

1-1-1993

The Role Of Simulation In The SY2000 Initiative

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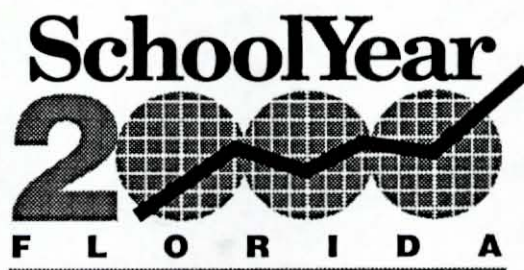
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The Role of Simulation in the SY2000 Initiative



June 30, 1993

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The Role of Simulation in the SchoolYear 2000 Initiative

INTRODUCTION

What is simulation and how can it be used to enhance the SchoolYear 2000 (SY2000) initiative? 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 to be an effective learning aid depends on the specific application. In all cases simulations should have a high degree of face validity to ensure acceptability. In learning applications, those simulations which require high content fidelity are usually very specific which provides a cost advantage. For example, a physics simulation for relative motion requires a high fidelity simulation model, but the breadth of the application is narrow, so cost is manageable. Large role playing simulations, on the other hand, can usually be implemented with only low to medium fidelity models. Hence, the nature of learning tasks permits a wide variety of cost-effective simulations. This makes simulations a viable and desirable instructional tool in SY2000.

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 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 simulation enhance memory recall of the learned information when the student is placed in the real situation. 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 in about 30 percent less time 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 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 for functional interaction by the trainer. This "device" can include written materials, pieces of equipment, visual aids, video tape, and computer software. This is in 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 are at one extreme and low fidelity training devices such as instruction manuals are at the other.

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. 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, 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 if the task is broken down into segments that are built upon one another, such as initially only controlling the aircraft's heading and altitude, rather than having to concentrate on heading, altitude, throttle, flaps, navigation, and communications.

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 education experience is not presented to occur in some specific, sequential manner. Other training devices typically present instruction in a sequential fashion. Even books usually require the reader to move from front to back. New multimedia training applications do allow the user 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. Some unrealistic features are often necessary to enhance training, such as the addition of instructional features such as 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? As previously discussed, in many educational settings, where general knowledge is more likely being learned than specific task procedures, less fidelity is acceptable and it is 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 to 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 now 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 fear of war (or losing deterrence). 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 by S. L. Pressey during this same period, in 1915 (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 advance 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 also 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). As a result of using simulators and other training devices during the war, instructors knew how valuable they were, 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 posed questions, 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 situation must be as similar to each other as possible (e.g., Hays & Singer, 1989; Thorndike, 1903, Wolfe, 1951). Due to learning theory and 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 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 been, until recently, primarily non computer based. 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 further education. In technical training, simulated "off 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 (Romiszowski, 1988).

Simulations which help students understand real world problems are becoming more common in education as well. For example, *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.

THE NEED FOR SIMULATION IN EDUCATION

Three 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 educational quality. Education must be improved to accommodate these individuals. A significant amount of money will be required to implement most aspects of the SY2000 design, including simulation. However, when looked at against the potential expenditures resulting from an uneducated society (e.g., dropouts, low-skilled workers, non-English speakers), the costs do not seem so high. Industry and the tax payers 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 will occur if some of these expenditures are reduced through improved education.

Second, as technological advances occur daily, business and industry have become much more oriented towards information processing and providing services, rather than manufacturing, with a corresponding decline in the need for unskilled laborers. Thus, the work force is requiring students to be literate and to possess basic technical skills such as word-processing and mathematics. Future jobs will be technology-based and will emphasize teamwork and competitiveness through efficiency, effectiveness, and productivity. SchoolYear 2000 can provide a technology role model to introduce students to this philosophy.

Third, technology is permeating the home environment through television, computers, and other electronic gadgets. Students now come from an environment in which information and images are presented in a vibrant, interactive manner. These individuals do not accept the traditional, non-dynamic instructional model in which a teacher lectures to the class. In some cases, students are bringing technology into the classrooms, which will force a change in education in and of itself, much the same way electronic calculators changed math and science education.

