1985

The development and evaluation of an experiential computer simulation for animal science students

Kathleen P. Coyle
Iowa State University

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THE DEVELOPMENT AND EVALUATION OF AN EXPERIENTIAL COMPUTER SIMULATION FOR ANIMAL SCIENCE STUDENTS

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The development and evaluation of an experiential computer simulation for animal science students

by

Kathleen P. Coyle

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY

Department: Professional Studies in Education
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Iowa State University
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CHAPTER ONE: INTRODUCTION

Today the amount of information available on virtually all topics far surpasses what previous generations had available. In biology, for example, knowledge doubles every five years and in genetics knowledge doubles every twenty-four months (Rifkin, 1983). And, in Megatrends it is predicted that within several years knowledge in most fields will double in a matter of months (Naisbitt, 1982). While this growth of information has increased our understanding of many events, its continued rapid expansion challenges our ability to effectively utilize our resources (Molnar, 1980, 1982; Sheingold, Hawkins, & Kurland, 1983; Rifkin, 1983).

This drastic growth of information has lead several futurists to suggest a shift in the basic nature of society, from an industrial base to an information base (Toffler, 1970; Sagen, 1977; Molnar, 1978, 1980, 1982; Naisbitt, 1982; Rifkin, 1983). More than half the work force and half the gross national product are now accounted for by the information industry (Molnar, 1982). The term "knowledge worker" was coined to describe workers who use and apply information in their jobs (Drucker, 1977). Reservations clerks and bank tellers who use electronic record keeping equipment are knowledge workers. Engineering technicians are another example of knowledge workers. Knowledge workers
represent the fastest growing segment of the workforce (Molnar, 1982).

While knowledge expands exponentially, the potential for "knowable knowledge" is growing smaller; Molnar (1982) describes this as the "ignorance explosion". The meaning of the verb 'to know' in the past "... meant 'to have stored in one's memory,'" but today knowing shifts from the actual physical possession of information to the process of having access to it (Simon, 1971, p. 45). Continued growth and exploitation of information is based not just on the production of new knowledge but on society's capacity to absorb and apply information in productive ways (Molnar, 1982).

The Computer as a Societal Tool

With the current exponential rate of growth of information challenging the human capacity to absorb information, the computer is seen as both the impetus for growth and the solution to the effective handling of the massive amounts of information (Molnar, 1980, 1982; Rifkin, 1983; Sheingold et al., 1983). Computers can be used to store, sort, organize, manipulate, and communicate large amounts of information. "The on-line information selection business has already become a $4-billion-a-year enterprise"
(Naisbitt, 1982, p. 17). For example, a national data base was recently created for the results of cancer research; the New York Public Library System just converted its card catalog files to a computerized data base; and electronic mail is being used by major industrial companies and research centers in order to speed the communication process. These types of computer uses emphasize the power of the computer to enhance our ability to utilize large amounts of information.

Another use of the computer to expand human capability is simulation. Computer simulations enable testing of the various models that explain real world events. Computerized simulations have been used extensively in business to determine future trends, isolate the effects of certain variables on production, and evaluate current practices (Watson & Christy, 1982). Meteorologists use computer simulations to forecast the weather; engineers use simulations to construct models of potential projects; and sociologists analyze population trends (Roberts, Anderson, Deal, Garet, & Shaffer, 1983). Such computer utilization allows for the compression of time and often replaces massive and expensive "real world" analysis. Whereas, hindsight was the norm, computer simulations are now used as a tool to facilitate the understanding of present and future events.
Education's Responsibility

As Benjamin (1939) so pointedly suggests in his satire, The Saber-Tooth Curriculum, educators must stay abreast of societal changes in order to provide the skills needed in ever changing societies. In this satire, caveman society is greatly advanced when New-First, a forward looking young man, determines that teaching children fish-grabbing-with-the-bare-hands, woolly-horse-clubbing, and saber-tooth-tiger-scaring-with-fire will enable the tribe to better meet its needs for food, clothing, shelter, and security. New First's ideas become popular and schools evolve in order to teach these three basic skills. Then, a glacier moves down from the mountains causing the waters to muddy and, the saber-tooth tigers and the woolly horses to become extinct. It is no longer useful to fish-grab-with-the-bare-hands, club-woolly-horses, or scare-saber-tooth-tigers. Yet, the schools insist that these are essential societal skills and continue to teach them. Eventually, new schools emerge that teach technologies appropriate for the changed environment.

