

Use of Simulation to Support Mining Industry Operators

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This paper presents two design examples that illustrate instructional issues in the design and development of interactive computer simulations. The examples have been designed as exploratory tools that support a real activity for mining equipment operators.

The first example, the Australian Conveyor Engineering simulator, was designed as not only a simulation tool, but also a sales and marketing tool. Simple, yet deceptive in its complexity, the conveyor simulator allows users to simulate the actions of a conveyor in a real-world underground environment. The user can adjust a wide range of options relating to the conveyor, and see the results (belt tension, power output of drive head etc) not only in mathematical and chart form, but also through a graphical representation, the conveyor. Components under stress react by glowing yellow, then orange, then red. Users can test a given situation before actually implementing the design underground.

The second example, the Joy Mining Machinery 12CM12 continuous miner simulator, has been designed to support operators in the initial phase of training for use of the continuous miner, where training on the job could be dangerous and lead to expensive losses. The simulator allows potential operators to perform all miner operations on-screen while using a multimedia training program. In an attempt to add more power to the simulation the program also incorporates a replica of the actual machine controls, so the user can operate the simulator not through a mouse and keyboard, but also use the actual controls.

INTRODUCTION

The mining industry has developed a comprehensive view of the need to have production personnel well trained in the use and maintenance of mining equipment. A strong commitment from the industry to this view has been instrumental in creating an efficient, profitable and productive industry based on modern production processes, sophisticated equipment and a multi skilled workforce. As the industry continues to develop, and the skills and knowledge needed by productive workers continues to expand, the training processes adopted by the industry will need to develop in parallel, not only making use of the latest advances in learning theories, instructional design and technology, but also using these new ideas in more efficient ways.

The mining industry has a high level of mechanisation with the production personnel, for the most part, working in small groups in isolated locations. Multi skilling of this workforce has been instrumental in improving the efficiency of the industry over the past ten years with much of this efficiency coming from the ability of workers to carry out routine maintenance and repairs to the complex equipment. For the production personnel to take on this type of role, they need to be well trained in the functioning and routine repair procedures for this machinery.

The successful transformation of learning and accomplishment in the next decade requires the effective bringing together of two agendas - an emerging consensus about learning and training and well integrated uses of technology. Each agenda alone presents possibilities for training design of a very powerful sort. In the past, approaches that consider trainees as active learners and, that aim for trainees to understand content and be able to think were seen as important for only highly skilled technicians. Now in contrast these goals and approaches are urged as priorities for multi skilled production personnel in many industries, and in particular in the mining industry. Use of new media technologies to support this training process is seen as an essential tool in increasing the efficiency and effectiveness of the training process.

Training materials developed to control and maintain complex machinery need to develop in trainees not only appropriate knowledge, but also a broad range of specific skills based on use of the machinery. Production personnel in the mining industry do not have high levels of literacy so the necessary training could be well supported through clear initial specification of goals, the use of simulation of the skills needed, constant review of the key concepts and

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assessment of the learners achievements on a regular basis. This instructional approach should also be supported with achievement of the stated goals being recognised and conveyed to the learner.

SIMULATION AS AN INSTRUCTIONAL STRATEGY

Much of the complex and expensive equipment that is used in underground mining needs to be constantly involved in the production process. In order to have operators that optimise the production process, they need to be skilled and expert in use of this equipment with minimal time spent on use of the equipment for operators to develop skill.

Simulation of such equipment in providing a realistic, 'risk free', learning environment has the potential to support the skilling of operators with minimum training time used in the production line.

Computer based simulations are programs in which the computer acts as an exploratory tool (Bliss and Ogborn, 1989), supporting a real world activity while helping users understanding of processes involved in controlling a complex dynamic system which may otherwise be inaccessible.

The current level of sophistication of interactive multimedia applications provides an incentive for designers to produce software which fully utilises the capabilities of such applications. This is particularly evident in many of the simulation based packages being developed today which exhibit a tendency to move away from the earlier reliance on a 'pre-set', 'fixed and repeatable outcome' model which provided a very simple approximation of the real world that it was trying to mimic.

There is a considerable volume of literature on the value and nature of simulations (Gredler, 1996). They may be defined as the dynamic execution or manipulation of a model of an object system for some purpose (Martin 1988). A simulation is considered as "... a special kind of model representing a 'real world' system, governed by a set of rules" (Crookall et al. 1987). During the use of such models, the user often comes to see the simulation itself as a 'real world' in its own right. Such models represent systems as either "in-place of" or a "bring to life" format. The question posed by some as to whether the terms 'model' and 'simulation' have similar meanings in this context may prove a pivotal point around which a better understanding of the cognitive outcomes for the users may be achieved.

