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ABSTRACT

The purpose of this report is to communicate findings on current knowledge of simulation design, development, and evaluation. Research on this project was guided by questions posed by the Defense Systems Management College in Fort Belvoir, Virginia. These questions fall into three categories: the constituents of good instructional simulations, the design and development of instructional simulations, and the evaluation and testing of instructional simulations. This work is based on careful review and analysis of the literature on the topic, and is supplemented by interviews with developers and users. Highlights of the report include: (1) emphasis on the need for an empirical approach in simulation design; (2) recommended set of phases for using instructional simulations which can serve as an instructional simulation users guide to increase learning from simulations; (3) comparison of the cost/benefits of simulation compared to other instructional methods; (4) instructional effectiveness of simulations and their fidelity to what is represented; (5) design steps; (6) discussion of the advantages and disadvantages of task, cognitive, or affective analysis during simulation design; (7) overview of instructional effects research; (8) frame or checklist for conducting a content analysis to evaluate the potential of an instructional simulation; and (9) procedures for conducting evaluations of simulation learning. The appendices contain a paper, "Computers in Instructional Simulation" (James E. Snellen and Steven L. Murray); a 116-item bibliography; a copy of the interview form used; and samples of interview reports. (57 references) (DB)

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A Report on the Research and Development of Instructional Simulation

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Executive Summary

In this report on the state of the research and development of instructional simulation we have responded to 12 questions posed by the DSMC staff. These questions are included in three categories: The constituents of good instructional simulations, the design and development of instructional simulations, and the evaluation and testing of instructional simulation. Our work is based primarily on careful review and analysis of the extensive literature on the topic supplemented by interviews with developers and users.

Highlights of the report are as follows:

- **Emphasis on the need for a greater empirical approach in simulation design.**
- **Recommended set of phases for using instructional simulations which can serve as an instructional simulation users guide to increase learning from simulations.**
- **Detailed comparison of the cost/benefits of simulation compared to other methods.**
- **Discussion of the issues relevant to fidelity between the simulation and what is represented.**
- **Conditions which determine the instructional value of verisimilitude or fidelity are enumerated.**
- **Design steps are listed and discussed.**
- **Emphasis on task, cognitive, or affective analysis as an early phase of simulation design.**
- **Discussion of the advantages and disadvantages of task, cognitive, or affective analysis during simulation design.**
- **Overview of instructional effects research.**

- **Frame or checklist for conducting a content analysis to evaluate the potential of an instructional simulation is presented.**
- **Step by step procedure for conducting local empirical evaluations of learning from simulations.**
- **Appendix devoted to special considerations of computers in instructional simulation.**

Introduction

Our purpose is to communicate our findings on current knowledge of simulation design development and evaluation. More specifically, we will discuss what currently is seen to constitute good simulation design, development, and practice. Throughout our research toward this purpose we were guided by a set of questions provided by DSMC personnel. These specific questions are incorporated in the body of this report as second order headings under three first order headings.

A study of instructional simulation cannot be isolated from the study of other instructional methods. Answers to relevant questions and responses to critical issues must be created in the matrix of comparisons and contrasts of other instructional methods and the designing of other types of instruction. In our view some of the problems attendant to the research and development literature of simulation and instructional simulation are functions of the failure to address similarities of issues and design strategies between other methods and that of instructional simulation and the failure to engage those similarities.

This is not to be taken to mean that we imply that there are not unique issues characteristic of design of instruction in other methods and instructional simulation. The probability is that there are some differences which must be honored among the various methods of instruction and the design of instruction within the rubrics of those instructional methods. We view instructional design as an applied science, albeit an applied social science, and one heart of any science is deep analysis of similarities and differences; and, for best application, "best management" of similarities and differences are essential.

The subsequent sections of this report are, first, a brief report on our methods. We follow this with a short overview of instructional methods other than simulation which will serve as a basis for later comparisons and contrasts. This is followed by three major topical headings: the constituents of good instructional simulations; the design and development of instructional simulations; and the evaluation and testing of instructional simulations. Following comes the conclusions, references, and appendices consisting of (A) a special short paper on computers in instructional simulation: (B) an extensive bibliography of items examined, (many of which were not cited in the body of the report); and (C) the interview guideline and the credentials of interviewees.

Methods

In this report we will record the results of a two dimensional effort. First, the report is based on an extensive review of the instructional simulation literature and to a lesser degree the instructional design literature. Second, the report is based on interviews of several individuals who develop and use instructional simulations. We think that this two dimensional approach is necessary for the construction of a record displaying the state of instructional simulation. In this area, perhaps more so than others in instruction, there are at least these two sources of knowledge. The extensive literature is, of course, a record of those in the field who not only design and use instructional simulation, but also a record of their findings and impressions in the professional literature.

Our review of the literature included use of the following reference aids: LCS (an on-line computer reference system); ERIC; INFO TRACK; Education Index; Social Science Citation Index (Citation and Source volumes); and Books in Print. In order to search the above reference aids, various combinations of the following key terms were used for the subject search: simulation games in education; educational games; simulated environment and teaching method; instructional simulation (and teaching methods, and study and teaching, and debriefing, and design, and models, and techniques, and heuristics, and learning effects, and evaluation); simulation methods; education and simulation methods; synthetic training devices; microteaching; cognitive task analysis; and affective task analysis. After reviewing relevant sources and their associated bibliographies additional searches were conducted for specific authors or titles cited.

In addition to the literature search and analysis we conducted interviews with individuals who design and use instructional simulations; but, who for a variety of reasons, do not publish routinely in the area of instructional simulation. Because we know that these individuals have considerable knowledge we have interviewed as many as our resources have allowed. We feel that their experiences are valid and important resources in the same sense that there are many who plan and give great lectures who have not contributed to the literature on the lecture as an instructional method and who could, nevertheless, provide considerable insight into instruction using that method.

Throughout our search we were guided by questions posed by the staff at DSMC; but, as we progressed, other questions emerged to which we feel bound to respond. These we have incorporated into assorted sections. These questions, taken together, have become the organizer for this report.

In our search we are impressed with the extensiveness of the literature. The uses of simulation extend as follows: into most disciplines; into most levels of instruction from elementary to adult; across several strategies, or simulation and game types [unregimented play, simple role playing, systems games, simulations relying on predetermined roles or action cards, person-computer, reactions simulations, and monopoly-type box games (Davis, 1980)]; and into practically all the intended outcomes or objectives of education in the three traditional domains of objectives. These three domains are, of course, cognitive, affective and psychomotor. The breadth of this literature makes it virtually impossible to review and analyze it completely. As an illustration of the variation across disciplines, a survey of those disciplines incorporated into Crookall, Greenblat, Coote, Klabbers, and Watson (1987) include language and communication, social issues, and management and business. In other literature, instructional simulation includes the areas of medicine, health, aeronautics, library and information science, military science, and political science.

In our next section we share a brief overview of instructional methods. In this introduction we have argued that issues about instructional simulation are best implanted within comparisons and contrasts with other methods. Again and again in this review we will haunt this argument. The following brief section is an overview which should provide the framework for comparisons.

Instructional Methods

In this section we present an overview of instructional methods. We have not attempted to discuss these in any detail. This list and a few associated issues will abet our discussions of similarities and differences between simulation and other methods. No single instructional method, not even instructional simulation, should be treated in isolation from other methods, nor should any be revered as necessarily "innovative" while all others are relegated to "traditional," an argumentative device so often observed in instructional literature. The strengths and weaknesses of instructional simulation should not be compared to all other methods together, as do some (see Sharrock and Watson, 1987, for example). Simulation should rather, be compared to other specific methods in specific contexts. Figure 1 is a list of other instructional methods to which comparisons will be made during this review.

Figure 1 Instructional Methods

Lecture
Independent reading
Demonstration

Lecture-discussion
Independent study (reading plus overt responding)
One-on-one tutoring or conferences
Small group tutoring or conferences
Dialogue (Socratic)

Cooperative learning (many forms)

Discovery (should read "Constructed" learning)

Case studies
Simulation

Field (or clinical) experience (sometimes called direct experience)
Cognitive apprenticeship

The methods listed are not necessarily independent of all others. It seems that the list is in some ascending (or descending) order, but the description or labeling of that order is tenuous. The classifications such as those which appear in West, Farmer & Wolff (1991, pps., 253-254) seem inadequate. Some reasonable classifications exist, but are weak from the standpoint of mutual exclusion. A taxonomy would probably be impossible, but a classification system may be. Some possible bases for classifications systems may include:

Independent vs. guided;
Individual vs. group;
Reception vs. construction
    (Discovery and reception are dated metaphors for learning.);
Teacher managed vs. student managed;
Passive vs. active
    (Not much potential for this. A reader or listener can be as intellectually active as a participant in an apprenticeship. There are possibilities that learners can be physically active without being mentally active.);
By objective or learning goal
    (On the surface this does not have much appeal as a possibility.);
By level of expertise of student required
    (From novice through advanced to expert.);
By instructional control.
    Who controls pace? (Tutor as machine or teacher or student?);
By planning/design (Amount before instruction.); and
By cost.

Related Questions

Considering the emphasis which should be placed on comparing the simulation with other instructional methods, it is important for those involved in the simulation to reflect on a number of questions. Is instructional simulation mutually exclusive from the other methods listed? With which does it overlap? From which may it be separated? We will not pursue these issues on other methods of instruction in this paper. We have mentioned them, however, for comparison purposes.

We now turn to a discussion of the constituents of a good instructional simulation. There are several listings in the literature, each of which are valid.

Constituents of a "Good" Instructional Simulation

(1) What Are Its Fundamental Components?

There are several listings of fundamental elements of simulation games in the literature. We have followed the terminology of the sources of these listings and note here that "games" or "gaming" is often used as a synonym for simulation. We enumerate in Figure 2 those found in relatively recent literature. From these listings, it is clear that considerable variability exists in the literature about the fundamental components of games and/or scenarios. This does not inherently mean that there are major disagreements among experts. Given the variation in instructional simulations discussed earlier, particularly in the types of games [unregimented play, simple role playing, systems games, simulations relying on predetermined roles or action cards, person-computer, reactions simulations, and monopoly-type box games (Davis, 1980)] one should expect that components will differ.

