom Simulation Development**

#### Content Area

The simulations to be used should be as broad in scope as possible to fulfill the requirement of curriculum design that there be as much overlap as possible between content areas. Therefore, simulations which include instruction on more than one topic should be given priority over those that concentrate strictly on one area.

Simulations currently on the market tend to concentrate on the areas of mathematics and science. The reason for this concentration is most likely that they are the easiest to develop, because they have the clearest mathematical models and algorithms. Recent educational reports indicating that students in the United States have sub-standard mathematics and science knowledge when compared to students in other countries may also be a factor. It is unlikely that future programs will have to develop their own simulations for these subjects due to the abundance of mathematics and science simulation software currently available. Rather, they should concentrate on developing simulations which support other subject areas. This focus will hold for all classes of simulations, including group, performance-oriented simulations, when industry begins to address this need. In addition to mathematics and science curriculum, simulations should concentrate on the following areas: history, civics, social science, geography,



foreign language, and vocational skills. These subject areas are equally important in performance-based learning environments.

Because all students in performance-based programs "will acquire the foundational skills and competencies needed to succeed in adult life assessments" in an information age (SYNERGY 2000, 1992), core academic subjects should be studied in addition to vocational subjects such as computer skills, drafting, home management, and mechanics.

### Co-Developers

Given the total scope of simulations that could be developed to support future initiatives, it is expected that agreements will be pursued with a number of co-developers. A broad spectrum of companies is currently involved in the development of educational software. These companies range in size from small business firms to major vendors, such as IBM and Jostens. A number of trade-offs must be considered in selecting co-developers. Large companies have more resources to contribute to co-development efforts, but they tend to be rather conservative in their developments. In addition, they generally have a large integrated line of software products, so they are sometimes less willing to undertake new development directions. Since it is expected that much of a simulation co-development will focus on new collaborative, performance-oriented simulations, large companies may not be an optimal co-development choice, although they should be consulted. Large companies will be well suited where co-development efforts focus on more conventional content-oriented simulations.

Smaller software development companies tend to be more aggressive and tend to establish newer trends. They survive by developing new ideas. Hence, they may be much better co-development partners for the class of simulations recommended for development in this paper. Very small companies do not have sufficient resources, but there are a number of medium-sized companies with a track record of marketing high quality innovative software. Strong consideration should be given to these types of companies as potential simulation co-development partners. Two companies which have consistently demonstrated their capabilities are MECC and Davidson. These companies will need to develop new capabilities to meet the requirements; however, this will be true of any firm.

In many cases, co-development efforts may require a group of companies, and may also include universities as part of the development team to provide the total ensemble of skills necessary to develop advanced simulation software for educational environments. The required technology necessary to develop effective simulation environments is only now emerging. Hence, at least in the short-term, it is expected that co-development teams will be the more effective solution.

### **Criterion Oriented Simulation Test Case - Hurricane Awareness**

As previously noted, the development of criterion-oriented simulations represents a new direction in educational simulations. This is especially true when they are embedded in a collaborative learning environment. Since this class of simulation represents a new technology direction, guidelines do not exist for their development. However, a future effort shall pursue the



development of a selected simulation in order to aid in the development of guidelines and standards that can be applied to other simulation developments. This test case would serve as a demonstration of this instructional technology and validate its benefits in meeting program goals and objectives.

The test case simulation should:

- be criterion-oriented according to the SCANS model
- integrate a broad range of subject areas within a real-world context
- incorporate a collaborative learning environment using a peer-to-peer network
- utilize distributed interactive simulation concepts
- be expandable.

### Evaluation of Software

Regardless of whether commercial or custom simulations are chosen for use in a specific class, it is imperative that a program be thoroughly evaluated for effective instructional design and support of exit performance. Ideally, the simulations chosen should incorporate as many of the learning objectives and subjects as possible. This concept is in accordance with the integrated, systems approach. A matrix checklist of suggested attributes that simulations should possess is illustrated in Table 2 below.