The 'in-place of' interpretation of representation applies to the 'standard' widely accepted notion of a model while, as suggested by Crookall et al. (1987), both the "in-place of" and "bring to life" representations may be applied to and equated with simulations.

The exact nature of what constitutes a 'true simulation' is not agreed upon amongst researchers or designers alike but we would suggest that, commonly the goal of the simulation must be to provide interactive experiences which approach or mimic the 'real world' experience as closely as possible.

We would suggest however that within this 'prescription', simulations fall into two broad categories, those which we might call 'Illustrative simulations' and those we might call 'Interactive simulations'. We would suggest that these categories are not mutually exclusive and that much of the software developed for teaching, learning and gaming environments, use simulations exhibiting varying degrees of hybridisation of the two types.

Purely 'Illustrative simulations' are those which require a minimum of interaction and provide simple feedback, often in the form of images. The user is not required to provide significant input data, often only being required to 'click on' the start button. If the simulation is under pinned by algorithms, it is usually of a 'closed type' and as such is not predictive of 'real world' outcomes. The outcomes are fixed and at best such simulations provide little more than an 'illustration' of the process. As a consequence, they are less educationally useful as they do not allow the user to make inferences regarding cause and effect relationships nor do they allow for the testing of hypotheses. Such 'simulations' in their simplest forms are little more than animated sequences depicting a process.

On the other hand, purely 'Interactive simulations' are highly interactive in that the user is able to fully manipulate inputs and receive and manipulate output in various forms from the system. In its most powerful form, the algorithms are such that they provide an 'open' model which fully mimics the 'real world' processes and can be fully predictive. User's also receive feedback on their actions, thus allowing them to study 'cause and effect' relationships and test hypotheses.

Such simulations promote the adoption by the user of the active learner mode and in so doing support the active construction of knowledge by the student during the process of solving a problem.

Placing such simulations within a multimedia environment and providing an interface which takes full advantage of the capabilities of such environments can provide unparalleled support for the user.

Regardless of the type or format of the simulation, the overriding purpose for simulating and modelling systems remains; to provide a substitute experience for those processes and systems which by reason of cost, scale, time or risk, would not normally be accessible and the ultimate aim of the developer must be to meet such essential criteria as:

- Producing a simulation that emulates as closely as possible the 'real world' experience.
- Design decisions are based on some appropriate educational paradigm.

TWO MINING EXAMPLES

Australian Conveyor Engineering Simulator

The Australian Conveyor Engineering (ACE) conveyor simulator was designed to allow mine personnel to perform "what - if" simulations of the load and power applied to a conveyor system before making changes to the real world system.

