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Beginning with definitions of "simulation" (a methodology for testing alternative decisions under hypothetical conditions), this paper focuses on the use of simulation as an instructional method, pointing out the relationships and differences between role playing, games, and simulation. The term "simulation games" is explored with an analysis of six dimensions of simulated environments: reality and fidelity; complexity of decisions; curriculum content; source of model, simulation, and game; replicability; and evaluation. After a brief discussion of computer-based simulation games, the advantages and disadvantages of simulation as a method of instruction are listed. Included are a glossary of terms related to simulation (analog, game theory, heuristic, iterative, model, role-playing, simulation, and system) and a 28-item selected, annotated bibliography. (JS)

SOME DIMENSIONS OF SIMULATION

Begun by Isabel Beck, Ph.D., while with the Southwest Regional Laboratory for Educational Research and Development. Expanded for presentation at the Symposium on Simulation, American Educational Research Association, February 1969, by Bruce Monroe and INSGROUP, INC.

ABSTRACT

Simulation (or gaming) is a methodology for testing alternative decisions under hypothetical conditions. As an instructional method, it emphasizes game rules, role playing, one (or more) model(s), iteration and replicability. Dimensions of simulated environments for instructional purposes discussed include:

- reality and fidelity
- complexity of decisions
- curriculum content
- source of model, simulation, and game
- replicability
- evaluation

Advantages and disadvantages of simulation as a method of instruction are proposed. Computer-based simulation games are explored.

Includes a glossary and an annotated, selected bibliography.

– BM

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DEFINITIONS

Simulation is an old word with a new application. For a time it meant "deception" or "misrepresentation", or more bluntly, lying. It now applies to a variety of technical (or pseudotechnical) activities in which models of, or analogs to, real situations are created for the purpose of testing or teaching, and is based on the philosophy of "let's try it out and see what happens". Additional definitions are given in the Appendix.

Simulation—the socially acceptable kind— is most frequently used in three different ways:

1. to evaluate or analyze an existing system (operations analysis)
2. to develop and evaluate a model or plan for a new system (experimentation, prediction)
3. to provide a learning environment that represents a life situation (training, transfer).

In all cases, relevant conditions are presented, assumptions, hypotheses, or courses of action are fed into the system, and the consequences are observable. Often, the consequences are used so as to shape the conditions or courses of action. Simulation designs range widely between abstraction and reality: mathematical models can be tested or real astronauts can "fly" vehicles to the Moon without ever leaving the Earth. The following items describe a progression from reality to abstraction:

1. The process, activity, or situation from which a model is derived (the real thing) is analyzed.
2. A trial run, a controlled operation, or a pilot study using components of the real system is analyzed.
3. A concrete laboratory model capable of replicated trials is analyzed.
4. A synthetic abstraction of elements in the real situation (such as a computer model) is analyzed.
5. An analytic model is analyzed.

Some would suggest only items 2, 3, and 4 are simulated.

Simulation provides a setting for directed change. The iterative approach to problem solving with successive simulated modifications of the model is the same whether its objective is to teach the human component in the system how to solve a problem or to modify the equipment part of the system in such a way that it will be more effective. Education is a system for changing human behavior; thus, simulation can be one of many useful tools to this end.

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The remainder of this paper focuses on the third type of simulation, simulating a life situation so as to provide a learning environment (simulation for instructional or training purposes).

CHARACTERISTICS OF EDUCATIONAL SIMULATIONS

Simulated experience is a naturally occurring activity in children in all cultures. Left to themselves, children spontaneously simulate (or pretend) aspects of their present or future life experience.

While many traditional childhood games provide little more than social experience, modern educational games are designed to achieve specific objectives in realms of communications, problem solving, scientific inquiry, information management, and decision making, through simulation methods. As a tool in training, simulation has four principal characteristics:

1. It starts with an analogous situation.
2. It provides for low risk input.
3. It feeds back consequences symbolically.
4. It is replicable.