(2) What Is It Designed to Teach (i.e., Why Is It Used?)?

Greenblat (1980) and others (Thiagarajan and Stolovitch, 1978; Adams, 1973; Dorn, 1989; and Szafran & Mandolini, 1980) have documented that advocates of simulation have claimed that simulation can be used to teach practically all levels of objectives from both the cognitive (fact learning to problem solving including what, when, how and why) and affective domains (awareness of affect to development of systems of values). Please see West, Farmer, and Wolff, (1991), pps. 46-49; Bloom, (1956); and Krathwohl, Bloom, & Masia, (1964) for further discussions of varieties of educational objectives.

Figure 2, Fundamental components of Simulations

Duke (1980):

1. Scenario (plot outline);
2. Pulse (event introduced to focus players' attention);
3. Cycle sequence;
4. Steps of play (sets of instructions);
5. Rules;
6. Roles;
7. Models (systems for keeping a record of progress through the game);
8. Decision sequences and linkages (connections among what players are doing, when, and how);
9. Accounting system (results of steps of play);
10. Indicators (characteristics of the accounting system which are emphasized for the players);
11. Symbiology (representations of indicators); and
12. Paraphernalia (materials required to run the game).

Thiagarajan and Stolovitch (1978, p. 15):

Critical characteristics include:

1. Conflict;
2. Constraints (rules);
3. Closure (ending with method for determining winning and losing);
4. Contrivance (artificial activities); and
5. Correspondence (parts of game are matched with the situation represented).

Variable characteristics include:

1. Type of conflict;
2. Type of constraint;
3. Type of closure;
4. Degree of contrivance and correspondence;
5. Replayability (Can the game be played again by players?);
6. Time requirements;
7. Equipment and materials;
8. Number of players; and
9. Purpose of game.

Brent (1977):

1. Roles for participants;
2. Interactions among roles;
3. Rules governing interactions;
4. Goals of interactions; and
5. Criteria for determining goal attainment and game termination.

Benson, McMahon, & Sinnreich (1972), parts of scenarios:

1. The character of all organizations in the game;
2. Team values (goals or ideals);
3. Team resources;
4. Interteam relationships;
5. Intrateam relationships; and
6. Player roles.

Simulation advocates have generated numerous claimed outcomes for simulation. Some are as follows. Instructional simulation helps:

1. students learn collaboratively (Thiagarajan and Stolovitch,1978, p. 61);
2. students have fun (Adams, 1973) (as in "Learning should be fun.");
3. student motivation, excitement, interest (Adams, 1973, Greenblat, 1988, page 16);
4. student appreciation of group dynamics (Adams, 1973);
5. student understanding the structure of knowledge (Adams, 1973);
6. students as they connect cognitive and affective learning (Adams, 1973);
7. students make later learning more meaningful (Greenblat, 1980);
8. students bridge gaps between the conceptual level and real life situations (Horn and Cleaves, 1980, p. 58);
9. by conveying information or facts, holistic impressions (gestalts), and relationships (Greenblat, 1988, page 16);
10. develop skills such as critical thinking, analysis, problem-solving, interactive, and communicative (Greenblat, 1988, page 16);
11. student self evaluation (Greenblat, 1988, page 16); and
12. students develop attitudes (Greenblat, 1988, page 16).

We are not declaring that instructional simulation cannot contribute to the attainment of any or all of these objectives. Our major point is that most sweeping claims generally are not yet empirically based (Greenblat, 1980), an issue which will be discussed in greater detail later in this report. Furthermore, given the wide range of simulation types, objectives, and disciplines within which instructional simulation has been used, any categorical claim for simulations effects *per se* is unwarranted (DeNike, 1976). It is time to surrender the broad, sweeping claims for effects of instructional simulation and become specific and empirical. **The time has arrived to investigate empirically the planned effect for the specific simulation for the stated purpose**, points elaborated by Bredemeier and Greenblat (1981).

As does Dorn (1989, p. 1), we visualize simulation as "one tool on the pedagogical shelf" which can be used in a variety of ways for many purposes. We, in all fairness to the advocates of instructional simulation, recognize that advocation of most instructional methods has been characterized by rhetoric and ideology rather that empiricism. This has been true of most of the instructional method innovations from discussion to discovery learning to cooperative learning, as examples.

In a later section we will discuss the various studies which constitute evidence for effects of simulations on various types of learning. Given the range of simulation across disciplines and objectives, no categorically positive claims for effects will likely be warranted.

(3) Within the Simulation. Where/how Does the Required Learning Take Place?

There can be no specific or definitive answer to this question across all students and all instructional simulations. In general, however, learning can take place from the moment an instructor announces that a simulation will be used weeks or moments from the use of the simulation, or during any phase of the simulation from giving instructions through debriefing. This is similar to the discussion by Duke (1980) that each cycle in a game reinforces any knowledge gained in previous cycles.

Guide for Using Instructional Simulation in the Classroom. This leads to an intuitively based set of phases for using instructional simulations. While the research on these phases is sketchy and imprecise they have some empirical support and considerable experiential support (Lederman,1984) and seem intuitively sound. Phases are as follows:

1. Introducing the game [Provide an overview of learning goals and topics (Dorn, 1989), not specific objectives. Include instruction on how the game is played];
2. Playing the game [Interrupt (Dorn, 1989) game play if necessary for running or if it promotes learning.];
3. Debriefing, including discussion (Livingston and Stoll, 1973) of how main points fit into earlier instruction (Dorn, 1989) [This should consist of comparisons with prior knowledge and with *in situ* applications. There is even some evidence that a sequence such as playing the game then discussion then replaying of the game is advantageous (Kidder and Guthrie, (1972)];
4. Supplement with other methods (Bredemeier, 1978, Dorn, 1989);
5. Testing and evaluation (Dorn, 1989) (Formally evaluating the simulation and testing the students will increase the probability of effective learning and subsequent efficiency of use); and
6. Reviewing and restating major points of the simulation and integrating those points during subsequent instruction when other method are being used.

These various phases of uses of simulation may involve lecture, discussion, and independent reading and could involve cooperative learning. Once again this shows how simulation cannot or should not be considered a method completely separate from other methods (Duke & Seidner, 1978, p. 18). **In actual fact, instructional simulation, properly used, is a synthesis of instructional**

methods. Following these phases can increase the probability of learning from simulations, of gaining the full benefits.

(4) What Are the Ways to Measure Learning? The Best Way?

The measurement of learning from a simulation should not be considered as distinct from the measurement of learning from any method listed in Figure 1 (list of methods). If there is a best way for all methods, it is placing the learners in the context (*in situ*) in which the skills, attitudes, or appreciations are to be used or displayed and systematically observing the extent to which these skills/attitudes or appreciations are used or displayed by those learners. This usually entails delay from presumed learning to testing and is extremely perilous in the cases of some performance areas and prohibitively expensive in most. Thus it is only best from the stance of validity: validity in this use meaning accurate measurement and precise allowable inference.

In most practical measurement, written, oral, or performance tests can be used shortly after the classroom experience whether that experience is a lecture, a discussion, an apprenticeship or a simulation. In some instructional simulations, particularly computer simulations, however, records can be kept throughout the simulation of the responses of the learner. This response record, based on careful programming, can take the place of many traditional testing or learner assessment devices. In some instructional simulations this would be the major virtue of computer-based simulation, as opposed to some other type of simulation.

(5) Is There Cost/Benefit over Other Teaching/Learning Methods?

Given the wide range of types of instructional simulations noted in earlier sections of this paper and the large number of other methods listed in Figure 1 there is no reasonably complete answer to this question. Rational comparisons may be made, however. Assuming the comparative method is equally effective in learning outcomes:

1. Instructional simulation is typically more expensive than lecture or discussion;

2. Instructional simulation is, in most disciplines, with most objectives, less expensive than clinical or direct experience or cognitive apprenticeship because every student must be placed within a job or professional context while a simulation can be run over and over again with numerous classes;

3. The "up-front" costs, such as design (research and development) costs of instructional simulation, are typically higher than many of the other methods;

4. It is important to consider that often learning in formal classrooms suffers from deadening sameness, a lack of change of pace [Simulations can also become boring when continuously used (Bower, Bersamin, Fine, Carlson et al (1974)]. No method is categorically better than any other method, but simulation can provide a welcome and justifiable change of style, approach, or method, even when it is more expensive; and

5. Simulations are sometimes preferable over clinical or direct experience (Locatis & Atkinson, 1981) or cognitive apprenticeships. Especially when direct experience (a) endangers learners (or others) in the experiential situation (b) is difficult or impossible to provide (c) is too complex for the novice to comprehend and (d) unfolds so slowly that valuable interconnections are lost.

Therefore, within a curricuium or program context, day in and day out, hour in and hour out, most of the methods should be programmed into the experiences of learners. There is no single most efficient method for all students, for all topics, for all objectives, and for all parts of the curriculum, during the long hours in which the curriculum or program unfolds. There are situations, however, as discussed in items four and five above in which instructional simulations **can** have a clearly favorable cost/benefit ratio.

How Are "Good" Simulations Designed/Developed?

The most accurate and general answer to this question is that good instructional simulations are designed in ways that are similar and consistent with the designing of any type of instruction. In many senses the design strategies of a good lecture or film strip are quite similar to the design strategies of a good instructional simulation. There are several traditionally acceptable models of instructional design which may be applied to the design of any instructional format.

Perhaps the most traditional, most simply stated, and oldest design strategy is that which had its origins in the early years of the 20th century in the time and motion studies (Please see West, Farmer, and Wolff, 1991, pp. 2-3 for more on this).

Figure 3 Five Steps in Instructional Design Cycle

1. Set objectives
2. Preassess
3. Plan instruction
4. Teach or trial
5. Evaluate/test

Following Figure 3 one would (1) set the objectives of the simulation; (2) preassess the prior knowledge, skills, or attitudes of the target learners; (3) plan the simulation; (4) conduct trial runs of the simulation to "debug" it; and (5) conduct tests of learning and evaluations of its effectiveness.