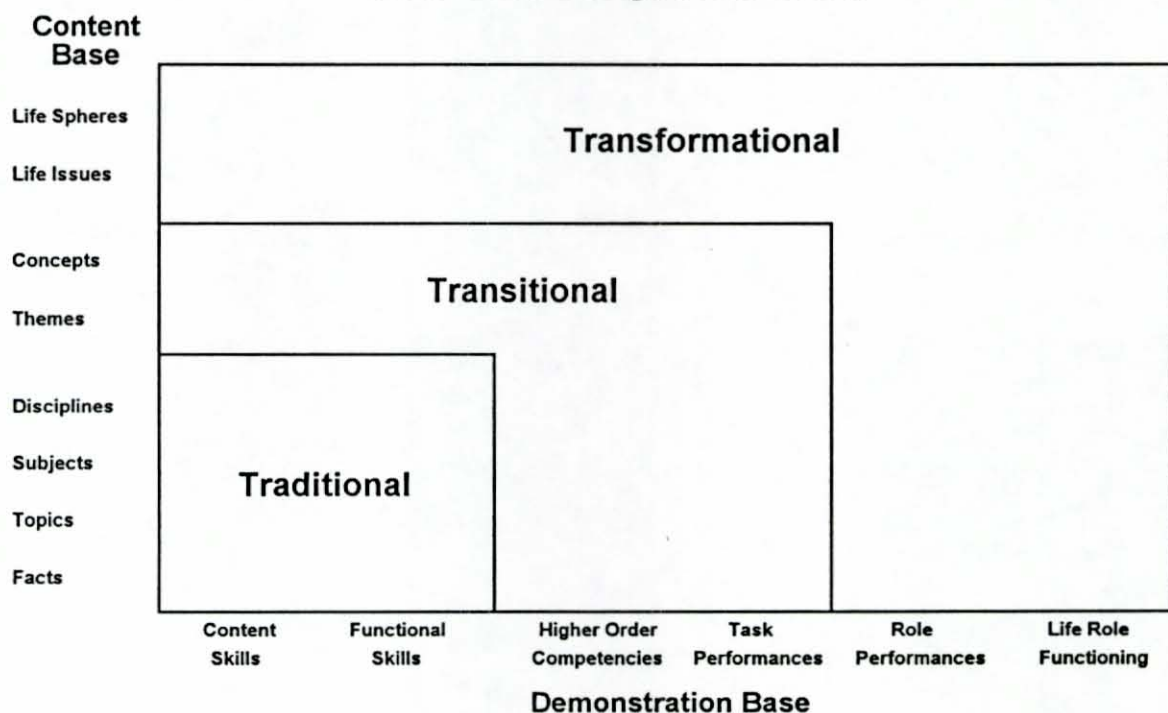
SIMULATION WITHIN SCHOOLYEAR 2000

Simulations should have a promising role in the structure and function of SchoolYear 2000. Simulation should be especially important to the SY2000 curriculum and instruction subsystems, and it should be used to train users how to operate various components and functions of the SY2000 Electronic System. The SY2000 curriculum consists of mission-driven outcomes 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 and need for simulation in SY2000 are derived from overall SY2000 goals and approaches. The two primary influences are the SY2000 emphasis on outcome based education and the SCANS report. Both of these influences have the need to inject relevancy into all phases of the learning environment. Simulation technology is well suited to this task.

Outcome based education emphasizes the design and organization of all curriculum and instructional planning, teaching, assessing, and advancement of students around their successful learning experiences. A primary emphasis is on real world experience, interacting with others in a cooperative learning environment. Outcome based education supports the use of simulations by providing an environment that will assist in the acquisition of skills that meet enabling objectives by using a set of "authentic tasks." The authentic tasks produce tangible results and successful outcomes. Outcomes can be interchangeable and the use of simulation enhances the learning process by providing a context in which to demonstrate these outcomes. The cooperative learning environments and context based real life experiences required by outcome based education can only be efficiently and cost effectively accomplished for all students through the use of simulation technology.

Outcome Based Curriculum Design Framework



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 (e.g. interpersonal and information competencies), parallel the objectives of outcome based education. 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 is an effective instructional tool for this class of problems. Simulation technology is an approach through which all students can adequately and cost effectively be provided with these learning experiences. The resources to provide these experiences to all students by other means is 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 tool for instructors in that it will enable them to determine if a student has mastered certain objectives which could not be found through traditional forms of assessment. Thus, 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 of SY2000.

The use of simulation within SY2000 could lead to a wide variety of innovative instructional applications such as:

- Students conducting chemistry, biology and physics experiments through interactive simulations.
- Students reliving battles in history via computer simulations using intelligent simulated entities.
- Students developing and testing concepts for the exploration of Mars using a distributed interactive simulation (DIS) network.
- Students learning about hurricane awareness and its impact on Florida communities, the economy, and the environment.

Summary of Benefits

- **Educational environment that reflects the future work environment**
- **More students can be handled with available resources**
- **Students receive a more consistent educational experience**
- **Diversity can be easily accommodated**
- **Advanced instructional material and resources can be made available to all students**
- **Curricula which reflect relevance**
- **Long term cost-effectiveness**

PRAGMATIC BENEFITS SPECIFIC TO SY2000

Several benefits of simulation are more pragmatic than pedagogical. For instance, simulations are generally used because they are less expensive, less dangerous, or are more readily available than training with actual equipment as previously mentioned. Within the SY2000 scheme, a single standardized simulation may be developed or procured and then transferred to each participating school. While the initial cost of the simulation may be expensive, when it is divided by the number of students receiving the benefit, the result is extremely cost effective. This approach provides standardized instruction and presumably lower costs since one simulation can be developed rather than many. Off-the-shelf simulations may be used if they are determined to be adequate for the SY2000 outcome based approach.