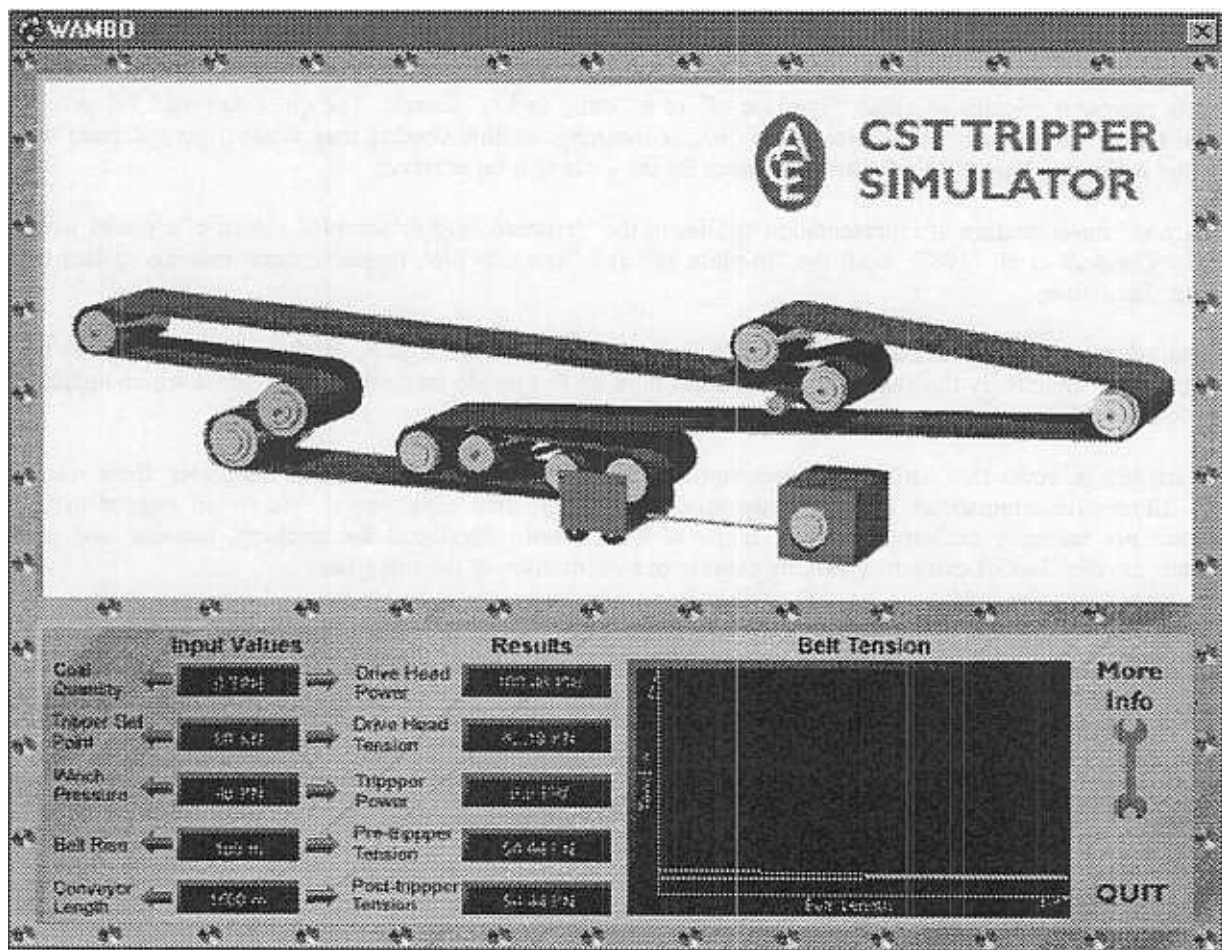


Fig. 1 - The Australian Conveyor Engineering Simulator

The program opens with all conveyor values set to default - the conveyor carrying no coal - and the simulation begins. The conveyor is represented visually in the top portion of the screen in three-dimensional form. The fact that the conveyor system is operating become more apparent as coal is supplied to the system through the input controls in the bottom portion of the screen.

By adjusting the numerical input controls the user has the ability to adjust the amount of coal which will be placed on the conveyor system (tonnes per hour), the set point for the tripper drive (kilonewtons), the pressure applied by the winch (kilonewtons), the belt rise over the whole conveyor system (metres), and the total conveyor length (metres).

The arrows on each side of the inputs are operating by clicking with the mouse until the desired setting is reached. Short clicks increment the setting by one unit while longer clicks can be used to increase the setting by a greater amount. The left hand arrow reduces the setting and the right hand arrow increases the setting. The controls are not designed to simulate the real world controls for the conveyor system, as this was not a goal of the simulation, so they are relatively simple, clear and intuitive.

Feedback is provided through the numerical outputs (located adjacent to the input controls), the belt tension graph (located on the right hand side of the screen) and the three dimension model of the conveyor system. Output consists of the power required by the drive head (kilowatts), the tension of the conveyor belt measured just before it reaches the drive head (kilonewtons), the power required by the tripper (kilowatts), the tension of the conveyor belt measured just before it reaches the tripper (kilonewtons) and the tension of the conveyor belt measures just after it passes through the tripper (kilonewtons).

A graphical representation of the length of the conveyor system versus the tension occurring in the system is located to the right of the numerical outputs. This belt tension graph provides users with a graphic representation of the relative tension on the conveyor belt at different points within the system.

The three dimensional representation of the conveyor system which dominates the screen provides users with a more accessible and visually appealing form of output. It provides a "rough" guide to the current state of the system, which can be used in conjunction with the numerical and graphical data to create a detailed analysis.