One of the frequently omitted steps in the design of instructional simulation is sufficient trial runs. In our opinion, an instructional simulation, particularly if it were to be marketed, should be subjected to developmental research similar to a standardized test of intelligence or achievement. Practically and minimally, several test trials ought to be conducted [as Stolovitch (1976) recommends] with samples of the intended learners before the instructional simulation is considered to be adequately designed or developed. The evaluation and monitoring of these trial runs should be characterized by empirical approaches, dispassionate observers, and, if possible, external review (evaluators). Testing and evaluation of these trial runs may result in resetting of objectives and replanning, or redrafting the simulation.

A more modern and complex version of design steps, and one consistent with the psychology of instruction and learning until approximately 1970, is that of Dick and Carey (1985, pp. 2-3) which is also recommended by Gagne, Briggs, & Wager (1988, p. 22). Unfortunately, this design model, or system, has not sufficiently incorporated innovations from the cognitive perspective which has guided experimentation in learning and instruction since the early 1970's.

A new design model, or system, (please see Figure 4) which is even more complex and which does incorporate this new perspective and research and development is the model of West, Farmer, and Wolff (1991, pp. 209-263). This recent model provides guidance for the designer from the analysis of social, economic, and political forces acting on instructional designers (Phase 1) through the establishment of aims and objectives, content considerations, learning (or cognitive) strategy considerations, and instructional methods and media considerations to the final stage of testing and evaluation (Phase 6). Each phase has several steps.

Figure 4 Simplified Version of the Instructional Design Template

1. Situational audit
2. Aims and Objectives
3. Contents and Uses
4. Cognitive strategies
5. Means of instruction
6. Evaluation and Testing

(1) What Is the Fundamental "Process"?

We have discussed the value of thinking of the design of an instructional simulation as an instructional design problem. In our view the failure of instructional simulation designers to follow the general instructional design strategies may be due to their taking cues from recreational game development, in which the general purposes are entertainment, or operations research, in which the general purposes are debugging of systems entailing problem solving. Now we turn to some of the more specific design strategies in the instructional simulation literature. First we discuss the issue of the extent to which a simulation should reflect the event or situation being represented. This is the issue of fidelity or verisimilitude. Then we discuss simulation design strategies including Greenblat (1987 & 1988), Thiagarajan and Stolovitch (1978) and Duke (1980a, 1980b) and recommend some steps in design which could supplement those strategies.

Fidelity, Metaphor, Modeling and Verisimilitude

A basic issue in simulation, and one given considerable attention in the literature, is the fit or match between the simulation and reality. Unfortunately, this phrase "the fit with reality," or, any approximation of it, tosses us into unresolvable philosophical issues. Unfortunate also is that this phrase, "fit with reality," is based on naive assumptions: that there is a reality and that humans have the cognitive means to know and represent it in some absolute sense. This is the familiar "naive realism." Another naive assumption is that correct procedures allow the development of an accurate model. The accent is on the singular correct model. Thus there is assumed in "naive realism" one reality to know, and one correct way of knowing it.

Naive realism is generally considered a dated philosophy, a dated model of "reality" actually. More recent "models" or perspectives include relativism and phenomenology. Both modern options promote visions of multiple "realities" which are socially and personally **constructed rather than discovered** through human observations and interactions among humans and the universe. These perspectives or philosophies dominate the natural and social sciences today and have yielded exciting applications.

The ways of knowing attendant with naive realism (its "cognitive" psychology) is essentially that **what we see, hear, touch, taste is the reality. Events in the world occur and the eye-mind informs us.** Knowledge is determined by an external reality. On the other hand, the more recent cognitive psychology is that the nature of mind and eye, including the contents and processes of mind-eye, are more profound determinants of knowing than the event or reality. Or, to paraphrase Easterly (1978, p. 24), who places this in the context of simulation, information drawn from the environment does not constitute reality, but the designer's **perceptions** of reality.

To paraphrase this more recent view of cognitive psychology (and philosophy), humans probably construct their own individual "reality". Just as the astrophysicist constructs models of the universe and tests the current model as best it can be tested, other humans create models of how their businesses, interpersonal relationships, and governments operate; then they live by/in, and thus test, those models. **The most current name for those models in current cognitive psychology is "schemata." These personal models or schemata largely determine what we sense and what we subsequently know.**

All of this may seem far from the problems of instructional simulation; but, once one attempts the creation of a model to represent an event (or situation), it is one thing to assume a sole correct model. It is quite another to assume that many helpful models may be possible each of which are joint functions of the situation and the people involved.

This does not mean that one can or should create models without deep knowledge of the event or the knowledge about which the simulation is to be developed. None would recommend the development of an instructional simulation, or any form of instruction for that matter, without expertise in the particular area, or that part of the discipline the game supposedly represents. It is clear that Greenblat (1988) would not, for she eloquently defends deep knowledge of the discipline, events, issues, or problem, being simulated.

Returning to the issue of validity of representation and simulation in the context of modern cognitive psychology and philosophy, what are the interfaces between the simulation and that to be represented? The task is traditionally and deceptively simply stated: to construct a model. To be instructive, most models (or simulations) have to be in some measure like something or some event, but like what thing or what event, or what part of the event?

Since we have argued that all knowledge is model (and schema) based, it seems candid to admit that when a model is built to represent something, then that model is a model of a model. In other words, a simulation is unlikely to be a model of a "reality," but it is more likely to be a model of some person or persons models or schema.

From the stance of modern philosophy and modern cognitive psychology let us, as simply as possible, outline a more modern statement of the related issues involved in the determination of accuracy of the representation with the accompanying task of designing a game for the purposes of instruction.

Tracing simulation construction through the conventional (and largely correct) procedures as outlined by Greenblat (1988, pps. 27 ff.), one

1. Sets objectives and parameters,
2. Develops a model,
3. Makes decisions about representation,
4. Constructs and modifies the gaming-simulation, and
5. Prepares the simulation for use by others.

It is in the first three stages that corrections of statements and, in some cases, reorientations of designer activities are needed; because it is here that most developers speak of "the real-world system" (for example, Greenblat, 1988, p. 28). It is in these stages that the issue of verisimilitude or accurate representation is paramount. The first correction, a verbal statement correction [Please see Bruner (1986) and West (1987) for discussions of the centrality of "utterance correction" (verbal representation) in education and science], is not to speak of modeling "real-world systems" or "the system," but of modeling (simulating) a model-- a choice of models among several models which probably exist. [Please see Anderson (1987) for further discussions of some implications of the "reality problem" for simulation].

To some in cognitive science this is tantamount to the creation of a metaphor. The simulation is a metaphor, analogy or model of "the real-world system."

Rather than speak or write of "reality" or the "real-world system" or "the system", let us speak of *in situ* (the place or situation where people perform and learn and from which simulators attempt to develop a model for instructional purposes). For example, *in situ* for management could be any corporation, organization, or business. Designing instructional simulation representing management procedures would likely involve observing managers on site and creating a model or several models of several observed managerial actions. The observations would likely vary among the sites, if there were more than one, and among individuals, if there were several. For simulation development a designer approximates a model, but that model is constructed from the individuals observed and their models in their situations.

Still it is essential that the game designer learn a great deal about *in situ*, the place in which models are used and from which instructive models are derived. For example, a designer seeking a model for a management simulation should become familiar with management practices in a variety of organizations. But there should be acute awareness that several equally operative models may be used by individuals *in situ*. Then an odd thing happens on the way to simulation design: the designer's models (schemata) are invested in the reconstruction of the *in situ* individuals' model or models. The goal is to simulate, to model, but existing *in situ* are simulation designers' models, observed individuals' models, and quite possibly communal (culture- or group-based or organizationally-based) models. What is meant by "communal" is the shared conventions of "the way things work in the represented field."

In the communal models, we may become embedded in discipline or *in situ* variables which are so powerful that the procedures of simulation development must be readapted. One very specific design implication is to be alert for such differences, to be alert to the communal or shared models of what works, especially when what works is either extremely controversial, not the best, or inadequate, but is merely habitual. In these cases the designer's simulation or model should be altered to reflect a better, improved method which the simulation will then help to teach. It is known (West, 1981) that group-based perceptions, judgments, attitudes and schemata have as profound effects as individual-based schemata.

Knowledge of the relevant discipline is convincingly recommended by Greenblat (1988) and is very necessary in designing all high quality instruction. This typically involves studying models of the experts in the relevant discipline, particularly in the cases in which one studies documents including recorded procedures. Someone or some group devised the documents. Specific questions such as the following should be attended carefully.

- Who devised this material?
- What is the implicit model? (Models may be as invisible as assumptions.)
- Is the model a consensus model?
- Are the informants consistent with consensus in the field?
- Do informants agree among themselves?
- If the model is a communal model, is there danger of group-think (Janis, 1972; West, 1981)?
- If the game developer's procedure is to observe the system (*in situ*) directly, what is the implicit model of the developer?
- If the system is a consensus based system, is it troublesome? That is, is there some sense of change imminent? Are there controversial issues abounding? Are vested interests gaining excessively from the consensus? Has the system become unnecessarily rigid?

Figure 5 Competing Models

1. Simulation Designer's Models
2. Observed Individual's Models
3. Other Communal Models

It is odd that deep study of the discipline (*in situ* in our words) receives such emphasis in the instructional simulation and simulation literature (please see Greenblat, 1988, pps. 27 ff. for an example) given that few educators would advocate any systematic design of instruction using any method listed in Figure 1 without knowing the field. Imagine developing a lecture, for example without knowledge of the subject. Yet, if simulations designers feel that it is necessary to emphasize this, it once again demonstrates the extent of simulation designers needs as well as their general and very undesirable isolation from instructional design. **All methods of instruction require knowledge of the content during their development.**

As we have mentioned, the variables in the knowledge domain, or discipline, can be significant. In particular, these questions are critical: Is the knowledge domain ill- or highly-structured? Is it overstructured? If ill structured be cautious. By ill- and highly- structured we mean the extent to which the field is governed by the rules of logic. Generally there are but two disciplines which are highly structured, logic and math. All other fields are generally ill structured and are rife with assorted "truths" and procedures. By "overstructured" we mean that there is high social agreement or consensus about "truth" or proper procedures when, in fact, there are several "truths" or effective procedures, but only one has become acceptable to the exclusion of perhaps other acceptable "truths" and procedures -- to the point of becoming excessively rigid.