While Benjamin's (1939) satire provides a vivid example of the difficulties involved in making change, Bruner (1966) feels that education must go further than simply reacting to change. Bruner (1966) states that education by its very nature must take a leading role in providing the skills
needed to manage and control societal changes and suggests that each new generation redefine the goals of education. In terms of computer uses in education, educators should not design their utilization as a reaction to outside pressure; they should lead (Aiken & Braun, 1980). Yet, in the National Science Foundation's report "Technology in Science Education" (1979) the world is said to be rapidly moving into the information age with information technology flourishing everywhere except in the field of education. The conclusion states that education is not only missing an opportunity but is failing to discharge a responsibility.

Since members of society will need to utilize amounts of information that exceed their human capacities, the ability to utilize the computer in order to manipulate large amounts of data will be useful. Educational institutions should lead in providing these information processing skills. And, the types of computer experiences students receive should emphasize the uses that are made in "real world" settings (Papert & Solomon, 1972; Molnar, 1977).

Educators' Current Use of the Computer

To date educators' limited use of the computer has not provided students with the skills that will be necessary for members of the information based society. Most computer
uses in education consist of using the computer to facilitate traditional teaching methods, the most notable is to provide drill and practice and tutorial lessons (Nievergelt, 1980; Papert, 1980; Sheingold et al., 1983; Bush & Cobb, 1983-84; Rodrigues, 1983-84; Thomas & Boysen, 1984). This singleness of use that focuses new technology on traditional teaching methods suggests that educators have not yet realized the true potential of the computer (Papert, 1980; Aiken & Braun, 1980; Thomas & Boysen, 1984). These types of observations led Sheingold et al. (1983) to state that the future of computing technology for education hinges on appropriately designed software and the ability of teachers to incorporate it into their classrooms.

Current problems

Bohnam (1983) suggests that computers could enhance our thinking power, but instead obsolete processes have been decorated with new technology. This lack of insight has lead to the production of massive amounts of drill and practice and tutorial lessons and very little development of other types of software. This almost exclusive use of drill and practice and tutorial lessons ignores the specific characteristics of the computer that enable it to provide learning environments that are appropriate for information processing and problem solving learning objectives.
Unfortunately, the standards now in use for computer-assisted learning (CAL) are extremely low and, more importantly, they are in great danger of becoming accepted as the final standards (Bork, 1984).

**Necessary changes**

While it is widely recognized that the lack of appropriately designed, quality software is a major deterrent to justifiable computer applications in education (Molnar 1977, 1980; Aiken & Braun, 1980; Scandura, 1981) attention must also be given to developing the ability of teachers to utilize the computer in new ways (Bork, 1984). Teachers have a tendency to teach using the methods by which they learned. Before teachers can be expected to provide students with new types of computer experiences, they themselves will have to use the computer for information processing, and problem solving (Thompson, in press).

A need exists for exemplary software of types other than drill and practice and tutorial. Although drill and practice or tutorial is appropriate in some instances, there are many instances when learning involves more than eliciting certain responses to specific stimuli (Bush & Cobb, 1983-84). A shift is needed from a model of stimulus-response associations to a variety of other models - models that emphasize information processing, model building,
problem solving and heuristics. Attention must be given to the mental states and processes of the learners, rather than simply to the behavioral outcomes (Gagne, 1980). Once these other types of software are more widely available, teachers will be better equipped to provide their students with more appropriate computer experiences.

Statement of the Problem

Although computer supported learning is viewed as desirable, and considerable effort has directed the utilization of computers in education, the present educational use of the computer is, in general, inadequate. This inadequacy is caused by a variety of factors, most notable of which is the lack of appropriately designed software - software that utilizes the potential of the computer to provide learning environments which emphasize problem solving, model building, heuristics, and information processing skills.