**Table 2.** Suggested checklist for use when evaluating simulation attributes.

| SUBJECT<br>AREA     | ATTRIBUTES                           |               |                        |                 |                                   |                       |
|---------------------|--------------------------------------|---------------|------------------------|-----------------|-----------------------------------|-----------------------|
|                     | Effective<br>Instructional<br>Design | Exit Criteria | Integrated<br>Concepts | Real to<br>Life | Collaborative<br>or<br>Individual | Simulation<br>Quality |
| Science             |                                      |               |                        |                 |                                   |                       |
| Fine Arts           |                                      |               |                        |                 |                                   |                       |
| Math                |                                      |               |                        |                 |                                   |                       |
| Language<br>Arts    |                                      |               |                        |                 |                                   |                       |
| Foreign<br>Language |                                      |               |                        |                 |                                   |                       |
| Social<br>Studies   |                                      |               |                        |                 |                                   |                       |
| Health &<br>P.E.    |                                      |               |                        |                 |                                   |                       |
| History             |                                      |               |                        |                 |                                   |                       |

The design of this checklist allows the evaluator to use the rating method he or she most prefers. For example, a number or letter grading system can be used, or the evaluator may choose to insert his or her own comments. However, the evaluator should create a legend of some sort to indicate to other readers the type of rating scale that was used.

The categories listed in the checklist should be evaluated on the following attributes:

Effective Instructional Design

Does the simulation accomplish the following:

- Present orientation information
- Present rules, directions, and guidelines for participation
- Introduce the initial scenario
- Elicit student responses
- Present a summary
- Use embedded strategies to help students organize, process, and integrate new information (e.g., advance organizers, mnemonic techniques, and imagery strategies).

Exit Criteria

Does the simulation help students attain the following exit performance criteria:

- Self-manager
- Capable worker
- Adaptable problem-solver
- Innovative producer
- Effective communicator
- Active facilitator
- Responsible collaborator.

Integrated Concepts

This term refers to the integration of more than one topic or subject area into one simulation. If a stand-alone simulation, defined here to mean one which presents a single topic area, has a positive evaluation based on the above criteria, it should be used. However, those simulations which cover more than one subject area, and thus, display the relationships among different topics, are usually more effective than the stand-alone variety.

Real to Life

Intuitively, a simulation should be designed to represent a real world situation. As mentioned earlier, it is not essential that the fidelity or even the timing of the simulations be exactly as it is in the real world; rather, if the situation seems real to the student the real to life requirement will have been met. This concept is more applicable to the scenarios and interactions that the learners will have with the simulation than to its presentation.

Collaborative or Individual

The evaluator should decide whether the simulation requires participation of more than one student or if it is designed for individual use. Collaborative simulations are most effective for team building and training while individual simulations may afford the student the opportunity to build requisite individual skills and knowledge. Depending on the application,



both types of simulation can be effective. Ideally, the evaluator should select a simulation that has the capability of being both a collaborative and an individual instructional tool.

### Simulation Quality

This category allows the evaluator to give his or her overall impression of the simulation under evaluation.

While most of the discussion has centered around computer simulations, it should be mentioned that role-playing and other non-computer simulations can and should be used effectively within the learning sites. These types of simulations would be particularly effective for topics requiring personal interactions, management decisions, and so forth. By simulating events in real life, learners can be provided with the opportunity to see how classmates react to certain situations and then they may discuss these reactions in class. Such discussions might not be as feasible or effective when conducted via computer.

Real-life simulations should also be evaluated by the same criteria developed for computer simulations. Evaluating real-life simulations may be more difficult than computer simulations because they will be presented with some degree of variability each time. This variability must be expected in the real-life simulations because the learners may find different aspects of the simulation interesting each time. Also, the instructor acts as a facilitator who also introduces variability into the presentation method each time. An instructor can alter the presentation from one time to another based on the past performance and reaction of the learners who have experienced the simulation. Obviously, it is more difficult to accomplish this task on a computer.

## **ELECTRONIC SYSTEM IMPACT**

A computer-based educational system design will provide the learner with a gateway to a personalized learning environment that will stimulate his or her individual interests, and provide a method to work and learn cooperatively. The networking and communications infrastructure is the primary component which facilitates the use of simulation. This subsystem should include the hardware and software needed to support overall system functioning. This infrastructure includes networking and communications within learning sites, between learning sites within a district, and between districts and the outside world. It should be specified to provide a seamless and transparent environment across all levels of the network. The bandwidth of the infrastructure must be designed to permit support of any learning paradigm and material format selected by a learning site, including simulation.