There are at least two types of systems which may be represented in simulation, thus two types of models: personally constructed (In which case go to the expert!) and consensually, socially constructed (In which case, go to the experts collectively!). Rorty's (1979) truth is "what works," and we add "what is **thought** currently to work."

Conditions Which Determine the Instructional Value of Verisimilitude or Fidelity

Verisimilitude, or, as it is in some texts referred to as fidelity, is generally viewed as an important and desirable characteristic in a simulation. This may be a transposition from simulations in operations research to instruction. In operations research fidelity is practically always imperative. In instructional simulation, however, fidelity is not always desirable for a variety of reasons. There seem to be three classes of variables which influence the desirability of verisimilitude [matching *in situ* characteristics (particularly complexity) with characteristics of the instructional simulation]:

I. Learner variables
    - stress tolerance
    - anxiety
    - ability
    - prior experience
    - tolerance for noise in an information system

II. Task variables

- complexity [Varying complexity within a simulation may be desirable should simulation constraints, rules, and variables become more and more like external models (more complex)]
- importance
- rapidity of output required
- noise management requirements

III. *In situ* or model variables

- complexity
- speed of running (when unfolding of *in situ* events occur so slowly that valuable interconnections are lost, for example).

This list helps to underscore the difficulty of deciding on the extent to which verisimilitude should be incorporated into an instructional simulation. We are, obviously, arguing that the value of verisimilitude is not trivial (Lederman & Ruben, 1978, Elder, 1973, Ruben & Lederman, 1982, & Sharrock and Watson, 1987) and that it is an interactive function of at least three types of variables: learner, task, and *in situ*. Each of these types of variables potentially subsume many more specific variables. In the final analysis, empirical methods should be deployed to determine the value of verisimilitude, particularly in designing simulations for highly sensitive, dangerous, or extremely expensive instruction.

Levin and Waugh (1988) have suggested an interesting and potentially powerful way of managing complexity and fidelity (or verisimilitude) in simulations for learners. Their idea is to provide learners with a range of fidelities in which the novice begins with simple settings and moves toward more complex settings. They use the phrase **dynamic support** for decreasing the amount of support necessary for novice learners as they engage increasingly complex simulation settings.

A major consideration about verisimilitude is to design the simulation to "bring the learner along," to cause gradual learning. It may often be necessary to gradually increase complexity when performance *in situ* is complex, or the situation is complex, otherwise the learner may be overwhelmed. Too great a match between the game and the complexity of efficient *in situ* performance can often overwhelm the learner, particularly at novice levels of learning. For example, for flight training simulation should usually have low fidelity initially, with gradual introduction of greater fidelity.

Another important consideration involving fidelity is credibility (Elder, 1973), the extent to which the learner believes that there is matching between the simulation and *in situ*. The credibility of the simulation increases the probability of learning, up to a point. Fidelity increases credibility, generally. Too much fidelity decreases the probability of learning complex tasks. Thus some instructional simulations become caught in crosscurrents of learning, credibility, fidelity, and complexity. Consideration of the three types of variables listed above can help designers instructionally manage those crosscurrents.

In the next section we discuss further simulation design issues. We begin with a presentation of the more widely used and cited systems.

(2) What Are the Discrete Design Steps of the Process? Are there Shortcuts? Alternatives?

We have located several design systems which seem to predominate in the field of instructional simulation. In the following pages we list the discrete steps and, later, attempt a comparison and contrast. Later we offer some additional or supplementary design procedures.

Of the first two systems, the Thiagarajan & Stolovitch (1978) is the more detailed. Notice that all three procedures prematurely stop once it is found that the system can be made to "run." It seems to be accepted that if the game can be played by the rules without the developer being present, then it is a success-- and that instructional objectives were attained. It is intriguing that Duke's (1980) procedure for step eight is that the client conduct the evaluation. There are no steps or phases included for the **testing of learning** or the evaluation of the success in terms of the effects of the game on learners, unless, in the procedures of Duke, the effects are part of the criteria specified in step 1. To us this lack is a recurring sign of the isolation of gaming design from instructional design and instructional research. As we have said, this may be a result of instructional simulation design being more influenced by the design of simulations for entertainment or for operations research and development than it is influenced by instructional design.

Figure 6 Simulation Design Systems

Greenblat (1976, 1988, pps. 27 ff.):

1. Set objectives and parameters.
2. Develop model.
3. Make decisions about representation.
4. Construct and modify gaming-simulation.
5. Prepare simulation for use by others.

Thiagarajan & Stolovitch (1978), checklist of steps, p. 68

1. Define the instructional topic.
2. Construct a model to reflect the real-life event.
3. Select a suitable game format.
4. Identify the major characters, resources, and constraints.
5. Specify the overall game sequence.
6. Specify the termination rule.
7. Establish the criteria for winning.
8. Design a sequence for each round.
9. Write a background scenario and role descriptions.
10. Assemble prototype materials and equipment.
11. Test the game with players and revise.
12. Write the player's manual.
13. Test the game under "hands-off" conditions and revise.
14. Specify the outcomes of the game.
15. Prepare the administrator's manual

Nine basic steps of Duke (1980a, 1980b):

1. Develop written specifications for game design;
2. Develop a comprehensive schematic representation of the problem;
3. Select components of the problem to be gamed;
4. Plan the game with the Systems Component/Gaming Element Matrix (column headings = game roles, row headings = steps of play);
5. Describe the content of each cell in the matrix (step 4);
6. Search "repertoire of games" for ideas for each cell in the matrix (step 4);
7. Build the game;
8. Evaluate the game using the criteria of step 1; and
9. Test the game in the field, and modify.

It is unlikely that there are any shortcuts to good design. All improvements of instructional design practices are intimations of making design more, rather that less, complex. If instructional design simulation is to be brought into focus within instructional design and development <u>in general</u>, and if instructional simulation is to fulfill its potential, more complex strategies are probably warranted. There should be more designer viewing of the on site situation (e. g. task analysis) or more study of the discipline. There should also be more designer produced models of *in situ* processes and practices, particularly in ill-defined domains and situations (up-front simulation design work), as well as more testing and evaluation efforts to observe the short- and long- term effects of the specific instructional simulation. These are better approximations to both the effective and the ideal forms of instructions-- whatever the method.

Procedural explanations such as those design steps outlined in Figure 6 are often overdrawn, excessively linearly presented, and not intended to be followed as sequentially as the lists appear. Good simulation design will incorporate these steps and numerous substeps or subroutines, some mentioned and some not, but will not often be as orderly (Easterly, 1978) or as linear as represented above.

At any point in the procedures enumerated in any of the systems in Figure 6 the designer may need to return to early steps or forecast shapes of steps not yet embodied or, even firmly conceived. Good technological guidelines exist; but they are, after all, guidelines, not immutable laws. This is apparent from the variances in the design steps enumerated in Figure 6 and from the interviews conducted.

When one designs instructional simulations shortcuts may be taken, generally, only at the peril of learning. What appears to be shortcuts usually are understatements or oversimplifications of procedures. While one expert (Greenblat, 1988) has listed fewer steps than others (Thiagarajan & Stolovitch, 1978) the difference is, in our opinion, more in Greenblat's preference not to list subroutines than in real differences of procedures.

<u>Improvements in Design.</u> Any of the three systems included in Figure 6 obviously work. There are, however, suggestions we can make which can, if followed, improve any of the systems. First, a task analysis (Jonassen, Hannum, & Tessmer, 1989) or its cognitive (Braune & Foshay, 1983) or affective counterparts may be needed for the setting of objectives or defining the topic of the simulation. Task analysis is basic to systematic instructional design. One caution, however: task analysis can aid the uncritical recording of current *in situ* practice and serve to only reinforce current, and flawed practice if fed into the instructional simulation. Any model or simulation can become seductive (Please see West, Farmer, and Wolff, 1991 for further discussion of seduction in instruction, particularly when metaphors are used and **simulations are metaphors**), that is, the simulation is erroneously taken to perfectly match *in situ*. When current *in situ* practice is known to be flawed, inefficient, or extremely controversial, task analysis may primarily serve to perpetuate those flaws, inefficiencies, or controversies.

Our second design recommendation is to provide for systematic psychometric evaluation of learning from instructional simulation. As a symptom of empirical, psychometric neglect, note the scarcity of it in the recent 342 page proceedings of the 17th International Conference of the International Simulation and Gaming Association (Crookall, Greenblat, Coote, Klabbers, & Watson, 1987), the 212 page volume edited by Hollinshead & Yorke, (1981), the 216 page volume of Ellington, Addinall, & Percival (1981), the 168 page volume edited by Megarry (1977) and the 375 page volume of Shears and Bower, (1974) . It is very likely that this inclusion in design would help to dispel many of the broader and unsubstantiated claims for effects of instructional simulation. It is also likely that it would result in more instructionally powerful simulations.

(3) How Are the Objectives for the Simulation Established?

In this there is no substitute for entering the situation in which the skills to be taught are to be used or applied and conducting a task analysis, or its cognitive or affective equivalent, as we have emphasized earlier in this report. The idea of an equivalent is significant because so many simulations are not intended to teach performance of "tasks" *per se;* but, rather, interests, attitudes, appreciations, and higher level intellectual operations. The basic idea is to find out what performance, intellectual operation, or attitude is deemed adequate or appropriate *in situ* (the place in which the skills are to be deployed) and describe it in detail.

One example of what we mean here is the designing an *in-basket simulation*, for example, to teach federal acquisitions. In other words the designer of this in-basket simulation should conduct an analysis of federal acquisitions *in situ* to determine how it is done. If the intention is to teach attitudes, then what are the attitudes present? If the intention is to teach the intellectual skills or information about procedures, then what are the procedures in place? In many cases the instructional objectives may be transcribed from the site by conventional task analysis.

But as we have discussed in an earlier section, if the *in situ* procedures are considered to not be working properly *in situ* or if they are controversial (e.g. models or schemas of experts are found to differ) then the direct transcriptions of skills to objectives may be very problematical. The "task analysis" may have to be supplemented or even replaced by defaults such as reliance on informants or experts. The choice of informants or experts then becomes a problem.

In summary, however, the typical strategy is to conduct an analogue of the task analysis and transcribe directly to objectives. It should be emphasized that there is little reason to be preoccupied with stating them in behavioral terms (Locatis & Atkinson, 1981 and West, Farmer, & Wolff, 1991). In most cases this transcription works. Care should be taken not to myopically focus on behavior.