Purpose of This Study

The purpose of this study was to provide an example of one type of heuristic model building and problem solving software that can be developed.
The research and development cycle described by Borg and Gall (1983) was utilized in the development of this product;

(1) research and information collecting (including review of literature, classroom observation, and preparation of report of state-of-art),

(2) planning (includes defining skills, stating objectives, and small scale feasibility testing),

(3) develop preliminary form of product (includes preparation of instructional materials, handbooks, and evaluation devices),

(4) preliminary field testing (conducted on a small scale - interviews, observational and questionnaire data collected and analyzed),

(5) main product revision (revision of product as suggested by the preliminary field test results),

(6) main field testing (conducted on larger scale - quantitative data on subjects' pre- and post performance),

(7) operational product revision - (revision of product as suggested by main field-test results),

(8) operational field testing - (conducted on large scale - interview, observational and questionnaire data collected and analyzed),

(9) final product revision - (revision of product as suggested by operational field-test results),

(10) dissemination and distribution - (report on product, commercial distribution).

Although the entire research and development cycle is a ten step process, this research project consisted of carrying out the first five steps of the cycle.
An experiential computer simulation was designed and developed in order to facilitate the learning of a concept in dairy cattle management. The simulation was intended to create a learning environment where students were challenged to develop and test their own model of the concept. A field test of the simulation was undertaken (1) to determine how the simulation might be improved and (2) to gain insight into how students utilize such programs and how more appropriate evaluative techniques could be designed.

Research Questions

The basic research question was: Is the simulation a useful learning tool for the intended learners? In order to better answer it, several secondary research questions were addressed.

1. What types of models of the concept do students have before using the simulation?
   • Do the students have an agreeing model, a conflicting model, or no model?
   • Can the student models be identified, and if so, how many of each type are there?
   • Do the more experienced students have models that differ from the models of the less experienced students?
2. What kinds of responses do students make to this type of software?
   • Can the students use the tool in order to test their own model?
   • Does the simulation point out inadequacies in faulty student models?
   • Do the students feel that the simulation is useful?

3. Has the simulation caused the student to change or reflect on his or her model of the concept?
   • Can the students verbalize their experience with the simulation?
   • Do the students believe the simulation reflects the real situation?

Definition of Terms

Since computer use in education has only recently received widespread attention, the terminology associated with the area is sometimes unfamiliar and used in differing manners. The following list attempts to specifically describe the terminology used in this paper.

Advance organizer

Advance organizers are instructional materials that are more general, more
abstract, and more inclusive than the learning material to follow. They serve to facilitate the linkage of new information with prior concepts of the cognitive structure or to link previously learned concepts (Novak, 1977).

Artificial intelligence

A science that attempts to use machines to model thinking (Wyer, 1984).

Cognitive discovery theory

A view of learning that assumes that perceptions are influenced by the way stimuli are arranged and a person's experiences and interests. Self-discovery learning is hypothesized to be more meaningful and to develop confidence and problem solving ability. The teaching approach is to arrange for pupils to find their own solutions (Biehler, 1978).
<table>
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<th>Term</th>
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<td>Computer-assisted instruction</td>
<td>A term used to describe educational software for the computer, having strong associations with the programmed instruction movement. This term is most often used to describe software of the drill and practice or tutorial type.</td>
</tr>
<tr>
<td>Computer-assisted learning</td>
<td>Terminology evolved to describe educational software for the computer that illustrates the need to shift from the overtones of the programmed instruction movement to uses of the computer for higher level cognitive skills.</td>
</tr>
<tr>
<td>Computer simulation</td>
<td>A &quot;... program that manipulates a model of the real world through the use of equations that map input values to output values...&quot; (Gress, 1982, p. 445).</td>
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<td>Experiential</td>
<td>Educational methods where</td>
</tr>
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<td><strong>Heuristics</strong></td>
<td>The selection of a few likely alternatives, exploring their consequences, and on the basis of this exploration, the selection of a &quot;best&quot; move (Ellis, 1974).</td>
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<td><strong>Information processing</strong></td>
<td>The process of receiving data, storing and operating on it in a variety of ways, so that it gains some meaning and then perhaps transmitting it to other systems (Simon, 1971).</td>
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<tr>
<td><strong>Intelligent CAI</strong></td>
<td>CAI strongly influenced by the artificial intelligence movement. Common</td>
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Microworld characteristics include; students learn via discovery and develop their problem solving skills, create a 'model' of the student's learning, and exhibit a variety of tutoring stages (Wyer, 1984).