The first characteristic, that of *analogous circumstances*, provides a setting in which a learner can function. This setting is equivalent to the assumptions in a scientific investigation; the "given" in a mathematical model; the equipment and the rules in a game; the definition of conflict and personal characteristics in role playing; and the independent variable in an experiment. In education for decision making it represents the "real" environment in which the learner is to function, and is assumed to have enough of the characteristics of the real environment to provide practice in meeting contingencies which could occur in the learner's life.

The second characteristic of simulation in training is the provision for tentative or *low risk input*. The learner can make a response without irrevocable commitment and without destroying the circumstances which are the basis of the simulation exercise. This allows the student to make disastrous mistakes, to "live another day", and to test alternative actions.

Low risk input leads to the third characteristic of simulation as discussed here: *symbolic consequences*. The simulation system informs the learner what would have happened had he responded as he did in the simulated situation. It delivers a message without modifying the physical or psychological learning climate.

With low risk response and symbolic consequence, the whole simulation exercise is *replicable*. Replicability provides an opportunity for iterative procedures in arriving at best solutions.

Although much of the literature in the field does not make clear distinctions among role playing, games, and simulation, some can be made on the basis of the four characteristics listed above. Role playing may be classified as a form of simulation limited to human beings and their behavior, whereas games and simulation involve human beings, hardware, or systems which include both.

In role playing, hypothetical but representative circumstances involving inter-personal relationships are established verbally, and trainees are assigned to roles in which they talk and act extemporaneously. The extemporaneous quality of role playing distinguishes it from dramatization. At the conclusion, the group discusses and assesses what happened in the role playing, role assignments may be exchanged, and the situation reenacted. Such sessions demonstrate consequences of interactive behavior and provide a basis for testing behavior strategies to achieve particular objectives. The method has been used in industry, particularly with supervisory personnel, is adapted from one technique of psychotherapy, and is largely intuitive.

While role playing seems to fulfill the requirements set forth above for simulation, the question as to whether it is truly replicable may be raised (at least on philosophic grounds). Can one ever go back to a previous point in the course of human experience? Once having played through roles in inter-personal relationships, can the role players go back to the point which originally was posited on the assumption that the situation is the same as it was the first time? Or is the simulation model now changed in the light of the intervening experience of the participants? With the reservation raised by this question, role playing can be classified as a limited form of simulation.

Games, on the other hand, vary widely in their concepts and processes; some may be classified as simulation and some not. For example, games of chance, such as the slot machine, probably are not a valid form of simulation, unless one assumes that a grove of oranges is superior to a grove which is a mixture of oranges, cherries, and plums, and that the behavior of the orchardist has only chance bearing on the yield of the three kinds of trees. Also, the loss of a coin is a more-than-symbolic consequence, and when all of the coins have disappeared into the machine, the play no longer is replicable.

Chess often is cited as a simulation game; this judgment is derived from the symbolic representation of men and horses on a medieval battlefield. In this century, the simulation is tenuous, for the rules of the game are not closely analogous to the strategies of modern war. This demonstrates a critical distinction between games and simulation which is valid for educational purposes. Games are very good to teach gamesmanship. But the strategies of gamesmanship are rather specific to the particular game involved. Simulation which is valid for general educational purposes, on the other hand, is transferable to real situations so that the learner, after experiencing the simulation is better prepared to cope with real events. In an educational setting, games should be designed to meet the criteria listed above for simulation, and to motivate learners.

The dual term *simulation game* now is in the language to describe instructional materials. Typical examples from among hundreds available include:

Manchester. A game focusing on rural to urban migration, and the roles of farmers, laborers, and mill owners possessing varying amounts of money, land, and equipment.

The Disaster Game, which simulates citizens' roles under disaster conditions, and encourages players to cooperate, organize, and plan ahead.

The Sumerian Game in which the player assumes the role of king of a mythical ancient society, and makes decisions on the economic life of his people, which can result in disaster or prosperity.

The Life Career Game, in which players make life decisions for hypothetical individuals and assess the "success" of persons whose lives have been planned by various teams in the playing group.

Management, a computer-based game in which teams representing small businesses make decisions on manufacturing operations and are issued quarterly financial reports.

Valleybrook Elementary Teaching Game, in which players make teacher decisions about their racially integrated classroom and assess their own beliefs, prejudices and commitments to equal education for all students.