This is generally not a problem in the simulation literature and practice. If, however, the objectives are behavioral in nature, it may be desirable to determine the affect and the intellectual operations associated with the behavior. This focus, of course, depends on the intended outcomes and other variables.

(4) How Are the Objectives Translated into (Incorporated in) the Learning Vehicle?

Once a task, affective, or cognitive analysis has been conducted, the most conventional strategy of translation is to take each detailed step in the analysis and turn it into an objective or a series of objectives. If each step is to be incorporated into the simulation, a miniature representation of each step, or phase of the analysis must be conceived by the designer and incorporated into the rules, routines, cycles, scenarios, components, criteria, or constraints of the games.

We recommend a systematic checklist for this operation consisting of the following: step or part of the analysis; corresponding objective of game; and corresponding component of game. Please see Figure 7 for a recommended checklist. If each part of the task, affective, or cognitive analysis is important then corresponding objectives should probably be conceived and specific components of games ought to be designed for each. Such a checklist should provide help for this incorporation.

Studies of Effects and Implications for Evaluation

In this section we will present an overview of literature on the evidence that simulations effect learning as well as how to internally evaluate an instructional simulation by the analysis of its contents. Since "let the buyer beware" is especially important in simulation, the latter can be very important to a user who may not have the desire or the resources to evaluate a simulation any other way.

Figure 7. Checklist for Incorporating Objectives
into the Instructional Simulation:
From Task Analysis to Game Component

	Corresponding Objective of Game	Corresponding Component of Game
Task #1 Part 1 Part 2 . . Part N		
Task #2 Part 1 Part 2 . . Part N		
. . Task #N Part 1 Part 2 . . Part N		

(5) How Is the Achievement of these Objectives Demonstrated?

As we have stated in an earlier section above, in well established instructional simulation design systems, the typical case is that many simulation designers assume that the conceptualized instructional objectives will be achieved if the simulation "runs" without bugs. This is equivalent to believing that if a classroom discussion is held, or a lecture given, the stated objectives will be achieved. Pedagogically this is unsound and naive. No instructional method has been found to be so robust a treatment even occasionally, and certainly not routinely.

The demonstration of the extent to which instructional objectives have been achieved should be a matter of systematic empirical observation, usually after the instruction. There is a rich and practical testing and evaluation research and development literature which provides a wide range of testing and evaluation techniques. There should be evaluative observations which are focussed on each important learning goal of the simulation.

While this evaluation of achievement is most often conducted after the instruction, it is possible to design some instructional simulations, particularly if they are computer-based so that the assessment of learning indicators are conducted systematically and recorded and monitored during the instruction itself. This is not restricted to testing low-level knowledge but can be extended, with careful and systematic design, to higher level cognitive and assorted affective goals. Responses students make and the patterns of those responses can be evidence of assorted kinds of cognitive and, properly and carefully sequenced, affective change. What that evidence constitutes is largely a matter of careful design, programming, and inference.

Even when testing and evaluation are conducted during the "run" of a simulation they should not be taken as the best evidence for learning (attainment of objectives). For most instructional objectives the demand is for long-term changes in behavior, cognition, or affect. Educational institutions invest heavily in the expectation of this long-term change. The best, then, as we have argued in other sections of this report, is to observe the former students performing *in situ*-- that is, in a working environment-- after the instruction.

In the following paragraphs we will discuss and present (Please see Figure 8) some of the attempts to empirically evaluate learning from simulation games and the existing reviews of attempts to research effects. Categorically, instructional effects for simulations cannot be claimed for a variety of reasons including student ability (Thorpe, 1971), variations in use patterns by the instructor (McKenny & Dill, 1966), and the tremendous range in quality and type of simulations.

In Figure 8 we will summarize several studies and reviews of effects of simulation on various dependent variables such as assorted types of learning, attitude change, and motivation. Column headings of Figure 8 are study (or review), specific simulation or topic if applicable, objectives, and findings. In the findings column in the cases of reviews, the first number represents the number of studies said by the reviewer to have results in which there were differences, or effects favoring instructional simulation. These reported effects are not always statistically significant. For some the appropriate phrases are "in the direction of" and "tends to support" which many social scientists would reject as merely not statistically significant.

One of the more thoughtful and carefully done early reviews is that of Pierfy (1977). He divides evaluation research on instructional simulation into three types. The first is descriptive studies of the effects of a game on one group of subjects. The second is explanatory in which the researcher tries to establish that the game had an influence on particular subjects. The third type of evaluation is the comparison of learning from simulation with learning from another method. Despite the favorable ratio for simulation noted in Figure 8, Pierfy has little faith in the validity of the studies themselves. Among the problems he discusses with the research are lack of representative subject samples, experimenter bias, failure to control for critical variables such as instructor differences, and validity (accurate measurement) and reliability problems with the tests or instruments used for the measures.

In another thoughtful review Bredemeier and Greenblat (1981) emphasize the disparity of the impressionistic evaluation *versus* the psychometric evaluation. They also emphasize the difficulty of determining the effects of instructional simulations. Some of the variables which they think mediate the possible effects of simulations are: administrative variables, such as instructor characteristics, nature and quality of introductions and debriefings, and variations in game play of the same game; internal game variables, such as fidelity, quality of the design strategy, and the matching of game characteristics with intended outcomes; group variables, such as group size (Gentry, 1980), and group dynamics; and student characteristics such as attitudes toward the game prior to playing the game, sociometric grouping (Brand, 1980), sex of players, cognitive style (DeNike, 1976), personality, academic ability and game ability. In the Bredemeier and Greenblat (1981) article, the basis for the claims of the effects of these mediating variables differs. Still, it is very likely that many of the dissonances in the literature on effects of games are attributable to these and other variables.

Figure 8, Overview of Reviews and Single Studies of Psychometrically Observed Effects

Study or review	Sim.	Objective(s)	Findings
Livingston (1972)	Democracy	attitudes	sig.dif. comp. to controls
		interest	no sig. dif. comp. to controls
Stembler (1975)	World War I	factual knowledge	sig. dif. comp. to reading
Szafran & Mandolini (1980)	SIMSOC	factual knowledge concept recognition	not sig. not sig.
Williams (1980)	topic: medieval history	attitudes	sig. diff. from reading only
Brenenstuhl (1975)	topic: management, The Executive Game	cognitive and affective	not sig. diff. from lec./dis.
Pierfy (1977) (review)	N/A	numerous, assorted	
		(initial learning)	3/18
		(delayed posttest)	8/11
		(attitude change)	8/11
		(interest)	7/8

In a more recent review, Dorn (1989) located numerous references which portray the complex and conflicting picture of simulation evaluation research. This more recent portrait generally is not substantially different from findings of earlier reviewers.

It is unclear whether or not instructional simulation is particularly superior to any other method for any given objective. There are not enough properly designed experiments to allow this inference. While much of the literature reflects a belief that simulation is superior as a method for such objectives as increasing motivation to learn, interest in the subject, or affective change, the psychometric evidence is very mixed. Thus, educators have every reason to be wary about **any claims of categorical superiority over any other methods.**

On a more positive bent, while the portrait of effects is indistinct, researchers have provided sufficient evidence that instructional simulation serves as, in Dorn's (1989) words, "one more tool on the pedagogical shelf." Looked at from this perspective, one **selects a method for a purpose** within a course or curriculum, not a method for a course or curriculum. It is clear that a **properly designed simulation, properly used, *can be* a powerful instructional method. It is not at all clear that simulation is categorically superior to any other method. Nor should there be any assumption that any type of specific objective can necessarily be better achieved with a simulation.**

(6) How Do the Designers Know when They Are 'There?'

There is no adequate substitute for objective, dispassionate, empirical testing and evaluation. After running the simulation with adequate samples of persons, after conducting the debriefing, after everything to be done with the simulation has been done, do adequate samples of learners exhibit the behavior, or affect, or cognitive process that was the objective and, to what extent? This is usually an adequate way of evaluating an instructional evaluation. Even better is to wait until students are in a work situation and see if they exhibit the intended outcomes of the simulation. Effective instruction -- whether it is a lecture or a simulation-- is that from which the learner exits having learned what was intended and that which persists to be used *in situ*.

There is, however, another -- **and, at best, complementary**-- approach to evaluating an instructional simulation game. That is to conduct a content analysis to determine if the game has characteristics deemed desirable. This complementary approach is crudely similar to art criticism, whereas the empirical evaluation by effect on the learner is similar to engineering. These content analyses range from simple and descriptive judgments including such considerations as topic of game, number of participants, run time, and so on (Ruben,1980) to the more evaluative including such considerations as significance, validity, flexibility, accessibility, and so on (please see Ruben, 1980 for more detail of these considerations). In Figure 9 we include several criteria (derived from Horn and Cleaves, 1980) in a frame which could be used as a guide to conduct an evaluation by content analysis and a checklist for recording results. It seems to be consistent with recent views among the simulation game developers and evaluators. The criteria included in Figure 9 vary from merely descriptive to more evaluative.

Implications for Users. Those who plan to use instructional simulations developed by others should be mindful of "let the buyer beware." Typically designers do not systematically, or psychometrically evaluate their simulation for learning effects. Until users demand this, and become more sophisticated consumers, users must either first purchase a simulation and later collect their own learning effects data or merely assume that the simulation is as cost effective as any other instructional method. **Our view is that every choice of a method suffers from this lack of demonstration of learning effects: there is no best method of instruction. Instructors and educators must learn to evaluate empirically what is done in the classroom. They must learn to try a method and test for effects, and, perhaps, try another and test it for effects. When costs are higher with any method, the necessity to demonstrate effects is greater.**

Conducting Local Evaluations. To accomplish this demonstration of effect we recommend that users follow a procedure similar to the following. First, carefully attend to the learning goals or objectives of the simulation used. Second, create a pretest consistent with those objectives or goals. Third, administer that pretest to students. Fourth, run the simulation on the class. If possible and feasible, have other classes as controls. For example, if there are two sections of the same course, withhold the simulation from one class which was selected randomly. Keep all classes as similar as possible except for the simulation treatment. Fifth, administer a posttest. Sixth, examine the results for significant or important differences on test performance. **This is not a perfect evaluation plan but it is feasible in many situations.**

Figure 9
Simulation Evaluation Frame

Criteria	name of game	evaluation comments
Substance		
scope		
depth of content		
awareness		
social skills		
Communication		
Clarity of information		
Completeness of guides		
Pedagogy		
support of teaching		
Appeal		
Transferability		
Instructors Role		
preparation		
supervision		
debriefing		
Rules		
clarity		
(for instructor)		
(for player)		
organization		
(for instructor)		
(for player)		
completeness		
(for instructor)		
(for player)		

Figure 9 continued
Simulation Evaluation Frame

Debriefing

adequacy

thoroughness

Flexibility

Game resources

Scoring

Model validity

Packaging

kind

cost

completeness

durability

reusability

Purpose of simulation

Effectiveness
(in achieving purposes)

Style of interaction

Preparation by students
to play

Role play

structured?

interest factor

changing roles?