A learning environment, usually represented on the computer, where students are given a goal and by working through the lesson gain insight into their own understanding of the phenomenon. Specifically, the microworld approach is the representation of a domain of knowledge where the user is able to control the outcome (goal) by the manipulation of the "primitives" of the area of knowledge that is represented.

Model building A learning process where
students are challenged to test and modify their model of a concept. Interaction with a system that provides feedback on the student decisions leads the students to evaluate and hypothesize about the topic.

<table>
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<th>Problem solving</th>
<th>&quot;... problem solving involves reorganization of stored information... to reach some specified goal. Where new information is required for a solution, problem solving may include search procedures such as hypothesizing or experimentation&quot; (Novak, 1977, p. 104-105).</th>
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<td>Simulation</td>
<td>The representation of a system, event, or apparatus by a device... that imitates the behavior of the system.</td>
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<td>Stimulus response theory</td>
<td>A view of learning that</td>
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attempts to shape behavior systematically; based on Skinner's strict scientific view that the world acts on the person and Bandura's modified scientific view of anticipatory control (Biehler, 1978).

Student-controlled computing

Educational software that places the student in an active role with the material to be learned. The term represents a critique of educators almost exclusive use of drill and practice and tutorial where the computer controls the student (Papert, 1980).

Tool Software

Educational software that helps people accomplish tasks, yet does not specify the exact procedures involved in the task. Examples include, word processors, data base
management programs, spreadsheet packages, calculators, and statistical packages (Sheingold, Hawkins, & Kurland, 1983).

Transfer A phenomenon that occurs when one task influences another. Transfer is thought of as the amount of influence Task A has on Task B. Three cases are possible; positive, negative, and zero transfer (Ellis, 1965).

Summary

The present use of computers in education, almost exclusive use of drill and practice and tutorial, only skims the surface of the total role computers can and should play in education. And while numerous authors recognize this problem, more adequate computer use will not become a reality until teachers themselves understand how the computer can be used to facilitate active student learning of a problem solving or information processing nature. In
order for teachers to come to this understanding, they must be provided with examples of software that encourage the use of the computer to facilitate model building, information processing, and problem solving. It was with these ideas that the researcher developed an experiential computer simulation in order to facilitate the learning of a concept in dairy cattle management and serve as an example of the type of problem solving computer software that is needed.

In each of the following chapters the procedures involved in each of the research and development steps are addressed. In Chapter Two the related literature on the present use of computers in education, the problems with the current use, and the state-of-art are described. In Chapter Three the procedures involved in the planning and development of the preliminary form of the product are illustrated. The results of the preliminary field test are presented in Chapter Four and recommendations for product improvement and possible future projects that will assist the completion of the remaining steps in the total research and development cycle are identified in Chapter Five.
One purpose of research and development projects is to bridge the gaps between state-of-art educational research and educational practice. As a first step in initiating a research and development project, then, it becomes necessary to identify the gaps that exist between the state-of-art educational research and current educational practices. Since a secondary outcome of this activity is often the identification of problems with the present state-of-art and current educational practice, these gaps are also identified. A brief discussion of the gaps between the state-of-art educational computer uses and current computer uses in the schools was presented in Chapter One. In this chapter, further details are given regarding the problematic areas of computer uses in education and the types of computer uses that might exist.

In order to provide an appropriate review of computer uses in education it is necessary to summarize the results of present research reviews, discuss the problems inherent in the current approaches, and present possible new directions for future efforts in the area. This chapter, then, is divided into four major parts; What the CAL Research Shows, What's Wrong, Possible New Directions for CAL, and Possible New Directions for Research. Because the
researcher developed a computerized simulation, extensive attention is also given to the results of educational simulation research.

What the CAL Research Shows

For the most part, research on the effectiveness of the computer in education has yielded conflicting or minimal positive results. For instance, Vinsonhaler and Bass (1972) found CAL drill and practice lessons enhanced math and language arts learning yet, they suggest the same positive results could have been obtained through other less expensive means. Edwards, Norton, Taylor, Weiss, and Dusseldorp (1975) found CAL often provided better results than conventional methods on final examinations, but not on retention exams. In a meta-analysis of college level CAL, Kulik, Kulik, and Cohen (1980) found small significant contributions to course achievement. At the secondary level, Kulik, Bangert, and Williams (1983) found CAL to raise examination scores from the 50th to the 60th percentile with smaller effects on follow-up exams. Roblyer's (1984) review summarizes the findings of eleven previous reviews of CAL finding small positive differences in terms of achievement results between students using CAL over those not using CAL.
While these reviews do not strongly support the need for computers in education, many teachers and researchers believe the reality is better than the research shows. The current classification system, drill and practice, tutorial, or simulation, has been identified as a bottleneck to more effective research results regarding the use of computers in education. It has been suggested that a need exists to further classify the various types of CAL. This further classification would enable more appropriate evaluations of CAL (Thomas & Boysen, 1984). Hence, in the following sections specific attention is given to the research results regarding the effectiveness of educational simulations. After this review of educational simulations, attention is reverted to a more elaborate description of the problems with the current classification system and the present research.