Although such instructional material exists, its use is not widespread and is typically described as innovative. Simulation is not included in the list of 23 methods of instruction defined in the Office of Education, Department of Health, Education and Welfare document, *Standard Terminology for Instruction in Local and State School Systems.* "Experimentation" and "problem solving" are listed and simulation may be thought of as a combination of the two methods.

SOME DIMENSIONS OF SIMULATION GAMES

Selected aspects of six dimensions of simulations will be sketched out here. The reader is encouraged to explore these and other aspects (and dimensions) in references cited in the bibliography.

A. The reality/fidelity dimension (previously mentioned in the discussion of *analogous circumstances*) has two unique aspects deserving attention. The first relates to the degree of fidelity desirable or possible in the analogy to the real life situation. The content of the game and the human risk of the consequences to be fed back determine the realism of the various stages in the game. Careful attention to the reality dimension may provide part of an answer to contemporary student demands for relevance in the curriculum.

   The second relates to the time reality. One unique aspect of a simulation is the opportunity to expand and/or contract the time the learner has to decide or the time in which the player(s) receive the next input.

B. The complexity of decisions to be made is manipulable in at least five aspects. One has been previously mentioned in the discussion of *symbolic consequences*. In the instance in which the player views his response as highly problematic, his demand for additional information will be greater and his complexity of analysis of the potential decision is typically greater. By manipulating the consequence of any decision (or combinations of decisions) it is possible to vary the learner's complexity of analysis leading to any decision.

   In a second aspect, game rules requiring, advocating or rewarding group consensus or majority decisions (in contrast to unilateral decisions) will influence the complexity of decision process and consequence analysis. Related to this is a third aspect of collaborative/competitive play. Games may be designed to be played as either or both. Researchers have found both learner socioeconomic and sex variables to influence play on this aspect.

Fourthly, competitive game rules may cause the setting of decision time constraints and game length constraints.

Timed vs. indeterminant decisions and/or games also interact with the fifth aspect, that of the number of decision parameters under consideration in one (or more) moves. Since some games emphasize skill building vs. divergent production, in skill games, it is desirable to reduce chance over time and replace it with skilled response. To prompt this, one design consideration would be the control of the number of decision parameters at any point in the game.

C. Five curriculum content aspects are viewed next. An obvious first is the player's (or group's) entry knowledge of the subject of the game. Previous instruction in the subject or subjects closely related to the subject will expedite the speed of decisions and games. This is the consideration explicated in Carroll's "Model for School Learning" which explained learning variability as several time considerations. In games designed to increase generalizable skills, attention must be given to keeping the unsophisticated player persisting over long periods of time, as generalizations are acquired.

A second aspect concerns the taxonomic domain and level of the player's task in dealing with the curricular content of the game. Using one or more taxonomic classifications, it is possible to arrange the sequence of the introduction of stimulus materials. This will effect the proportion of "correct" decisions and possibly player satisfaction and persistence.

Thirdly, content/process considerations may be analyzed and decided. Simulations build skill in process, particularly those related to decision-making. Elaborate requirements for content at various points may cause the play to become unwieldy or exceed cognitive processing limitations.

The fourth aspect is curricular integration. Only occasionally has care been given to curricular considerations of what activities and materials are used in conjunction with the game. What precedes, goes on simultaneously or follows aspects of the game requires integration if maximum effectiveness is sought. Reviewers have proposed a "system approach" in which the game becomes one of a set of multi-media, interrelated components orchestrated to achieve the learning objectives. Overlap and parallel play with related games is rarely studied for effectiveness along with other considerations of curricular integratedness of games.

The fifth aspect considers designer bias and learner relevance. A simulation designer will typically leave his impression on the simulation. Although there may be authoritative agreement on content, not always will authorities agree on the decision-making process or come to the same probability statements on decision consequences. To the extent that constraints in game rules favor a given decision, to that extent the player's view of the game's relevance may be reduced, especially in games having high fidelity as viewed by the player.