The use of simulations for conducting experiments in science classes is a prime example of the cost benefits of simulation. Science projects in chemistry and biology can require considerable expendable resources (e.g., chemicals, animals, equipment, etc.). These consumable resources can represent a significant budget expenditure for these types of classes. In addition, these expenditures are repeated year after year. While they cannot be used to replace all necessary experiments, simulations 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, hazard 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 are extremely inexpensive. Hence, more students across the state can participate in these hands-on learning experiences. The socio-economic status of a school district is no longer a limiting factor in providing students with this 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. SY2000 simulations can provide learners with valuable practice on realistic, work-related activities. This practical experience will be invaluable when learners enter the work force.

Moreover, by using simulations and other electronic instructional tools through the SY2000 Learning Support System (LSS), more students can be handled by the instructors and with the available resources. This system will allow teachers to become facilitators, freeing up time to provide assistance to learners who need it, and allowing other students to work at their own pace.

Using standardized instructional approaches and software, including simulations, will foster cohesiveness within and across the SY2000 membership (i.e.,

learning sites). This arrangement should improve communications and information management throughout the system, and hence, provide a cost-effective educational experience into the 21st century. The use of simulation as an instructional tool in SY2000 can provide parity and consistency in the educational opportunities for students in all school districts across the state of Florida. In addition, the flexibility of simulations can also be used as an effective method to achieve parity across the diverse student population represented within the state. Diversity based on physical challenges, ethnic heritage, etc., can be effectively addressed through the proper design of simulation based instructional technology.

PEDAGOGICAL BENEFITS

There are many pedagogical benefits associated with the use of simulations within SY2000. One important 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 have had limited contact with the world outside of their own neighborhoods. Wisely selected and developed simulations can bring the world into these kids' hands.

Second, the entire SY2000 curricula will 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 SY2000 learning sites will have access to the same education. Thus, advanced materials will be made available to more students. Along a similar vein, students who require diverse instructional materials can obtain them, regardless of their location.

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 teaching and spend less time concerned with administration of discipline.

Also, simulations can be developed to act as stand alone training devices or they can foster cooperative learning. In a networked environment such as that proposed in SY2000, learners can interact with the same simulations simultaneously. In this approach, learners would be required to work cooperatively to meet the required

learning outcomes. Simulations provide a learning environment that is standardized and unbiased. Student learning and assessment can occur objectively in a setting in which the background of the learner is irrelevant. Simulations that require cooperative learning to solve a specified problem may also be helpful in reducing racial intolerance, by requiring cooperation and interdependence among learners of different cultural background, by requiring the participants to have equal social status during the simulation, by producing a positive outcome for the group, and by requiring that the participants from different backgrounds get to know one another and be seen as typical members of their cultural group and not exceptions (Bernstein, et al., 1991).

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 applies to using simulations to teaching users to operate components of the SY2000 Electronic System.

Lastly, 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 a discovery approach to learning. They can encourage 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 will help learners become creative thinkers who address challenges and problems in new ways.

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 will 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 can relate the components of the problem in a meaningful manner (Greeno, 1978). A study on the solving of physics problems by both experts and novices illustrated that the difference between the two groups is 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 "data base" of rules (Holland et al., 1986). This data 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 provide a qualitative perspective to the information being presented.

Finally, if a cooperative learning approach is used for working with some simulations, then learners can become responsible collaborators can be achieved. 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.

CONSTRAINTS

Several constraints will have to be handled before incorporating simulations into SY2000. The primary constraint is cost. Developing and implementing simulations for SY2000 will likely be very expensive. One factor that will help is that if SY2000 is truly networked as proposed, then only one set of simulations needs to be developed. This set can then be delivered to each learning site on the network.

To develop simulations for the entire SY2000 system will require significant planning and a wise implementation strategy. A needs analysis should be conducted to determine what types of simulations are needed to meet the curriculum, instruction, and assessment goals of SY2000. Off-the-shelf simulation packages should be investigated as well, but it is doubtful that many will meet the SY2000 outcome based requirements. Current off-the-shelf simulation software will be more appropriate as instructional aids in specific subject matter areas. 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? Political and regional conflicts may be encountered on the issue of simulation.

A fundamental constraint on the effective use of simulation within the SY2000 initiative is the need for hardware and software standards. These standards are needed not only on a statewide basis, but are also required 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, not simply choose one platform over another. Current hardware and software for computing and networking will be adequate for the short term needs, but they can not meet the requirements for the future.

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 of SY2000.

The second concern is in the bandwidth of the network. Current network bandwidth is design 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 which are utilizing the network is increasing dramatically. Given that the network is the cornerstone of the SY2000 electronic system design, bandwidth will be a limiting factor on successfully implementing SY2000 learning objectives.

The third networking concern is software protocols. Current Transmission Control Protocol/Internet Protocols (TCP/IP) protocols can not support distributed simulation environments. The restriction to host simulations at local workstations or local area network (LAN) levels restricts the potential benefits of simulation in SY2000. 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 DIS. 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 by SY2000 is the computer platform(s) for the learning environment. In this area the standard should not be hardware oriented, it should focus on open software operating systems. Too often the debate pits IBM 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 for the Windows and MacIntosh environments are indistinguishable and provide total file transportability between platforms. This represents the model for future hardware/software standards.