Simulation Uses in Education

Educational simulations have been in wide spread use since the 1960s. The purpose of these educational simulations is to have students develop problem solving skills and/or aid in students' understanding of concepts (Gress, 1982). Educational simulations typically are used to provide access to real world situations that are not
normally provided by the classroom teacher. The nature of simulations is to put the student in an active controlling process and provide feedback on the outcomes of the student's decisions. In general, the educational simulation functions to increase the student's ability to perform in the real situation and to increase his or her knowledge and understanding of the situation (Livingston & Stoll, 1973).

**Factual/Conceptual learning**

Most simulation game research supports the ability of the simulation to teach factual and conceptual information at least as well as conventional methods (Anderson, 1970; Heinkel, 1970; Stahl, 1970; Fletcher, 1971; Chartier, 1972; Lindblad, 1973; Hsiao, 1975; Ellinger & Brown, 1979; Silvia, 1981; Cox, 1974). Hsiao's (1975) study provides an example of the type of research that supports this claim. Two sections of a college micro-economics course participated in this study. One section served as the control group and the other as the experimental. Both sections had the same instructor. During the initial phase of the project, both sections received four weeks of instruction and took a pretest. In phase two, the control group continued with the traditional lecture while in the experimental group traditional instruction was replaced with a simulation of a firm's behavior. Post-test results showed no significant
difference at the .05 level between groups on economic knowledge. It is generally concluded from these kind of results that computer simulations teach factual and conceptual information at least as well as traditional instruction. It should be noted, however, that computer simulations are often designed to enhance certain higher level cognitive skills and that the typical evaluation measures used in most research studies are not able to identify these differences.

**Higher level learning**

Research results regarding the ability of educational simulations to effectively teach problem solving strategies and the transfer of these skills are mixed. Glenn, Gregg, and Tipple (1982) studied the effect of educational simulations on students' problem solving abilities, finding no significant difference between students who used the simulation and those who did not. Ellinger and Brown (1979) found computer-based educational simulations to enhance the problem solving ability of students with one instructional simulation. Yet, with the second simulation reviewed in Ellinger and Brown's (1979) study no significant difference was found in the problem solving abilities of the control and experimental groups.
A notable problem with this type of research is the difficulty involved in designing appropriate measures of higher level learning. In a third study, reviewed by Greenlaw and Wyman (1973, p. 267), a different evaluative technique is presented; "... the faculty unanimously agreed that the students in the simulation section seemed to be better able to synthesize the various functions in an over-all plan ... (and were) more aware of ... measurable variables in a planning situation." And, Hsiao (1975), who found no significant difference in terms of factual learning, indicated that the use of the simulation stimulated student curiosity in micro-economics.

**Attitude change**

Educational simulations have affective learning potential (Stahl, 1970). For instance, Vogel (1973) found that playing in a educational simulation is a powerful attitude change technique. And, Livingston and Kidder (1973) list a number of other studies that show educational simulations to effectively change students' opinions and attitudes.

**Motivation for learning**

On course evaluations, students who use educational simulations frequently report high satisfaction with the
course, feel they learned more, and express having their motivation and interest stimulated (Chartier, 1972; Hsiao, 1975; Thomas & Willham, 1976; Ellinger & Brown, 1979). Pierfy (1977) reviewed this matter further, finding seven of eight studies to report significant differences between the motivation of students with and without simulation games.

**Educational simulation research directions**

Bredemeier and Greenblat (1981, p. 327) conclude their review of educational simulation research with the following:

> We do not yet have (1) a theoretically based taxonomy . . . [of educational simulations] with (2) clear theories about (a) what aspects of them are expected to have (b) what sorts of distinct effects (c) on what sorts of students (d) for what reasons.