D. Consideration may be given to the source or originator of the model on which the simulation is based, the simulation itself and the game rules that constrain the simulated events and environment. Two aspects are proposed here. The first concerns the instructional designer's decision to the adopt-adapt-invent question. Games and simulations may be tailored to a particular player or group with small to extensive eliminations, revisions or elaborations, or may be used exactly as proposed by the source of the simulation.

Secondly, the designer(s) of the model, simulation and game may range from instructional material publishers to teachers to learners (or combinations of these). Since a thorough knowledge of the interrelations of content and process in a given field of interest is required to produce either descriptive or explanatory models, and to produce a simulation game, maximum learning may take place when a learner designs his own simulation game or one for his peers or juniors. Cooperative projects will have higher probabilities of versatile games. In every instance, the experienced teacher's role is likely to be reference and consultant, if not producer.

E. The replicability dimension can be dichotomized into the aspects of replicability for the same player or for subsequent players. In the first aspect, the former mention of replicability in role playing applies. In essence, the guideline becomes; if concern exists to allow the player to return to a highly replicable situation when the feedback indicates his decision consequences are disfunctional, then care must be taken to provide multiple options of discrete consequences. This in turn will introduce additional artificiality into the simulation and reduce the reality/fidelity dimension.

The second aspect concerns replicability in the simulation for subsequent players and interacts with D.1 above, the adapt question. For formative evaluation validation analysis and summative evaluation research, replicability of a high (or complete) extent is essential. To that end, designers find it necessary to impose more game structure during development and validation to achieve replicability and then restructure the directions and teacher's manual later to foster adaptability if desired. Under competitive game rules, replicability may be desired.

F. The final dimension considered here relates to evaluation. Two aspects are introduced here. The first relates to the teaching/testing continuum and considers simulated environments as both (or either) learning or testing opportunities. In the instance of competitive game rules, it is possible to consider every play and game a test. While the result in a competitive mode is norm-referenced, a criterion-referenced evaluation is also possible and may be the designer's choice. If one holds (as I do) that there is only one way to distinguish between a teacher's teaching actions and his testing actions, that way being to note when a grade or mark is recorded, the importance of this aspect declines. However, simulated environments offer a ready-made approximation of the eventual on-the-job (in the broadest sense of "job") environment and consequently, highly realistic situational testing and a valid screening test.

The last aspect discussed here relates to who sets the criteria(on), collects the evidence and makes the evaluation of the player(s) achievement, success or mastery. This relates to the "adapt" question again. It may be effective to build maximum self-assessment into the game rules to preserve the low risk characteristic of the simulation. If the player views the game as a test, his responses may vary from what would occur if he saw it as an experiment or lark. For purposes of replicability, it would be effective to standardize (to the extent possible) the perceptions and expectations of the players. One way of accomplishing this is to organize a self-assessment procedure with player documentation of his decisions and progress toward the objectives of the simulation game.

COMPUTER-BASED SIMULATION GAMES

While games and role playing offer attractive opportunities for personal interaction among learners and among learners and teachers, simulations using computer facilities may be more effective in reaching certain instructional objectives. With computer-based simulations, it is possible to design complex programs for teaching problem solving or decision-making. In the problem solving design, the process required to arrive at a specified answer is learned. In the decision-making pattern, a learner acts upon a series of contingencies supplied by the computer which evaluates and describes consequences of learners' responses.

In an example of a problem-solving program the computer has a data base on the trajectory of a satellite. The student's task is to plot this trajectory. From the computer he receives successive readings transmitted by the mythical satellite, and plots successive positions on a graph or computes successive positions mathematically. At the conclusion of the exercise he compares his results with those previously produced by the designer of the program, and thus evaluates his own work.

The decision-making type of program would not have just one correct answer, but would teach the learner how to apply and evaluate alternative courses of action at the choice points. The computer could print out successive status reports, and the learner could decide whether or not he were satisfied with the state of affairs; if not, he could go back to the beginning and again work through the problem, making alternate choices.