The state must take the lead in defining new hardware and software standards for its educational computing environments. Industry standards have always tended to favor the strongest competitor. This is not compatible with the goals of the SY2000 initiative. An open computing environment is necessary to implement SY2000 simulation based learning environments cost effectively.

SIMULATION TECHNOLOGIES

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. Medin (1990) describes several of the resulting new instructional approaches which will ease the transition of education into an outcome based approach:

- intelligent tutoring systems that provide the knowledge of an expert 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);
- integrated tools and electronic performance support that will allow learners and instructors to easily handle routine tasks, thus enabling them to focus on more complicated problems;
- new assessment techniques that will allow instructors to track learning, diagnose learner understanding, correct deficiencies, and evaluate attainment of learning outcomes;
- authoring tools to help instructors 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 addressed below.

ANIMATIONS AND SIMULATIONS

Interactive, dynamic animation and simulation technology can greatly enhance the discovery learning process. The LSS shall have instructional activities utilizing these techniques. 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, the learners can access the 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. 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 to provide 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 (Malone, 1980) in which the learner is challenged to achieve those goals. 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 will 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 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 motivational appeal of computer games has drawn much interest in instructional environments (e.g., Malone, 1980; Malone and Lepper, 1987). The premise behind most of this research has been that if students are intrinsically motivated to learn, then they are likely to spend more time and effort learning it. Many students entering schools today have grown up with video games, MTV, and so forth. With this in mind, 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.

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 by those 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 the 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 and SY2000. 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 relevance 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 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 involve 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 DIS is that the simulations can be run on hardware manufactured by different vendors.

COLLABORATIVE LEARNING

One of the emerging technologies for education is collaborative learning environments. Collaborative learning environments are simply 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, forming hypotheses, gathering and analyzing data, and formulating solutions. This is the basis for teaching students how to access and utilize data from remote locations and how to work in a group or team environments.

Computer Supported Intentional Learning Environments (CSILE) is an example of a current computer based collaborative learning environment (Scardamalia and Bereiter, 1993). This approach to collaborative learning focuses on group knowledge base development. CSILE is a software package that incorporates a multiuser database, 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. Its shortcoming is that it is limited only to data base development.

The newest approaches to the implementation of collaborative learning environments are being facilitated by a new networking architecture, peer-to-peer networks. While current collaborative learning environments currently still focus on data utilization, the logical next step is to provide access to and interaction with simulations within the 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 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. IST has been funded by the Army Simulation, Training and Instrumentation Command (STRICOM) and the Defense Advanced Research Projects Agency (DARPA) to develop standards for the interoperability of defense simulations.

Obviously, SchoolYear 2000 is not interested in military simulations. However, advances in this area are likely to strongly impact the overall networking structure of SchoolYear 2000, and specifically, the ability to conduct networked educational simulations and distance learning. This type of networked learning environment

provides an effective basis for teaching group problem solving skills and team work. 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 even world. 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 community.

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, in a military setting the opposing force may be completely computer generated, yet each entity of that opposing force would act and respond as if it were a real person. This permits large scale events to be practiced or experience when there are only a limited number of real 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. Imagine rather than reading about history watching history unfold in a dynamic simulation. For example, students could watch the battle of Gettysburg being recreated. Furthermore, when combined with DIS technology, students could watch the battle unfold from any perspective, and even change conditions to see what might have happened. While this technology still requires significant advancements, the long-term possibilities offer an exciting potential to education.

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 change what happens. Objects may be touched, grasped, moved, and so forth. Finally, presence implies that the user believes that he or she is actually immersed in a real place, and that one 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. In 1997, VE educational applications should be fairly common. However, high bandwidth networking will be required.

Virtual Environments really go back only to the 1980s with the million dollar flight simulators of the military and airlines. In the early 1990s, virtual worlds can be created for \$50 thousand or more, which allows colleges and technical users to have access to them. In the late 1990s, three-dimensional interfaces should cost less than \$1,000 and the possibility is there for them 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. This scheme jells nicely with the SY2000 Electronic Performance Support Sysytem (EPSS), only at a much more sophisticated level.

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 accomplished 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 databases would allow a visual immersion into some scenes.

A sample simulation for SY2000 will now be described. It incorporates the technologies just described, although the VE is presented on standard two-dimensional computer displays rather than through three-dimensional eyeglasses. This approach is taken solely because of cost.

Learners could be required to participate in a cooperative learning activity involving a crisis simulation that demonstrates the exit outcomes. This example simulation will 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 will 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 will achieve curricular objectives or outcomes 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 until 1989, 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 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 outcomes associated with the assignment.