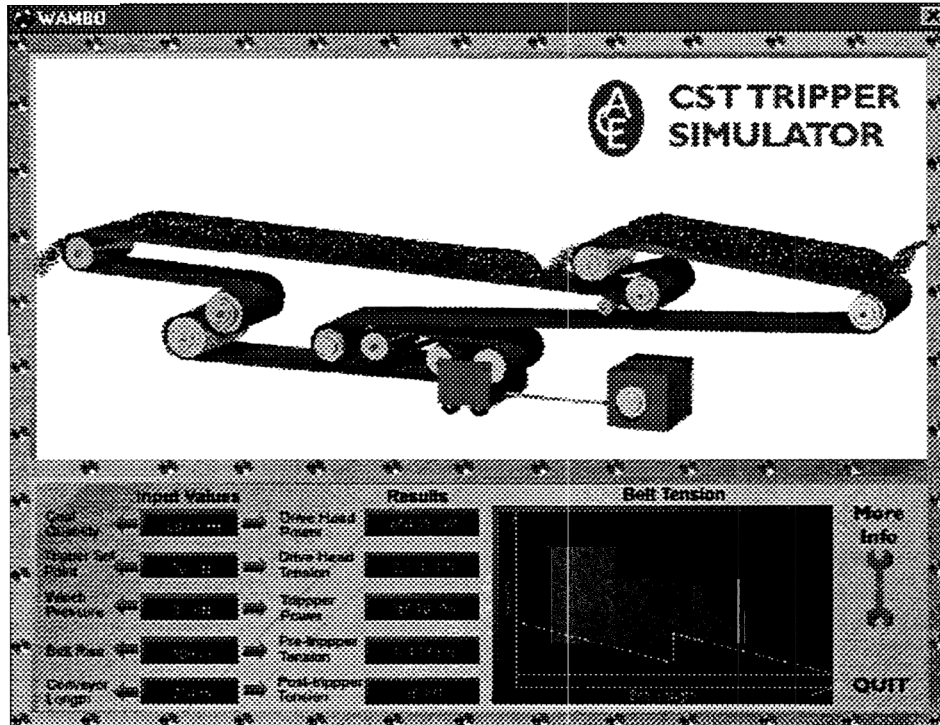


Fig. 2 - The Australian Conveyor Engineering Simulator with coal on conveyor.

Using the numerical outputs, the model displays warning indicators (visually represented as colour changes) to determine whether the power required by the motors or the tension applied to the belt is likely to cause damage to the machinery. This becomes a rough guide to the amount of coal it is safe to load on the belt given the input parameters. The warning indicators occur on the drive head and tripper motors and on the conveyor belt before the drive head, before the tripper and after the tripper. By viewing these colour changes the user can determine whether their input settings are appropriate for the conveyor system, or whether they are likely to cause damage to the equipment. By combining the colour changes with the numerical outputs, the user can also determine the exact tension at each of the measuring points, as well as the power demands for the drive head and tripper motors.

If the user enters all required inputs and finds that the system will not be able to function correctly, they can then 'experiment' with the inputs performing "what - if" simulations to determine the most appropriate settings for their conveyor system.

The ACE conveyor simulator provides an interactive experience which attempts to mimic the real world operation of a conveyor system, but fails to mimic the actual controls and physical operation of the machine, and therefore can be considered to be a hybrid 'Illustrative simulation' and 'Interactive simulation'. The simulator has elements of an 'Illustrative simulation' - simplified controls, relatively simple visual representation of a conveyor system - while taking advantage of some of the highly interactive features of an 'Interactive simulation' - fully manipulate inputs, displays output in various forms from the system, and immediate user review of their actions. This type of system strongly supports active learning in that the user can study cause and effect relationships and test hypothesis in a safe, controlled environment.

Joy mining machinery 12CM12 continuous miner simulator

The second example, the Joy Mining Machinery 12CM12 continuous miner simulator, has been designed to support operators in the initial phase of training for use of the continuous miner, where training on the job could be dangerous and lead to expensive losses. The simulator allows potential operators to perform all miner operations on-screen while using a multimedia training program. The simulator was designed to allow users to learn how to operate a 12CM12 continuous mining machine through experimentation. The simulator combines rich three dimensional animation with replica controls to enrich the learning process.

The 12CM12 continuous miner is operated by a small team of personnel, each with specific tasks to perform. The simulator is designed to augment the training of the miner driver. The driver operates the movement and coal shearing on the machine through a radio remote control unit. The remote control unit features a collection of switches which are used to send instructions to the machine.