A computer-mediated learning program combining simulation and role playing also is possible. In this, a whole system involving a number of people playing various roles could be the basis of testing the efficacy of the decisions of the individuals in the roles, and the effect of the individuals' decisions on group objectives. To teach a group of students some of the responsibilities involved in a scientific expedition, for example, three roles could be programed: The senior scientist, manager of survival logistics, or living conditions, and the manager of transportation. The data base would contain a description of the objectives of the expedition, the location, and the number of people who would staff it, and the length of time that the expedition would be away, for example. From this common data base then, a program developed for each of the three students in the various roles, would require decisions as part of the advance planning for the expedition. As the students make their responses, the computer would process them and feed back a scenario of the developing plans for evaluation by the team. This could be followed by a computer programed "field test" of the plans with intervening events introduced on either a systematic or a random basis. Decisions based on these events and outcomes of the expedition could be assessed by the students at the conclusion of the simulation program. A prerequisite to this kind of simulation, of course, is easy and effective interaction between the computer and the learner.

RESEARCH ON SIMULATION GAMES

As happens with most forms of educational innovation evaluated in traditional research design, the effectiveness of simulation games for teaching is uncertain. Some studies indicate that as much content learning takes place in the game as in traditional classroom experience, and an occasional study indicates less content learning takes place in games. But the *content* learning is not the crucial objective in simulation game instruction. The method is peculiarly suited to teaching *process* and particularly the decision-making process. Studies which compare content taught by two or more methods have a built-in fallacy which makes results vulnerable to biased interpretation.

Research has been hampered by a lack of precision in the statement of the objective(s) of a simulation. In some cases, none are stated. Researchers must then infer any educational benefits from the game experience and proceed to develop criteria to evaluate thy effectiveness of the experience.

Few (if any) simulations exist which are accompanied by "technical specification" of the type recommended by Tyler and others at the 1968 AERA Meeting. As a result systematic evaluation programs to discover the optimum use of simulation with various types of learners are thwarted. Also, cost/effectiveness studies of simulation vs. other method/media combinations interacting with learner characteristics have not been carried out on a programmatic basis in the public education environment as yet.

ADVANTAGES OF SIMULATION AS A METHOD OF INSTRUCTION

Simulation as a method of instruction can be assessed along two dimensions—in comparison with other instructional methods, and with direct experience. Arguments favoring simulation follow.

A. Advantages of simulation over lecture-reading methods include:

(1) Simulation can provide experience in a wider range of educational objectives: affective as well as cognitive; process as well as content oriented; evaluation by self and system criteria as well as by the instructor; and an elaborated concept of cause and effect.

(2) With simulation there may be greater transfer from the training situation to the life situation.

(3) Simulation provides a responsive environment which may give learners a sense of immediacy and involvement.

B. Advantages of a simulation over direct experience fall into three general categories:

(1) Cost: Simulation can provide experience in a low cost model of a high cost environment. Practice in business management is possible without the risk of bankruptcy; a pilot trainee can make a "fatal" mistake without loss of life or aircraft. This is a comparative statement. Simulation *can* be expensive.

(2) Time Control: Simulation can provide short time experience and feedback in long time processes. Results of farm management decisions can be evaluated without waiting for harvest time; a flight around the moon can be achieved in minutes instead of days. An elaborate technology would be required to support this time manipulation.

Simulation allows practice in decision making in a timeless environment. Traffic patterns requiring rapid decisions can be slowed down for beginners in driver training; instruments which signal emergency conditions can be studied for a longer time than the actual situation would allow.

(3) Experimentation: Simulation can provide a field for practice in hypothesis formulation, testing, and modification. Successive strategies in problem solving can be tried on an "unaltered" base situation.

Simulation is a setting for rehearsing responses in a structured environment. Teacher trainees can practice responses to filmed classroom situations; students can practice test taking.

Simulation can provide systematic exercises in inquiry training. Science exercises can be conducted on a question and answer pattern as an alternative to laboratory "cookbook" procedures.

Simulation is vehicle for display of creative designs for learning. Both teachers and students can create designs for sharing experience with others.

DISADVANTAGES OF SIMULATION AS A METHOD OF INSTRUCTION

Simulation games for teaching have the same disadvantages as other systematically developed instructional programs—they are difficult to design and they are expensive.

Design problems center on two themes:

(1) achieving fidelity to the real situation in the variables relevant for transfer to life situations as they are met; and

(2) validation of the simulation program.