---

(7) How Do the Students Know when They Are 'There?'

This is the best: when it can be graphically demonstrated to the students that they have learned what was intended and/or some valued incidental learning. As we stated earlier, this ideally happens after the learner takes skills to the site of use. More realistically, the tried and true design strategy of pretesting operates well, but at this point it operates to provide the demonstration of change from skills mastered or not mastered prior to the simulation to skills mastered or not mastered after the simulation. But, again, the best demonstration is well after the simulation when the learner is on the site of the intended use of the skill. This is too late for the learner who has left a program of instruction, but it provides valuable information for those yet to enter the program.

In so many formal learning situations the instruction is evaluated solely by the opinions of the students, that is, whether or not they feel that they learned. This is generally the weakest form of instructional evaluation, but its virtue is that it is easily conducted.

Conclusions

There is excessive reliance in the literature on the dichotomy "us" (the simulation designers and advocates) *vs.* "them" (those who use any or all other instructional methods). This is a familiar dichotomy used by so many entrenched in the self-assigned and self-serving role of innovator. This is very typical for advocates of any instructional method. It is true of those who advocate discussion versus lecture and it is true for those who advocate cooperative versus competitive methods.

There are excessive, unnecessary, and nonempirically based claims of outcomes for simulation. While we have found evidence that some simulations produce claimed desirable effects, many claims are made which are unwarranted. This should not, however, substantially detract from the willingness to use instructional simulation, to try it, and to evaluate its learning effects locally using the step by step plan we recommended in this report or one similar to it.

Instructional simulation is a worthwhile instructional method which has had some proven positive outcomes. There are conditions in which it is cost effective and we have enumerated those conditions. The probability of an instructional simulation being worthwhile should be increased if the design and evaluation recommendations made herein are followed.

There is an unusual frequency of reliance on claimed outcomes that are affective in character, and thus assumed naively by advocates to be practically impossible to measure. It is naive to assume that affective learning cannot be empirically assessed. The psychometrics of affective measurement continue to develop.

In this report we have responded primarily to three categories of issues or questions (components of good simulations, proper design, and evaluation and testing for effects) about current practice and have argued that current practice is quite good, with a few exceptions such as the failures of simulation designers (1) to conduct task, cognitive, or affective analyses during early phases of design; and (2) to psychometrically evaluate the instructional effects of simulations prior to marketing the simulation and (3) to include that as a part of design. In the absence of the latter we have recommended that users conduct empirically based evaluations of simulations themselves. We included a step by step procedure of accomplishing this. We have also recommended that they use the detailed checklist provided to conduct a content analysis of simulations offered to them for purchase. We have also presented a step by step guide for the proper instructional use of instructional simulation by instructors and educators.

We think that the future of instructional simulation design and use during instruction will be substantially congruent with our recommendations. While research incorporating our recommendations would require complex designs, it is not beyond feasibility. Without complex research and development designs, instructional method questions and controversies will continue to be resolved within rhetoric and bias rather than systematic observation.

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Appendix A

Computers in Instructional Simulation

Computers in Instructional Simulation[1]

James E. Snellen
Steven L. Murray

PERSPECTIVE

A computer does not make possible, in instructional simulation, anything which could not also be done by human facilitators. For certain types of educational simulation, the task of execution becomes easier, or even feasible, by the addition of computer support. What computer support encourages, and in some cases absolutely demands, is a strict degree of rigor and consistency in defining and executing:

- **The underlying model on which the simulation is based.**
  If an algorithmic model (i.e. a model in which all rules and methods are explicitly defined) for the simulation cannot be established, then it is not possible to base the simulation upon computer driven support.

- **The way in which the learner(s) will interact with that model.**
  For computer mediated simulations, interaction with the model requires interaction with the computer. For putting information into the computer, the options available include devices such as the keyset and pointing devices (e. g. mouse, touch panel, light pen, etc). Voice input is possible although its development is still at a primitive stage as of this writing. For receiving information from the computer, there is the computer screen (monitor), the computer speaker (for sound effects) and paper prints. The issue of how to facilitate human-computer interaction has been a major subject of study in itself (Shneiderman 1986).

  The second consideration is one of interaction style. Input from the learner can range from free-form text input to pre-defined menus to video game formats. This range of styles roughly corresponds to a spectrum of maximal to minimal cognitive processing and minimal to maximal reflexive processing by the learner.

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[1] In order to discuss the role of computers in instructional simulation, it is necessary to use some of the technical jargon from the field of Computer Science. As an aid to the reader, this paper includes a glossary which defines those terms which may otherwise be obscure. Because this paper deals with the application of computer technology to instructional simulation, we have attempted to define the terms in the glossary in a way that is meaningful in the context of computer based instructional simulation. Also we have simplified (in some respects, *oversimplified*) some of the concepts in order to make it easier to understand the general concept of the terms.

- **The way in which evaluation data will be collected during the execution of the simulation exercise.**
  The question to be considered here is whether or not we want the learner to be directly or indirectly involved in the evaluation. If the learner is to be directly involved then the possible means of evaluation available include pre/post testing and self-evaluations. If the learner is to be indirectly involved then transactional recording and analysis is an obvious choice.

  One great advantage of using computer support for simulation is that this technology is particularly well suited to doing transactional recording and analysis. This is particularly true because the computer can record, as well as analyze, in a completely rigorous manner. Since transactional recording/analysis is, of necessity, an algorithmic process, its application by a computer is, by definition, completely explicit and consistent.

Implementation

To understand the current practice of how computer technology is applied to instructional simulation, it is necessary to understand the distinction between the **software** which determines the behavior of the computer and the simulation *database(s)* which determines how the instructional simulation itself behaves.

For the purposes of this discussion, **software** refers to computer programs written in some high level programming language such as PASCAL or FORTRAN. These languages are designed for expressing the algorithms which govern the computer's behavior. Using these languages effectively requires the specialized skills of a trained programmer who can translate the task to be done into the types of algorithms that a computer can execute. By this definition, **software** is *computer-oriented.*

On the other hand, a **database** or set of **databases** which define the behavior of a computer based simulation are *human-oriented*. This means that the database(s) are designed to express the characteristics of the simulation in a form that is meaningful to a simulation content expert. This relieves the content expert from any need for skill in using programming languages.

When a simulation is based upon a suitable algorithmic model, then developing computer support for the simulation requires a heavy investment in software/database design and development. For the software, this takes the form of:

- defining the problem(s) to be solved.

- reducing those problems to algorithmic definitions.

- coding the algorithms in a suitable computer source language.
- testing and debugging the source code that embodies those algorithms.
- writing the documentation upon which programers will depend for the future support of the source code.

For the database(s) which define the nature and behavior of the simulation model, design and development means:

- determining what types of databases are needed to define the simulation model.
- determining what kinds of data structures are required to embody those databases.
- developing, where necessary, the compiling software to build these data structures.
- debugging these databases so that they produce the desired behavior in the simulation.
- writing the documentation that future scenario designers will need in order to support existing scenarios and to create new scenarios.

Even after the design and development are completed, it is necessary to make an additional long term commitment to support both the software and databases which embody the simulation. For the software, this means:

- correcting bugs which are discovered through the continued use of the simulation.
- revising the software to utilize new capabilities in the simulation database(s) as they are developed.
- revising the software in order to take advantage of new technologies in computer hardware and software as they become available.
- revising the software to satisfy perceived needs for changes in the simulation utilities. Such utilities include the user interface and automated support for evaluative data gathering.

For the simulation databases, this continued support takes the form of:

- correcting bugs which are discovered through the continued use of the simulation.

- revising the databases to improve their fidelity in model representation.
- writing new scenarios and updating old scenarios as the need and/or opportunity arises.

In return for the investment of this time and effort, the simulation and its associated repertoire of scenarios embodies the expertise which the simulation is designed to convey.

DESIGN CONSIDERATIONS

User Interface

The very fact that a computer is being used to support an instructional simulation means that the user(s) of the simulation will have to learn the skills required to use the computer. The notion here is that one must know how to manipulate the computer in order to take advantage of the instructional simulation. Shneiderman (1986) recognizes this as *syntactic* (computer manipulation) as opposed to *semantic* (simulation specific) knowledge. To the extent that these syntactic skills are irrelevant to the simulation itself, the learning involved may be referred to as *unrecoverable* as opposed to *recoverable* learning which is relevant directly to the task or event being simulated (Frank Mabry, personal communication). Ideally, the cost of this unrecoverable knowledge should be kept as low as possible through the use of computer - user interfaces which are carefully and consistently designed.

Pavia (1990) has written an excellent description of the features which constitute a good computer based instructional simulation. The example he uses is SQUALOR, which is a simulated exercise in organic qualitative analysis. Among the factors which constitute a good user interface for a computer simulation are the following:

1. *Interactivity*
   The essential notion of interactivity, as described by Pavia (1990), is that the users must feel that they are in control and that the simulation is responsive to their needs and goals.

   a. *the "home base" concept*
      Central to this idea is the concept of a "home base" to which the user knows that (s)he can always return. The "home base" is a known starting point from which the user can browse through all options offered by the simulation in order to get a feel for how the simulation is laid out. At any time, and from any point in the

simulation, however, the user can return to the "home base" via a consistent keypress (usually by pressing the Escape key one or more times. Typically, this "home base" is a main menu which leads to all other options in the simulation.

b. *menu design*

Menu design is another critical feature of interactivity. Pavia (1990) favors drop down-menus so long as there are only a few options contained in each menu. Such menus are particularly useful when a mouse is available. However, there is also a danger that neatly organized and simplified menus could preempt some of the organizational thinking that the learners should do for themselves. This issue arises when the learner must make a *strategic* decision when choosing an option from the menu.