The 12CM12 simulator is part of a larger computer based training program which features maintenance procedures, electrical and hydraulic circuit education and fault finding trees.

The simulator initially presents the user with a cutaway side view of a roadway showing the strata above the roadway, the floor below, and the miner side-on (three dimensional model). The miner is positioned at the left hand side of the screen with the roadway continuing to the right. Below the miner is a graphical version of the radio remote control panel which is used to operate the machine.

The graphical version of the remote control features a collection of switches which are used to operate the machine. By moving the mouse over a switch, holding the mouse button down, dragging the switch up, down, left or right and releasing the mouse, the user can trigger an operation on the machine. The operation is displayed by the three dimensional model, which was created using the actual engineering drawings for the 'real world' machine, ensuring visual accuracy. The model moves or animates to display what would happen on the actual machine. All operations are timed and synchronised with the actual machine, ensuring that the user gets a true indication of the real world activity which is being simulated.

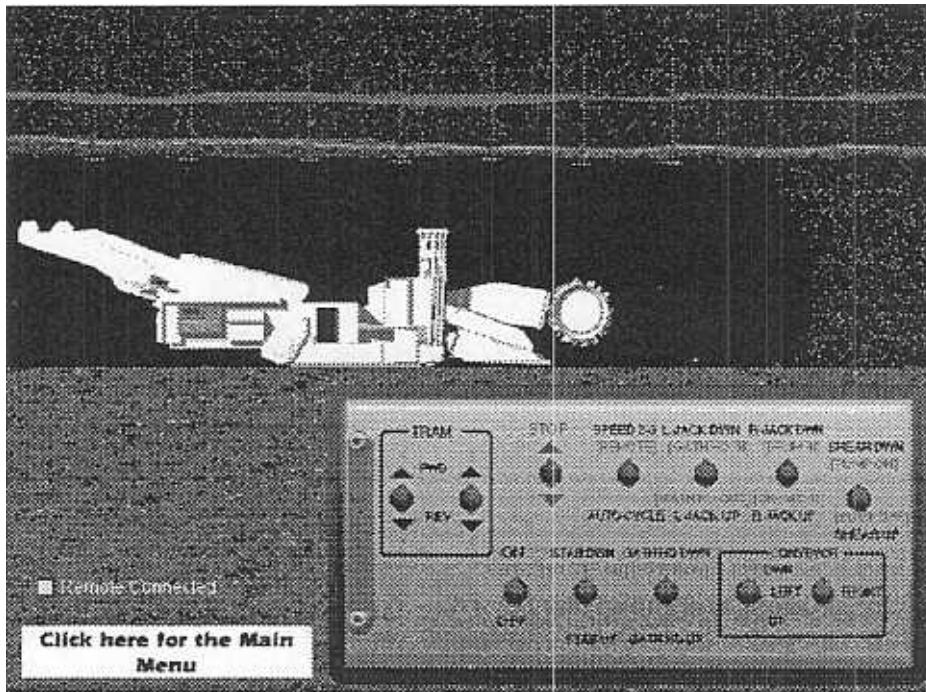


Fig. 3 - Continuous Miner Simulator

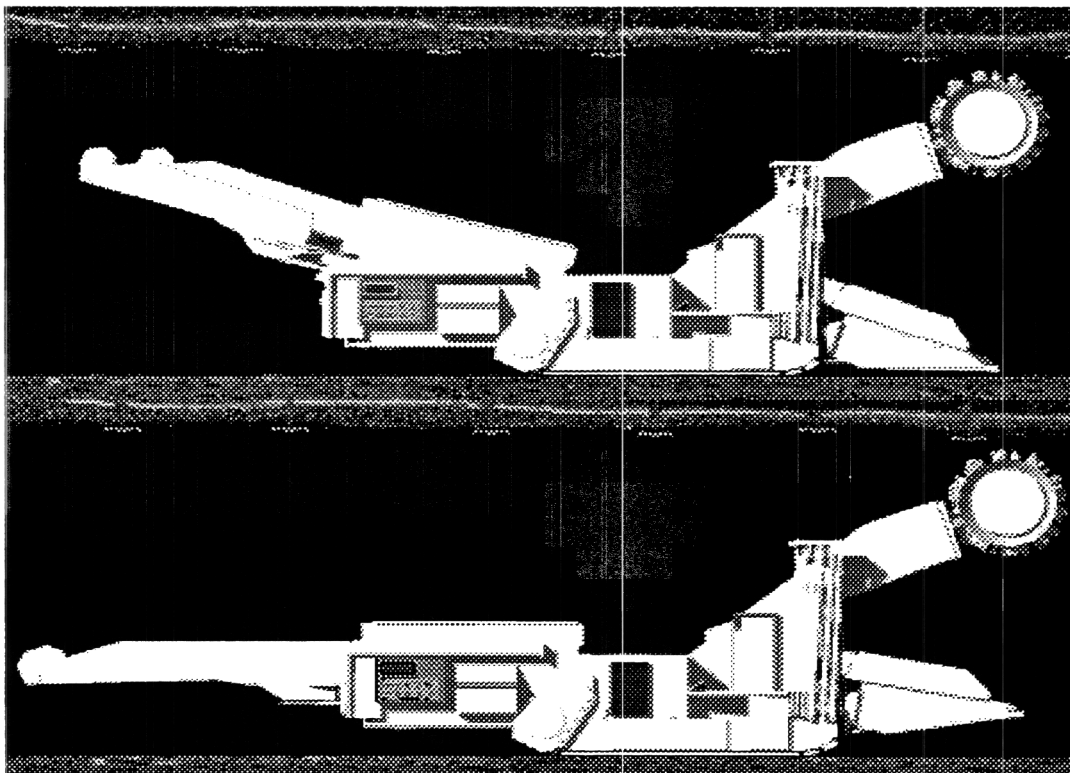


Fig. 4 - Continuous Miner Simulator in different positions

The simulator can perform a number of operations including tramming, shearing, gathering head operations, cutter head extend and retract, cutter head on and off, stabilising jack operations, and full conveyor swing operations. When an operation cannot be displayed from the side-on perspective, an inset window appears in the centre of the screen to show the operation.

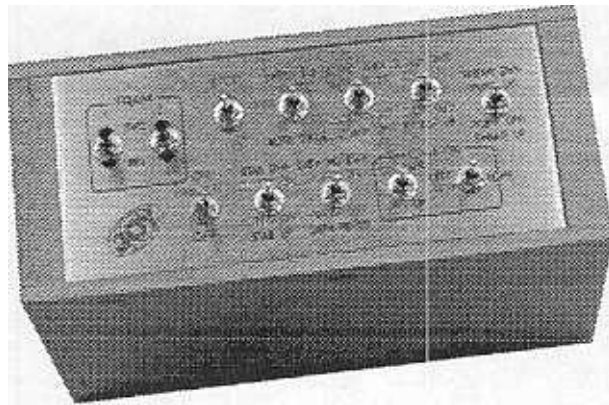


Fig. 5 - Photo of Replica Control