Part two: Assessment

Using the information you already have, you will contact an expert in Panama on your network or a different network to obtain more information. You may also refer to any reference materials (resources/tools). 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 outcomes associated with this assignment. Students will be assessed on the basis of this objective and outcome only. After the presentation, you should compare the notes of the pre-test to this second part, noting any improvements.

As the example demonstrates, the use of simulation is compatible with SY2000 concepts. Further, the SY2000 EPSS capabilities, such as networking to an expert, having multiple users networked for role-playing, and having access to a general knowledge database, enhance the effectiveness of simulation by making it more informative and realistic.

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 standalone simulations versus group simulations. Each of these distinctions are discussed below.

CONTENT ORIENTED SIMULATIONS VERSUS OUTCOME ORIENTED SIMULATIONS

One of the major distinctions that can be used to classify educational simulations is based on focus. Most current simulations are 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 to SY2000, it is only loosely coupled to the driving learning objectives embodied in outcome based education and SCANS.

The other class of simulations can be envisioned as outcome oriented simulations. This type of simulation 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 multisubject 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 examples of this class of simulation. This type of simulation is closely coupled to the SY2000 learning objectives embodied in outcome based education and SCANS.

Outcome oriented simulations are the primary type of simulation needed to support the objectives of the SY2000 initiative. 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. Outcome 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. SY2000 needs to focus on stimulating the development of outcome based simulations to achieve its goals. In general, content oriented simulations will continue to be developed on their own merit. SY2000, however, may want to facilitate the development of content oriented simulations which incorporate more advanced technology concepts, such as virtual reality, because of their potential cost impact.

STANDALONE SIMULATIONS VERSUS GROUP SIMULATIONS

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 current simulations are designed for the single user. This reflects the drill and practice instructional strategy and individual learning environments which are currently the mainstream. The future, however, is in cooperative simulations. This type of simulation supports the critical objectives of outcome based education and SCANS. Real life experiences can only effectively be provided to students in group settings. As mentioned earlier, the learning group may be geographically distributed. The educational software industry is primarily focused on standalone simulations. Only a few group learning environments appear to be under development. Facilitation of technology development in this area is critical to SY2000.

WHEN TO USE SIMULATIONS

While there is much research regarding 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. 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-instruction use of simulations, when simulations are used after formal instruction, 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. The objectives of the SchoolYear 2000 initiative are very clear, and thus, the role to be played by simulations is quite specific. Simulations chosen for the SY2000 initiative should possess, at a minimum, the following attributes:

1. The simulation should be interactive.
2. The simulation should be motivational.

3. The simulation should be inherently easy to use.
4. The simulation should support one or more of the SCANS competencies.
5. The simulation should support outcome based criteria.

Simulations as Instructional Tools

While the list of commercially produced simulations grows at a steady pace, it is suggested that a panel of curriculum experts be formed to evaluate the instructional effectiveness and application for SY2000 learning outcomes of these commercially produced packages. While commercially produced simulations (i.e. games, animated programs and simulated environments) may be effective for some applications, there is much to be said for custom packages. With present authoring system capabilities, it would be relatively simple for a teacher or designer to create a simulation designed to support the learning outcomes of SY2000.

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 have to have the knowledge to function in other environments. The students of today will have to work as members of teams and communicate with people from other countries. 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. The students of today must learn how to work with others and to contribute as a productive member of a team. Computerized simulations provide the perfect forum for practicing team activities, especially with presently increasing networking capabilities available to the schools.

Over the past several years, IST has conducted research on the design and development of simulations for education and training. These programs include: Ecological Awareness for Young Adults, ExploreNet, Laser Safety, and Electro Adventure. Short descriptions of these programs are provided here to illustrate the types of educational simulation programs that can be developed to support the learning objectives of the SY2000 initiative. These simulations incorporate many common simulation strategies such as gaming and learner control. To date, these programs have produced positive results for their intended audiences.

Ecological Awareness for Young Adults

Ecological Awareness for Young Adults is designed to increase motivation for learning ecology and biology principles, and to foster a concern for the environment among school age children. A series of text and animations that explain basic ecology and biology concepts to junior high school students. The program was developed on a Macintosh II computer using MacroMind™ Director. When using this program, the student is presented with a menu of options and has the ability to choose any of the program's animations or the simulation. The animations consist of: Food Webs, Chemical Cycles, Biomes, Pollution, and Clean-up Methods. Each category consists of one or more animations and descriptive text to explain the concept. In some cases, the student can click the cursor on parts of the animation to receive information on that component via hypertext links. A content test pertaining to each of the animation topics is presented when the student has completed that topic. Instructors can also use the animations as a teaching tool. This program was originally developed for the Center for Advanced Technologies at Lakewood High School with funds from the Florida High Technology and Industry Council.