Others echo this idea. Ellinger and Brown (1979), for instance, suggest that part of the difficulty in evaluating instructional simulations is due to the lack of understanding about what simulations are supposed to teach and to the lack of good methodology for evaluating student performance. As long as this void exists, it is probable that the results of studies about educational simulations will provide inconclusive results.
What's Wrong

The problems identified with the research on educational simulations, particularly the need for further classification of specific software, are similar to those of CAL in general. The current classification system, drill and practice, tutorial, and simulation, pools all simulations together regardless of each simulation's specific objectives. By pooling the different types of simulations under limited evaluation techniques, the classification system fails to encourage exploration and development of new types of simulations. Other types of educational software are similarly stifled by this classification system and the limited techniques of the current research.

Problems with the present research

The question 'what does the research say?' looks simple in its face, but turns out to be deceptively complex. In general the answer is: 'not nearly as much as it can, will and already should have' (Bracey, 1982, p. 52).

One explanation for the lack of significant positive results regarding the use of computers in education may be the lack of appropriate utilization of theory in the design of CAL which leads to the lack of quality software and inappropriate comparisons of CAL with other types of
instruction. Since the majority of computer uses in education focus on drill and practice type lessons, the research literature is flooded with the results of these types of programs. Very little research on other types of CAL can be found, and when it is found, evaluation of these new types of programs is most often based on traditional drill and practice type achievement measures.

Present reviews and meta-analysis studies of computer assisted learning typically pool the various types of software into similar evaluation schemes. An example of this type of evaluation scheme is found in the meta-analyses of Kulik (1980, 1983) and his colleagues. Kulik, Kulik, and Cohen's (1980) meta-analysis of computer assisted learning at the college level, for instance, reviews 59 independent evaluations of computer-based instruction. The basic procedure of the meta-analysis is to obtain all possible research results on the topic, disregard the flawed studies and then pool each study's findings with the others in order to determine an overall effect. Results on achievement test scores from drill and practice lessons, tutorials, and simulations were pooled together in order to determine an overall score for CAL in general.

Using a similar methodology, Kulik, Bangert, and Williams (1983) reviewed computer assisted learning at the
secondary level. And, other major reviews of CAL have provided similar types of evaluative data (Edwards, Norton, Taylor, Weiss, & Dusseldorp, 1975; Roblyer, 1984). The typical evaluation measure is achievement test scores regardless of the type of software under evaluation. These reviews are often cited in research and theory papers on computer uses in education and serve as a basis for most educators thoughts regarding the usefulness of computers.

Yet, if we recognize that computers can and should be used for other types of experiences, such as acquiring information management skills, development of personal models, and becoming more self-directed, then reliance on research measures designed for drill and practice and tutorial lessons is inappropriate. The research reviews and meta-analysis type studies on the effects of computer uses in education that are now widely available fail to recognize this phenomenon and only serve to "dig in the primitive uses" as Papert (1980) suggested would happen.

Problems with the current classification system

At the grass roots level, teachers recognize problems befalling the well-known software categories of drill and practice, tutorial, and simulation. Most notable is the inability of the category name to provide insights about how the software is to be used in the classroom; Is the
simulation designed for use before, during, or after instruction? Does the tutorial stand alone or do students need some knowledge prior to its use? Unfortunately, software vendors use this classification scheme in order to describe available software for educational purchases and so, teacher after teacher who has ordered software admits to getting something totally irrelevant for use in their classroom.

Software designers also face problems associated with this classification system. The use of the drill and practice, tutorial, and simulation classification system is based on the use of the computer not to change instruction, but to facilitate current instructional practices. A classification system that defines CAL in terms of traditional methods will not stimulate the development of software that facilitates information processing and problem solving skills.

Researchers also face problems with this classification system. CAL can be designed for numerous types of learning objectives, yet the present classification system is not able to classify CAL in terms of its intended learning purpose. So, researchers often evaluate lessons designed to motivate students in terms of achievement test scores. What is needed is a method to further divide instructional
software so that more appropriate comparisons can be made; comparisons that group lessons together based on the learning objectives. After all, not even all simulations, for example, are designed for the same purpose.