In an attempt to add more power to the simulation the program also incorporates a replica of the actual machine controls, so the user can operate the simulator not through a mouse and keyboard, but by using a replica of the actual controls. Although internal operations were created from scratch for serial communications with the computer, the replica remote has the same visual appearance as the remote control used on the 'real world' machine. The miner simulator allows users to fully manipulate inputs and outputs, use the controls which are used in the 'real world' and extend the simulated aspects of the learning experience in the tradition of 'Interactive simulation'. Conclusion

The mining industry makes use of complex and expensive equipment that must be operated by skilled miners. Developing operator skills must be achieved with minimum down time for the equipment in circumstances that minimise risk to operators, co-workers and the equipment. One approach is to simulate the skills necessary to develop well trained operators using sophisticated visual representations of models that can be manipulated in ways that simulate as closely as possible operator skills.

The two simulations described in this paper are now in use in various mines in Australia, as well as internally at Joy Mining Machinery in the United States. Evaluation of the learning outcomes will be a priority before development of further more extensive products based on the same instructional strategies.

REFERENCES

- Bliss, J., and Ogborn, J. (1989) Tools for Exploratory Learning. *Journal of Computer Assisted Learning*. (5)., 37-50
- Crookall, D., Oxford, R., Saunders, D. (1987). Towards a Reconceptualization of Simulation: from Representation to Reality. *Simulation/Games for Learning*. 17 (4).
- Gredler, M.E. (1996), Educational Games and Simulations: A technology in Search of a (Research) Paradigm, In Jonassen, D. (Ed), *Handbook of Research for Educational Communications and Technology*, N.Y.
- Martin, A. (1988). Out of the Screen: Computers and Simulation. *Simulation/Games for Learning*. 8 (1).