Costs fall into three categories:

(1) development of the program, including field testing and revisions;

(2) the environmental requirements for installation and use of the simulation program after it is developed; and

(3) training teachers or others for effective supervision of simulation training programs will offset a potential disadvantage but is not uniformly carried out.

GLOSSARY

Citations refer to publications listed in the references at the end of this paper. Non-cited definitions were formulated by the authors.

ANALOG A devised model or set of circumstances which has characteristics of an existing object or system. Representation of numerical quantities by physical variables. – Sackman, P. 602.

GAME THEORY A model for situations of conflict among several people, in which two principal modes of resolution are collusion and conciliation. – Luce and Raiffa, P. 10.

HEURISTIC An iterative sequence of questions that reduces the amount of search time necessary for an accurate solution to a problem.

Serving to discover, to stimulate investigation, or to lead to possible solutions of specified problems. – Sackman, P. 609.

Heuristic programs discover solutions, are designed to handle non-numeric symbols, and are designed to proceed by attempting to build paths to goals with no guarantee of success. – paraphrased from Reitman, P. 330.

Neither human nor heuristically programed computer need be guaranteed beforehand that any given method will work, or indeed that a particular problem exists at all. Both proceed by searching for "likely possibilities" and then trying them out, using specified classes of cues and tests to guide the search process. – Reitman, P. 331.

ITERATIVE A procedure in which a solution is sought through successive approximations or evaluation-revision cycles, with each revision being shaped by results of previous trials.

MODEL A model of a system purports to be a *representation* of the system under study. ...One model may be a physical replica of the system, whereas another–such as those used in digital computer simulation–may be an entirely symbolic representation. – Evans *et al*, P. 5.

A scientific model can be defined as an abstraction of some real system that can be used for purposes of prediction and control.–Naylor *et al*, P. 9.

ROLE-PLAYING In role-playing, hypothetical but representative circumstances involving inter-personal relationships are established, and participants are assigned to roles in which they talk and act extemporaneously.

SIMULATION Simulation may be defined as the creation of realistic games to be played by participants in order to provide them with lifelike problem-solving experiences related to their present or future work. – Cruikshank, P. 23.

A simulation of a system or an organism is the operation of a model which is a representation of the system or organism. The model is amenable to manipulations which would be impossible, too expensive, or impractical to perform on the entity it portrays. The operation of the model can be studied and, from it, properties concerning the behavior of the actual system or its subsystem can be inferred. – Shubik quoted by Naylor, P. 2.

Simulation means the reenactment of a situation, or set of circumstances, or an observable problem for which the designer has to make decisions or take other action. – Rice, P. 10.

Simulation is analogy, and the human capacity for analogy is unlimited. – Sackman, P. 301.

Simulation is the symbolic or physical representation and exercising of some aspects of a system. – Fitzpatrick quoted by Sackman, P. 304.

(1) Simulation is the general application of analogy in experimental method, regulated and modified by the changing requirements of experimental inquiry throughout the evolution of object systems.

(2) Simulation is the differential representation of objects and events in any portion of a referent system and its environment by actual and analogous counterparts as they are operationally defined and exercised in an experimental test setting. – Sackman, P. 305.

The difference between a simulation, model, and a game is simply that a simulation is a more inclusive simplified representation of some process that is to be understood by the student. A model is a theoretical representation of such a process, and a game is its formulation into a competitive activity among human players whose outcome is uncertain and whose outcome is decided by various combinations of skill, chance, and knowledge. – Teaching Research, *Of Men and Machines*, P. 5.

SYSTEM A system is a collection of identifiable parts capable of interacting in such a way that the entire collection functions together to satisfy a set of specific requirements. – Evans *et al*, P. 4.

Any related set of objects and events including the collective organization of information these possess; the means for acquiring, storing, transmitting, controlling, or otherwise processing such information; all in relation to, but distinct from, the external environment in which the behaviors and history of the object system are embedded. – Sackman, P. 620.

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Ch. 8. Simulation and Training. Defines simulation generally, and describes its use in astronaut training and system training in air defense.

Ch. 12. Computers, Scientific Spirit, and Evolving Society.
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