To accommodate the simulation requirements, the basic design principles for the communications and networking infrastructure need to be based on:

1. an open, cooperative computing architecture (including both hardware, software, and communications protocols).



2. a basic client-server computing concept, augmented by peer-to-peer computing, as required (peer-to-peer communication should be available to and from any learning site).
3. distributed technology and network connectivity.

Client-server approaches to networking have been the recent mainstay concept. This form of computing permits the user to initiate access or transmittal of data and programs in a unilateral fashion. This approach optimizes the efficiency of an individual's tasks. It is expected that the client-server approach will be the primary networking approach for most applications within this environment.

Peer-to-peer networking will play an increasingly important role within a computer-based support system. An increasing emphasis is being placed on cooperative learning as part of the trend to introduce relevance into the learning environment. Peer-to-peer networking approaches are more appropriate to this type of application. They may exist within a classroom, between classrooms within a learning site, or between learning sites (within or between districts/states/countries).

The combination of these two approaches in the networking concept provides the mechanism to support both individual stand-alone and collaborative simulation-based learning environments.

The primary impact on the system is the need for significantly higher bandwidths to achieve the desired simulation environment. The bandwidths available over the short- and mid-term will restrict real-time simulations to the workstation and local area network level. It will be possible to download simulations from state, national and world sites on the network in non real-time, but not to run the simulations on these remote resources. Hence, the logistics of distribution of simulations to learning sites will be very important. In the long-term, high bandwidth networks should be available at acceptable cost to permit the true seamless simulation environment for remote world-wide distributed learning environments. This type of environment will eventually permit students to learn in the global environment and achieve all desired performance envisioned by designers.

While hardware bandwidth is a major impact and limitation, it is not the only limitation. The software protocols required to support high fidelity, real-time simulation in a distributed environment are very different from those encountered in today's networking environment. Currently, the predominant networking protocol is TCP/IP, the protocol defined by Internet. Internet is the primary national and global network being used by education. The Internet TCP/IP protocol, which is also being adopted widely for state network backbones, was designed essentially to handle non real-time data transfer.

Until recently, most data transmitted via networks consisted primarily of blocks of text data. As use of networking has progressed, there has been increasing demand for transfer of other types of data, such as video. The Internet TCP/IP protocol cannot adequately handle this new type of data or accommodate real-time simulation applications. It is expected that in the next five to seven years a new network that can handle the higher bandwidth and real-time



intensive applications will supplant Internet. The likely basis for this new network will be the National Science Foundation sponsored National Research and Education Network (NREN) or the National Information Infrastructure (NII) initiative.

As part of the development of a new national and global network infrastructure, new protocol standards will need to be developed or implemented. The new protocol may be a modification of TCP/IP, though this is unlikely. The more likely approach will be the development of an entirely new protocol or the implementation of open system interconnection (OSI) protocols. OSI has been under development for a number of years, though it has not been widely implemented on large-scale networks. OSI's design can accommodate high bandwidth applications, such as real-time distributed simulation, so it provides a viable option to meet the needs for long-term simulation requirements. Of special interest have been recent efforts to incorporate the DIS protocol standards into an extension of the OSI protocols. This approach could therefore support the total spectrum of simulation applications that might be developed.

Future initiatives should closely monitor, and preferably become actively involved in, the next generation of network protocol standards and architectures to ensure that the communication and networking infrastructure which emerges provides the capability to support the instructional goals established for the effort. The implementation of the long-term educational system design developed to support the learning and curriculum objectives cannot be accomplished without these new hardware and software standards.

An additional concern in the development of new networking standards is the platforms accommodated under the standard. Currently, the focus of the networking standards has been on interconnection of UNIX-based computing platforms. This type of platform encompasses what are currently considered workstations. The protocols have addressed direct interconnection of this class of platform. Individual computing devices, such as PCs and MacIntoshes, have had a lower level of interconnectivity routed through UNIX-based platforms. As the power of individual computing platforms continues to increase, the new long-term protocols will have to include all three classes of computing platforms (i.e., the protocols will need to be truly platform independent). This will permit applications to run under a variety of computing environments, and, thereby, reduce the need for platform specific applications which increase cost and reduce access.

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