In order to more adequately utilize the computer for information processing, model building, and problem solving learning goals, educators must recognize the problems associated with the present research and current classification system and how they effect each other. This recognition will enable CAL to move in new directions. As Nievergelt (1980, p. 7) suggests, the main lesson for the CAL practitioner is to avoid the imposition of "... a straight-jacket on an emerging field."

Possible New Directions for CAL

Instead of using the new technology to do the "same old things", computers should facilitate new kinds of learning (Sheingold et al., 1983). Educators must use the computer to support the types of uses that will be needed by members of the information age (Molnar, 1982; Sheingold et al., 1983) and recognize that the computer offers new types of learning environments (Papert, 1980; Thomas & Boysen, 1984).

Successful students of the information age will be those who can effectively access, manipulate, evaluate,
query, and communicate about information (Sheingold et al., 1983). Educational software should provide for success with greater emphasis on problem-solving, algorithms, graphics, dynamics, and data processing at all levels of education (Molnar, 1982). Computers should be used to provide learners with experiences that facilitate the quest for meaning (Bush & Cobb, 1983-84) and computer uses should be somewhat like the use of the computer in real world settings (Papert & Soloman, 1972; Molnar, 1977).

Educators should not view the computer as just another media since other forms of media can only dispense information, while the computer can react to individual needs and encourage students to achieve higher levels of cognition; the computer should be viewed as a learning tool rather than a teaching tool (Thomas & Boysen, 1984). Resulting software will distinguish between the transmission of past knowledge and the eliciting of new understanding; it will consist of students testing their own models, learning to deal with failures, gaining power to debug these failures, and developing a powerful store of ideas (Dwyer, 1974).

Bush and Cobb (1983-84, p. 9) present a view of the type of learning environments that should exist; "Learning involves the student's active construction of knowledge, and
there needs to be an emphasis on using computers to provide learners with experiences which will facilitate their quest for meaning." An example of this type of environment might consist of learners becoming aware of and attempting to "... overcome contradictions in their personal theories by reflecting on their activities. Or, they might draw an analogy between two or more experiences and generalize their existing knowledge" (Bush & Cobb, 1983-84, p. 10). Research findings indicate that such active strategic involvement with the material enhances learning (Sheingold et al., 1983).

In providing materials, curriculum developers must go beyond presenting principles; they must define the knowledge necessary in order to understand and solve problems (Molnar, 1982). In terms of teacher responsibilities, the instructor's primary task is not to tell the student how to do something, but to help the student build his or her own model of the process (Dwyer, 1974; Howe, 1978). Researchers must now focus greater attention on the structure of knowledge and the thinking process used by experts (Molnar, 1982).

In an editorial on the use of computers in education, Bohnam (1983) states that a few good learning programs are being developed; but that they are the work of talented
individual teachers and that profit margins and sales goals rarely coincide with educational effectiveness. At a recent convention regarding the use of computers in education, a software vendor stated; "... it will take us some time to convert our slide sets to the computer." This statement disregards the specific capabilities the computer can offer education that other media cannot; the computer is simply seen as a new media to do the same old things, its potential for providing new types of learning environments is not realized. It is just this type of situation that makes some authors suggest that a comprehensive national effort is needed to ensure the development of quality software (Molnar, 1977; Bohnam, 1983).

**Taxonomy for instructional computing**

In order to overcome the problems inherent in the current classification system, Thomas and Boysen (1984) present a taxonomy for the instructional use of the computer. They tell us that in order to effectively design, utilize, and research computer assisted learning we must focus on the status of the learner in relation to the material presented (Thomas & Boysen, 1984).

Dispelling the current widely used CAL categories of drill and practice, tutorial, and simulation they propose the categories of experiencing, informing, reinforcing,
integrating, and utilizing. Experiencing lessons are designed to set the stage for future learning. These lessons allow students to manipulate a model of a concept and should be used where students have little or no experience. A simulation that allows students to envision a process that is not normally accessible to them would be an example of an experiencing lesson. Informing software is used to transmit information. These programs are similar to tutorials; they replace other mediums such as lecture or text. Reinforcing programs are used to strengthen previously learned, often factual, material. The reinforcing category encompasses drill and practice type lessons. Integrating software are those lessons that facilitate the students' "pulling together" of various bits of information that were previously learned. These lessons could be quite similar to experiencing software but the status of the learner is different. Utilizing programs permit the computer to be used as a tool to mechanize a learned process. Statistical packages and calculators are examples of this category of software.