ExploreNet

An already can be used is "ExploreNet" is an example of a collaborative learning networked distributed simulation. "ExploreNet" provides a situation in which several students must cooperate with each other to learn mathematics concepts. This system also employs an adventure game format and a rudimentary virtual environment. However, unlike most computer games, ExploreNet requires the students to cooperate with one another to succeed. Thus, it requires multiple computers networked together. The learner at each computer chooses a character and proceeds into the simulated world. When students are in the same scene, they see the same perspective and each other, and they can communicate with each other by sending messages. The goal of ExploreNet is to teach math skills and cooperation through a motivating, interactive interface. This system employs color graphics, animation, scenarios, networking, and a virtual environment.

The simulation, which incorporates some gaming, takes place on the fictional deserted island of "Caruba." The object of the simulation is for the student to get his or her character off of the deserted island with the help of another player. The player sees both his or her character and that of the other player. In order to accomplish the various tasks required to get off of the island, the players must work together to get food and solve the problems that stand in their way. For example, there is a river which the players must cross. They are given certain pieces of information about the river such as speed of the current and danger zones. Based on the information given, the players must decide where to enter the river in order to reach a specified point on the other side. In another instance, the players are told that to continue, they will have to get something to eat. There is a coconut that can be shaken down from a tree, but two players must shake the tree to get the coconut. The players have message boxes that

can be used to send and receive information from the other player. In a situation such as this, the players would perhaps suggest to each other that they both shake the tree.

Simulations such as ExploreNet provide an excellent environment for collaborative learning. The users of a program like this could be in the same classroom or school, in homes, or theoretically, in different countries. Networked simulations increase the potential number of students who can benefit from this application of the technology. This type of simulation also provides the perfect forum for expanding the technology to include evolving strategies for education such as virtual environments. For example, through the use of virtual reality, the user would be able to feel as though he or she was actually on the island of Caruba. He or she could see many other users and could interact with the environment.

Laser Safety

IST developed a simulation to visually represent the concept of eye safety when dealing with lasers. The simulation was developed with funding from the Florida High Technology and Industry Council with the safety training of the Laser Institute of America in mind. The simulation shows a cross section of the human eye, a laser, the parameters of the laser (i.e., wavelength, power, and duration), and a goggle. The simulation also allows the user to manipulate the optical density of the goggle.

The simulation is designed to display the concept of maximum permissible exposure (MPE). There are several common laser types that have been "hard wired" into the program. When these are selected, the variables of the laser are automatically set. The user only has to adjust the power and duration of the laser and click the start button. The simulation will show the effect of that particular laser on the eye. Currently, the simulation shows whether the damage incurred was to the cornea or the retina. In addition to the laser types that are programmed into the simulation, the user can manipulate the wavelength to create the type of laser desired.

The user has the opportunity to look up the appropriate optical density for a given laser by choosing the Laser Status option. Among other information, this menu displays the exact optical density required to prevent eye damage from a particular laser. It is expected that the Laser Institute of America will implement this simulation as part of their safety training course.

Electro Adventure

An example of an instructional computer game is "Electro Adventure." "Electro Adventure" is a computer-based adventure game being developed under a U. S. Navy contract to augment present basic electronics training. Electro Adventure was developed in response to the Navy's complaint that approximately 20% of students were failing a basic electronics course at the Aviation "A" School in Millington, Tennessee due to a lack of motivation. A Skill Enhancement Program (SEP) working group was formed to decide how to decrease this failure rate. It was decided that an

adventure game similar to those presently on the market should be developed. This decision was based on the target population (18-25) and the perception that this age group participated in computer gaming on a regular basis. A game designer from Atari was consulted, and IST was contracted to develop the software.

The game takes place on a futuristic ship that has been sent back to the present time. The student's mission is to return the ship to the future. The software package presents trainees with a series of rooms that they must pass through to successfully complete the game. It follows the adventure game format in which trainees must acquire objects and accomplish goals within each room. Each room also requires certain electronics concepts to be learned before the trainee can pass through. As the trainee advances from room to room, the tasks become more complex and difficult because they build on material presented in earlier rooms. This package was designed to increase trainee motivation to learn electronics through a discovery approach to learning. It incorporates color graphics, animation, multiple scenarios, challenge, score keeping, sound, and text material within an interactive, multilevel hypertext environment.

To date, three formative evaluations have been conducted to ensure the instructional validity of the game and to assess its motivational appeal. The results from both students and instructors have been favorable concerning both the motivational appeal and the quality of instruction. The performance of students using the game as a means of instruction will be compared with traditional instruction, page-turning computer based training, and interactive computer based training. Based on existing literature, it is expected that the game will be most effective when used either before or after formal instruction rather than as a replacement for it.

Simulations for Teacher Training

Simulations may be used to train teachers how to perform various tasks, such as learning how to use functions of the SY2000 EPSS, 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.

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. Another 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-simulated environment, each item is often completed in writing. However, using 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 with them which teachers must handle on a daily basis. In addition, beginning teachers must know how to handle unusual situations that might arise in the classroom. While the effective handling of these situations comes with experience, the use of a simulation can provide the inexperienced teacher with ideas of how to handle 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.

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.