In Pavia's SQUALOR program, such a situation arises when the learner must choose from among many analytical tests which vary both in power and cost (usually in direct proportion to each other). In this case, Pavia uses a large, complex menu which provides some sense of the complex choices the organic chemist faces when conducting a real analysis. To expedite the use of such a complex menu, Pavia provides single key input for selecting menu options.

c. *Interruptability*

Unless there are good reasons not to do so, it should be possible for the learner to interrupt the simulation at any point and store a recallable image of the simulation's state variables. This allows the learner to begin a new problem, or resume the old problem at will. It also has the advantage of allowing the learner to store an image of the simulation at a point when some difficulty arises so that the problem can be reviewed by the instructor.

d. *availability of help*

There should be both generalized help and context-sensitive help available at all times. However, when designing the online help for a simulation, it is critically important that the help not unduly bias the learner toward conclusions or actions which (s)he should draw from their own judgement within the context of the simulation.

e. *self-assessment*

The simulation should provide some feedback to the learner as to "how well they are doing". In Pavia's SQUALOR, this takes the form of recording how much of the unknown organic sample is consumed by each test as well as charging the learner a varying number of resource points for each test depending on the difficulty and usefulness of the test. Adequate feedback of this type lets the learner evaluate whether they have solved the simulation problem efficiently or by brute force.

f. *availability of appropriate information and tools*
Ideally, the learner should not have to bring any extraneous materials to the simulation session. If the simulation requires the use of a calculator or note pad, these can be provided as pop-up utilities within the simulation itself. Also, any reference materials such as data tables or graphical data should be accessible from within the simulation.

2. *Visually interesting and informative displays*

a. *minimal clutter*
There is a natural tendency for instructors who are used to the printed page to cram as much information as possible onto the available display area. The reader will frame the information for themselves. On a computer display, the information is framed for the user. In this context, excess information is a distraction which detracts from the learning experience; therefore, the tendency to cram information onto a screen should be resisted when designing displays.

b. *highlighting and emphasis*
The judicious use of contrasting colors helps to highlight important information. Also, enclosing critical information within frames and boxes helps focus attention. If the learner is to follow a logical sequence of displays, then it is helpful to vary the size, format and/or color of the displays to enhance the feeling of moving from place to place.

c. *display consistency*
Screen displays should have a "family appearance" to make it easier for the learner to keep track of where (s)he is in the simulation. For example, if all help displays shared a common color and/or format, then it is easy for the learner to know when (s)he is looking at a help display. The same is true of menus, data tables, etc.

Model-driven vs. Script-driven Simulation

Simulations can be characterized as "model-driven" or "script-driven". A "model-driven" simulation is one in which the events that take place, and the way in which they take place, are governed by an underlying algorithmic model of the reality being simulated. Typically, the model-driven simulation has a random number generator at its heart. It is the output of the random number generator, as interpreted by the frequency distributions incorporated into the model, which determines what happens in the course of any given simulation run. By contrast, a "script-driven" simulation is one in which the course of events is controlled by a predefined script. The script is produced by a content expert who specifies the events that are to occur and the sequence in which they occur. A pure script-driven simulation is deterministic.

It is, of course, quite possible for an instructional simulation to follow a model-driven/script-driven mixed paradigm. An example of this is the MALOS-OPS (Snellen & Murray, 1985) and MALOS-QDX (Snellen & Murray, 1988) simulated combat environments developed for the U. S. Army. In these simulations, the combat mechanics follow a model-driven paradigm while the opposing force (OPFOR) tactics are script-driven. The degree to which these two design paradigms are used in constructing an instructional simulation is a matter of judgement. The simulation designer must decide the mix between model-driven and script-driven techniques when constructing a simulation.

Mode of Learner/Computer Interaction

Since the art of simulation is based on the notion of creating a self-contained reality in which the learner(s) play some role, there are two very obvious strategies by which the simulation designer can employ computer support. The computer may act as a *participant* in the simulation reality or it can act as an non-participating *mediator* in that reality.

1. *Computer as Participant*
   Actually, it would be more appropriate to speak of the programmer and/or scenario designer as being the participant since that is the true source of intelligence which drives the role played (or perhaps more accurately, *executed*) by the computer. Normally, for the computer to act in the role of participant, the simulation must have, at least in part, an underlying model-driven design paradigm.

2. *Computer as Mediator*
   By definition, a computer based simulation will always include this role as a function served by the computer. That is, the computer will manage communication between the learner(s) and the simulation reality as well as all of the routine internal housekeeping tasks of data management, disk I/O, and whatever else is necessary just to make the simulation operate. The real issue is whether or not these constitute the *only* tasks performed by the machine. The classic simulation paradigm in which the computer acts

only as mediator is when the simulation is based on the interaction between *multiple human participants.*

The reason why the distinction between participant/mediator roles for the computer is important is that it has a profound impact on the design strategies that can be used by the simulation system designer. It has a significant impact, as well, on the way in which the resulting instructional simulation can be used. If the computer is to act as participant, then the domain of interactions possible is constrained by the depth and flexibility of the underlying model upon which the computer depends in order to execute its role. On the other hand, such a design paradigm allows the possibility of solitaire play in which the learner has the maximum degree of control over his/her learning environment. If the computer is to act only as mediator, then the simulation reality can have all of the depth and flexibility that is inherent in purely *human* interactions. However, this precludes any meaningful way to operate the simulation in solitaire mode.

Database Oriented Simulation

It has become generally recognized that it is preferable to embody an instructional simulation within a database rather than in the software that runs the simulation. This is what Pavia (1990) refers to as "Adequate Practice"; that is, providing the means by which the simulation can readily be changed without altering the software that runs the simulation. Typically, the software is nothing more than a central driver that reads a set of one or more database files which define a scenario within the simulation. The software then runs the simulation according to the terms and specifications found in the database. In Pavia's SQUALOR, the database consists of a data record indicating the properties of the organic compound to be identified along with specifications as to the results of any analytical procedures that the learner might wish to perform. Each database, then, constitutes a scenario within the instructional simulation.

What apparently has *not* yet become generally recognized, is the best means by which database (scenario) development can be supported. Usually, this support takes the form of a series of database editors which are used to construct and maintain the database(s) used by the simulation driver(s). The problem (as is noted by Pavia) is that the design, development and support of these database editors usually is as costly as it is for the simulation driver itself. Moreover, if the scenario database is at all complex (as it is in MALOS-OPS and MALOS-QDX), then database construction is bound to be error prone with no good way of doing internal error checking.

Some types of database construction do, in fact, lend themselves readily to the use of a database editor. For example, when the data is graphic (or more generally when there is a *spatial* and/or *temporal* aspect to the data), then an editor may provide the best means of creating the necessary database. In the MALOS system, this was the approach taken to create both the OPFOR tactical plans and the terrain maps on which those plans are executed. On the other hand, we feel that all quantitative and textual data is far better handled by recording this data in a text file. A compiler can read the text file(s) and build the necessary databases (Mabry, Personal Communication). This approach provides a number of significant advantages as follows:

1. A database compiler can be developed more easily than can a database editor. The compiler does not have to incorporate the sophisticated insert, delete, modify and data display capabilities that are required in a database editor. In effect, these functions are already available in whatever text editor one chooses to use when writing the text files that become the source files for the database compiler.

2. Making extensions to a database compiler, as the needs of the simulation grow, is faster and easier than making extensions to a database editor for the same reasons cited under #1.

3. When using a database compiler, the source files become the main depository of the database library. Because these contain the data in a form easily readable by a human, it is not necessary to write a separate print facility to produce hard copy from a database maintained by a database editor.

4. If the simulation database ever becomes corrupted or lost, it is only necessary to recompile it if one has a database compiler. Otherwise, it is necessary to reenter the database by hand using a database editor.

5. It is easier to incorporate database consistency checking into a database compiler than in a database editor.

The Problem of Evaluation

The value of an instructional simulation is unclear unless some means exist to evaluate its effectiveness. This is particularly true since instructional simulation tends to emphasize the development of soft skills as defined by Begland (1982). While there is no substitute for human judgement in evaluating any instructional method, computer technology offers some unique advantages in constructing an evaluation strategy. First, the rigor with which a computer based instructional simulation must be designed provides an excellent basis for developing a well disciplined data collection format. Second, a computer is superbly well suited to perform *transactional recording* during the simulation run. From the transactional record, it is possible, at a later time, to reconstruct the simulation run for analysis and evaluation. This approach was used in the debriefing option of the MALOS-OPS and MALOS-QDX combat simulation systems (Snellen & Murray, 1985, 1988). Finally, because these computer generated transactional records have a consistently defined format, it is easy to use the computer to automate the statistical analysis of the transactional records. This was the approach used in a study of problem solving behavior in which one of us (J. Snellen) provided computer programming support (Steinberg et al. 1986).

GLOSSARY

Algorithm

An ***algorithm*** is any explicitly defined procedure for accomplishing a task. The procedure is laid out as a detailed series of steps to be followed in sequence. When the sequence of steps is completed, the objective of the task will be reached.

Compiler

A ***compiler*** is an automated language translator. It reads messages written in human readable ***source language*** and translates them into a machine executable ***object language***. Normally, the ***source language*** message is contained in an ***input file*** which is read by the ***compiler***. The ***object language*** produced by the ***compiler*** is contained in an ***output file***. The source language can be a formal programming language such as PASCAL or FORTRAN, or a simulation-specific database language.

Database

A ***database*** is any body of information written in a predefined ordered format. Under normal usage, the term ***database*** generally refers to a body of information that has been assembled by humans in a form that can be read and manipulated by a machine. Common types of databases are inventories, mailing lists, and pricing tables. However, a ***database*** can also be a table of values which govern how a computer program will behave. A ***database*** can also be a script which governs how an instructional simulation will behave through time.