SY2000 SIMULATION RECOMMENDATIONS

There is no doubt that simulation will be used in some form to support SY2000. The extent to which it will be used, however, requires much careful thought and planning. This discussion of the exact application of simulation for SY2000 will center on the following points:

- Type of Simulations
- Commercial vs. Custom Simulations
 - Content Areas
 - Co-Developers
 - Software Evaluation
- Impact on SY2000 Electronic Systems

TYPE OF SIMULATION

As discussed earlier there are two dimensions which can be used to categorize simulations: content versus outcome oriented and standalone versus group. The table below summarizes the recommended simulation emphasis for the SY2000 initiative based on goals, objectives and current technology trends. These recommendations also take into account current educational software development trend. It is recommended that SY2000 take a leadership role in fostering and sponsoring required simulation development in those areas which the educational software industry is not actively pursuing.

Recommended SY2000 Simulation Priorities

	Content Oriented	Outcome Oriented
Standalone	3 - long-term 5 - short-term	2
Group	4	1

The highest priority simulation development is in the area of group, collaborative, outcome oriented simulations. While considerable effort is being invested in the development of outcome 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 the SY2000 initiative. Without this class of simulations it will be difficult to provide a consistent outcome based learning environment for all students within Florida.

The second highest priority should be placed on individual outcome oriented simulations. The outcome based learning principles of SY2000 are one of its distinguishing characteristics. The development of any type of outcome oriented simulation is necessary to ensure effective accomplishment of SY2000 goals. The importance of SY2000 fostering the development of outcome oriented simulations is critical because the educational software industry is not currently focusing in this area.

The next highest priority class of simulations is content oriented standalone (individual simulations). The recommendations for this category are two fold. Because the educational software industry is so heavily involved in developing this class of simulation, it is not deemed necessary for SY2000 to advance developments in this area during the short term. A wide variety of high quality software is emerging to meet this need. However, there is the need for SY2000 to place a higher 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 standalone packages which will require little specialized development.

COMMERCIAL VS. CUSTOM SIMULATIONS

It is not going to be possible for SY2000 to develop all of the simulations which will be necessary to support the curriculum, instruction and assessment needs. This is a factor of both cost and development time. The priorities presented above provide recommendations on where SY2000 should invest its efforts, and hence, provides guidance on the mixture of commercial and custom SY2000 simulations. SY2000 custom simulations should focus on group, outcome oriented simulations.

Custom Simulation Development

Content Area

The simulations to be used in support of SY2000 should be as broad in scope as possible to fulfill the requirement of the curriculum design team 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 that are presently on the market tend to concentrate on the areas of mathematics and science. The reason for this concentration is most likely a result of recent educational reports which indicate that students in the United States have sub-standard mathematics and science knowledge when compared to students in other countries. It is unlikely that SY2000 will have to develop its own simulations for these subjects due to the abundance of mathematics and science simulation software currently available. Rather, SY2000 should concentrate on developing simulations which support other subject areas. This will hold for all classes of simulations, including group, outcome oriented simulations when industry begins to address this need. It has been suggested that in addition to mathematics and science curriculum, SY2000 simulations concentrate on the following areas of *history, civics, social science, geography, foreign language and vocational skills*. These non-technical subject areas are equally important in outcome based learning environments.

Since all students in SY2000 "will acquire the foundational skills and competencies needed to succeed in adult life assessments," 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 the SY2000 initiative, it is expected that agreements will be pursued with a number of co-developers. There is a broad spectrum of companies currently involved in the development of educational software. These companies range in size from small business firms through major vendors, such as IBM and Jostens. There are a number of trade-offs that must be considered in selecting co-developers. Large companies have more resources to contribute to co-development efforts, but at the same time 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 the simulation co-development for SY2000 will focus on new collaborative, outcome oriented simulations, large companies may not be an optimal co-development choice. 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 SY2000 development in this paper. Very small companies do not have sufficient resources, but there are a number of medium sized companies which have a demonstrated track record of marketing high quality innovative software. Strong consideration should be given to these types of companies as potential SY2000

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 for SY2000 are only now emerging. Hence, at least in the short-term, it is expected that co-development teams will be more effective.

Outcome Oriented Simulation Test Case - Hurricane Awareness

As previously noted, the development of outcome oriented simulations represents a new direction in educational simulations. This is especially true when it is embedded in a group, collaborative learning environment. Since this class of simulation represents a new technology direction, guidelines do not exist for the development of this class of simulations. It is recommended that SY2000 pursue the development of a selected simulation to:

1. aid in the development of guidelines and standards that can be applied to other SY2000 simulation developments
2. serve as a demonstration of this instructional technology and validate its benefits in meeting SY2000 goals and objectives.

The test case simulation should

- be outcome oriented
- 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
- be relevant to Florida

The recommended test case is to develop a simulation based collaborative learning environment dealing with hurricane awareness and preparedness. This simulation would permit students to assume various roles during the preparation, occurrence and aftermath of a hurricane. Low to medium fidelity models could be used to demonstrate various concepts. Students might be able to vary severity, population, location, and other factors which might impact their decisions. This type of test simulation is obviously relevant to Florida and represents the type of outcome oriented

simulations which would provide relevant real life experiences as defined by SY2000. This test case is relevant to a wide variety of subject areas including science, math, civics, geography, social sciences, among others. It represents an optimum choice to demonstrate this fundamental aspect of SY2000.

Evaluation of Software

Regardless of whether a commercial or custom simulation is chosen for use in a specific SY2000 class, it is imperative that the program be thoroughly evaluated for effective instructional design and support of SY2000 exit outcomes. Ideally, the simulation chosen should incorporate as many of the SY2000 learning objectives and subjects as possible. This concept is in accordance with the integrated, systems approach adopted by SY2000. A matrix check list of suggested attributes that simulations for SY2000 should possess is illustrated on the following page.

ATTRIBUTES

SUBJECT AREA	Effective Instructional Design	SY2000 Exit Outcomes	Integrated Concepts	Real to Life	Collaborative or Individual	Simulation Quality
Science						
Fine Arts						
Math						
Language Arts						
Foreign Language						
Social Studies						
Health & P.E.						
History						

Due to the design of this checklist, the evaluator can 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. It is suggested, however, that the evaluator create a legend of some sort to indicate to other readers the type of rating scale that was used.

Using the attributes listed in the checklist, the evaluator should note that they are comprised of the following:

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 (i.e. advance organizers, mnemonic techniques, and imagery strategies).

SY2000 Exit Outcomes

Does the simulation assist students in the attainment of the following exit outcomes:

- 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, meaning that which covers only one topic area, has a positive evaluation based on the above criteria, it of course should be used. However, those simulations which cover more than one subject area, and thus, display how different topics relate to each other, are usually more effective than the stand-alone variety.

Real to Life

Intuitively, since a simulation should be designed to represent a real world situation, it should be real to life. 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 the presentation of it.

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 focus and concentrate more intently than in a group environment. 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. Again, due to the nature of the checklist, the evaluator can rate the program with letters, numbers or words.

While most of the discussion has centered around computer simulations, it should be mentioned that role playing and other non-computer simulations could be used effectively in SY2000 learning sites. This type of simulation would be particularly effective for topics such as personal interactions, feelings, and relationships which fall under the affective domain. By simulating events in real life, learners can be provided with the opportunity to see how classmates react to certain situations and 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 strict criteria developed for computer simulations.

Whether a simulation is computerized or real life, it should be evaluated by the same strict criteria. 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 rather than the computer as a facilitator 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. A computer, obviously, cannot.

SY2000 ELECTRONIC SYSTEM IMPACT

The electronic system design for SY2000 will provide the learner with a gateway to an advanced learning environment. Each child will experience a personalized learning environment to stimulate his or her individual interests, and to provide a method to work and learn cooperatively. As the electronic system design for SY2000 has been defined, the requirements to support simulation, as discussed in this simulation paper, have been included.

The networking and communications infrastructure is the primary component which facilitates the use of simulation. The networking and communications subsystem includes the hardware and software infrastructure needed to support the overall SY2000 Electronic System. It involves networking and communications within learning sites, between learning sites within a district, and between districts and the outside world. It is specified to provide a seamless environment across all levels of the infrastructure which is transparent to the user. The bandwidth of the networking and communications infrastructure will 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 design are that it must:

1. be based on an open, cooperative computing architecture. This includes both hardware, software and communications protocols.
2. utilize a basic client-server computing concept, augmented by peer-to-peer computing as required. Peer-to-peer communication should be available from any learning space to any other network user.
3. utilize distributed technology and network connectivity.

Client-server approaches to networking have been the recent main stay concept. This form of computing permits the user to initiate access or transmittal of data and programs in a unilateral fashion. This type of approach optimizes the efficiency of an individual's work tasks. It is expected that the client-server approach will be the primary networking approach for most applications within the SY2000 electronic systems environment.

Peer-to-peer networking will play an increasingly important role within the learning support system. An increasing emphasis is being placed on group or 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. The peer-to-peer networking 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 SY2000 electronic system networking concept, provide the mechanism to support both individual standalone and group/collaborative simulation based learning environments.

The primary impact on the electronic system for SY2000 is the need for significantly higher bandwidths to achieve the desired simulation environment. The bandwidths available for SY2000 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 nodes 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 will 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 SY2000 desired outcomes.

While hardware bandwidth is a major impact and limitation, it is not the only critical 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 widely being adopted 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 can not 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 will supplant Internet, which can handle the more bandwidth and real time intensive applications which are in development. The likely basis for this new network will be the National Research and Education Network (NREN) or some modification of that National Science Foundation (NSF) developed network.

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 SY2000 simulation requirements. Of special interest have been recent efforts to incorporate the DIS protocol standards into an extension of the OSI protocols. Hence, this approach

could support the total spectrum of simulation applications that might be developed for SY2000.

The SY2000 initiative 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 SY2000 electronic 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 platforms. Individual computing devices, such as PCs and MacIntoshs, 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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