Debugging

Algorithms, as well as the way those ***algorithms*** are expressed in ***source language*** frequently contain mistakes. These mistakes produce unexpected (and usually unwanted) results when the ***algorithm*** is executed. Early in the history of Computer Science, the term *bug* was adopted as a name for these mistakes; hence the process of finding and removing these mistakes became known as ***debugging***.

Disk I/O

Computers store information on magnetic media which are usually in the form of floppy or hard disks. To be useful, that information must be transmitted from the disk into the computer as well as from the computer out to the disk. The terms used to describe this two-way transfer of information are ***input*** for information moving from the disk into the computer and ***output*** for information moving from the computer out to the disk. Normally, this is abbreviated as ***disk I/O***.

Hardware

This term refers to any piece of physical machinery. It is called "hard" because once it is constructed, its form is not readily altered (also, see the definition of ***software***).

Input File

A computer program operates on data supplied to it from outside the program. An interactive program normally receives data typed by a human user using a keyboard or mouse. However, such data also can be placed in a disk file from which the program can read its input data. Such a file is called an ***input file***.

Object Language

Humans and computers understand two very different types of languages. Programming languages (such as PASCAL and FORTRAN) are designed to express formal algorithms in a way that humans can write and understand readily. However, the only language that computers understand is a sequence of raw numbers in which each number indicates the next instruction to be executed or evaluated. When a human needs to communicate with a computer, the human writes the message in a form that is understandable to him/her (for writing programs, this means using one of the programming languages; for describing data, this means writing the data in some database language). Since this human-understandable language is the source of the information given to the computer, it is referred to as the ***source language***. A ***compiler*** then translates this ***source language*** into an object (i.e. a sequence of numbers that specify the machine instructions to be executed) that the computer can "understand". These objects are then referred to as the ***object language***.

Also, see the explanation under ***compiler***.

Operating System

As a raw piece of hardware taken out of the shipping crate, a computer is virtually useless. All of the components such as disk drives, keyset, monitor, communication ports, central processing unit and memory are there; however, to do anything useful, one needs to make all of these hardware components work together in a meaningful way as well as communicate with the human user and/or with other machines. These goals are accomplished by providing the computer with a set of programs which allow it to operate in a coherent manner. This set of programs is known collectively as the ***operating system***. For personal computers, the best known ***operating systems*** currently are MicroSoft's **DOS**, Apple's **MultiFinder**, and **UNIX**.

Output File

When a computer program produces data that is to be transmitted to some location outside itself, that data is called *output*. An interactive program normally transmits output data to the computer's display screen, or some other hardware device. This data also can be written to a disk file for storage and later use. Such a disk file is called and ***output file***.

Pop-up Utility

This term applies specifically to the DOS operating system which is designed to run one task at a time. It often happens that one needs to use some utility, such as an appointment calendar or a calculator while they are running a program (such as a spreadsheet). In a single task ***operating system*** such as DOS, it normally is necessary to stop one program before invoking another. One way around this is to write a utility in such a way that it can be loaded into the computer's memory prior to starting the main program. The utility can then be activated by pressing some special key which temporarily halts the main program and begins running the utility program. When the utility program is activated in this way, it "pops up" temporarily on the screen. Therefore it is referred to as a ***Pop-Up Utility***.

Single Key Input

A menu is a natural decision point in a computer program. It allows the user to control what the program does next. If the menu is used frequently, then the programmer usually will design the menu to operate via ***single key input***. This means that one letter (usually the first letter) of each menu choice is highlighted to indicate that it is the active letter for that choice. When the user presses the key for that letter, the menu immediately invokes the function associated with that choice. Note that the user does not have to press the Enter (or Return) key, only the highlighted key. If the menu is frequently used, then the user soon memorizes which keys correspond to which menu choices. This allows the experienced user to operate the menu with maximum efficiency.

Scenario

This term has essentially the same meaning in instructional simulation as it does in drama. A ***scenario*** is a description of the particular details of the simulation. For a role-playing simulation, the ***scenario*** defines the roles to be played, as well as the goals, problems, and viewpoint of each role. In computer based simulation, this term refers to the ***database*** which defines the nature of the simulation.

Software

Central to the notion of a stored program computer is the idea that the function of the machine is not determined by the hardware (i.e. the physical machine itself). Rather, the function that the machine serves is determined by a stored, executable body of ***software***. For example, a single piece of hardware (e.g. and IBM AT) can be a word processor, a spreadsheet calculator or a database manager depending on type of ***software*** that the hardware currently has loaded and is executing. From the programmer's perspective, ***software*** is called "soft" because it is easily modified to suit changing needs and objectives.

Source Language

See the explanation under ***object language***

State Variable

A computer based simulation (or, for that matter, any computer program) operates by keeping track of, and manipulating, a series of numerical values. Some of these values serve the purpose of recording the state of the simulation. During a wargame, for example, there may be variables for recording the number, type and location of combat units, the supply state of these units, the current weather conditions, etc. Because these variables determine the current state of the simulation, they are referred to as ***state variables***.

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Appendix C
Interview Outline
Credentials of Interviewees

PCSL/IDOC Task Order 90-3[a]
Interview Form

Interviewee Name: ____________________________

Date of Interview: _____________

Phone: ___________________

Issue #1 (Situational Audit):
We would like to establish your working situation; that is, the context in which you have developed and used an instructional simulation. Could you summarize this for us?

Issue #2 (Relationship to use of simulation)
What work have you done with instructional simulation? Do you design it, construct it, publish about it?

Issue #3 (Design of instructional simulation)
What, in your judgement, is the best approach to designing instructional simulation?

Issue #3 (Suggestions)
Do you have any suggestions/comments regarding use of instructional simulation in your class(es). Are there any problems/drawbacks in using instructional simulation?

Issue #5 (References)
Can you think of anyone else that we should interview about instructional simulation?

Issue #6 (Call Back)
May we call back if there are any further questions we would like to ask?

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[a] This questionnaire was used as a guide for discussion during the interviews rather than as a rigid set of questions to be answered. The interviews were conducted according to an expert interview model in which the interviewee was encouraged to discuss their field in an open-ended manner within the parameters set by these questions.

PCSL/IDOC Task Order 90-3
Interview Report

Interviewee Name: Bill Carstensen

Date of Interview: December 14, 1990

Dr. Carstensen is Associate Professor of Geography at Virginia Polytechnic Institute and State College (informally known as Virginia Tech.). He has been with the Department of Geography since 1983. His area of teaching is primarily in cartography, with sophomore courses in map reading, a course at the junior level in map production, courses at senior and graduate level in computer cartography and a graduate level course in cartographic information systems.

Dr. Carstensen received his Bachelor's degree with honors in Geography in 1976, his Master's degree in Cartography and Computer Mapping in 1978 and his Ph.D. in Automated Mapping in 1981 from the University of North Carolina at Chapel Hill.

From 1981 to 1983 he was at the University of Wisconsin at Green Bay as an assistant professor.

He has some formal training in Computer Science.

His research area is primarily in the area of accuracy of spatial databases for geographic information systems and for computer cartography. He is also interested in cartographic education in which he has done some simulation work.

He has developed a computer based simulation in map orienteering which is he calls "surrogate travel" in that the user of the software package experiences a simulated trip through unknown terrain. The sport of orienteering consists of placing a series of markers in and area which includes a variety of different types of terrain. The locations of the markers are indicated on a map. The object is for the orienteer to traverse the designated course, checking in at each marker and then reaching the finish line in the shortest time possible. The emphasis in the sport is on good map reading and judgement. Dr. Carstensen uses this simulation in some of the classes he teaches.

PCSL/IDOC Task Order 90-3
Interview Report

Interviewee Name: John Shatzer

Date of Interview: December 14, 1990

John Shatzer holds a Bachelor's degree in psychology (1967) at University of Evansville in Indiana, a Master's degree in Education (1969) at Indiana University. John currently is working on a Ph.D. in educational psychology at University of Illinois. John works for the University of Illinois College of Medicine as an instructional coordinator for the clinical phase of the curriculum. His office is at Carle Hospital in Urbana, Illinois.

John helps design live (i.e. role playing) patient simulations for use in the College of Medicine clinical program. The purpose of the simulations is to help medical students learn how to take medical histories. The medical history simulations are used both for training and evaluation of the student. The simulations are used for training and evaluating medical residents as well as students. The medical students which go through these simulations are in their second year of training when they are beginning to learn the clinical environment.

PCSL/IDOC Task Order 90-3
Interview Report

Interviewee Name: Charles Herring

Date of Interview: December 17, 1990

Charles Herring received a B.S. in Physics from the University of Mississippi in 1981 and a M.C.S. (Masters of Computer Science) from the University of Illinois in 1986. He has worked for the Construction Engineering Research Laboratory (CERL) in Champaign, Illinois for the past 10 years. During that time he has worked on applications development in construction management and tactical command and control systems. For the past three years, his primary interest has been in the development of simulation systems in operations research. He is primarily a software specialist currently working on a microcomputer version of the Force Structure Tradeoff Analysis Model (FSTAM). This combat simulation is intended to be an evaluative tool for the role of combat engineering in battle. Charles' interest is in the application of object oriented programming in simulation design. In addition, he is interested in the problem of machine representation of real numbers in developing computer based simulations.

PCSL/IDOC Task Order 90-3
Interview Report

Interviewee Name: Bill Olson

Date of Interview: December 18, 1990

Dr. Olson holds both a Master's and Ph.D. in pharmacology. He has three years experience as a post doctoral fellow in clinical pharmacology. He also holds a Master of Computer Science degree at U of I. He currently holds the position of Computer Analyst for Academic Applications and Assistant Professor of Clinical Veterinary Medicine at the School of Veterinary Medicine at the University of Illinois.

PCSL/IDOC Task Order 90-3
Interview Report

Interviewee Name: Marie Arnone

Date of Interview: January 14, 1991

Ms. Arnone studied English at the University of London in the early 1970's and then received a M.B.A. from New York University in 1981. She works as an independent consultant in experienced based learning for New York University in collaboration with Steven Stumpf and David Kolb. Dr. Stumpf and Dr. Kolb are professors of Business Management at the NYU School of Business. She currently is helping to develop a business simulation for use at the Defense Systems Management College.