With this taxonomy, the designer's attention is focused on the various types of desired outcomes, the teacher knows how to utilize the product in the class, and the researcher can better categorize the various effects of CAL. It is
important to note, however, that while the taxonomy has many advantages, perhaps its most important contribution is the attention given to the need for software of the experiencing, integrating, and utilizing categories. Most presently available software would fit into the informing and reinforcing categories. Teachers and designers must become aware of the need for these other types of software, software where the student has an active role with a lesson that emphasizes information processing, heuristics, and problem solving. And, researchers must find more accurate methods for evaluating the worth of these types of programs.

Examples of new software

Only recently have educators seen new types of computer uses for educational purposes. Logo and tool software are the most widely known examples of this new type of computer use. These new software packages view the computer as a tool to facilitate student learning and understanding. No longer is the computer simply an alternate delivery system for old instructional methods.

Logo With the publication of Mindstorms: Children, Computers, and Powerful Ideas in 1980, Seymour Papert was given many labels; while some considered him a radical and others a savior, most thought he was at least revolutionary. Prior to this publication, the idea of the computer-
directing-student was generally so well-accepted that this common practice of computer utilization in education went relatively unquestioned. Papert (1980) proposed the idea of the student-directing-computer rather than computer-directing-student. He developed Logo, a high level programming language, as an example of the student-directing-computer learning environment.

Papert (1980, p. 19) summarizes his ideas about computer uses in education with the following;

In most contemporary educational situations where children come into contact with computers the computer is used to put children through their paces, to provide exercises of an appropriate level of difficulty, to provide feedback, and to dispense information. The computer programming the child. In the Logo environment, the relationship is reversed: the child, even at pre-school ages, is in control: the child programs the computer. And in teaching the computer how to think, children embark on an exploration about how they themselves think. The experience can be heady: Thinking about thinking turns the child into an epistemologist, an experience not even shared by most adults.

Papert's (1980) ideas serve as a model for the development of new types of learning environments.

When students use Logo, a "mathland" is created where geometry comes to life ("mathland's" relation to geometry is equated with learning French in France). "Children are typically introduced to Logo by using the computer to control a turtle, an imaginary creature which lives on a
graphics display screen, the movement of which is controlled by commands typed at a keyboard; for example: FORWARD 100, BACK 50, RIGHT 90, LEFT 45, etc." (Watt, 1979, p. 255).

During the first uses of Logo, students might use these primitive commands to drive the turtle through mazes, draw simple figures, or outline their initials. Once students are comfortable with the primitive commands, they might teach the turtle new words, such as the SQUARE shown in Figure 1. The primitive commands can be used to do any number of projects. In this environment, each student is able to design his or her own specific project.

```
TO SQUARE
    REPEAT 4 [FD 50 RT 90]
END
```

**FIGURE 1.** Logo Square Procedure and Graphic

These new words can then be used as building blocks for other projects. For instance, students might make the SQUARE do something such as SPIN (Figure 2).
Later, projects with a theme develop. These projects usually involve division of the total project into more solvable portions, - "mind size bites" as Papert (1980) calls them. A TREE program that consists of TRUNK, LIMBS, and LEAVES could be written. And then a FOREST can be made by doing several TREES and adding a SUN (Figure 3).

During this whole process, the turtle is used as a mathematically expressive medium. It is also a medium that students can superimpose onto their own bodies. They can pretend turtle, executing the commands that they would give the turtle, in order to develop their instructions or debug their programs. Geometric concepts such as distance, direction, and angles come to life in this environment. Through the use of the turtle to create graphics, students
come to understand these concepts without "formal" instruction.

At the same time that students are learning geometry with Logo, Papert (1980) suggests that students also develop their ability to use heuristics. Logo users are forced to think about their own thinking. The turtle doesn't always draw exactly what the student had in mind. The SQUARE shown in (Figure 4) provides an illustration.
FIGURE 4. Logo Problem Square Procedure and Graphic

After initial exclamations of "the turtle didn't do what I told it to", Logo users realize that computers do exactly as they are told and that the real problem lies in the student's own thinking. With this realization, students learn to evaluate their own thinking and gain confidence in their problem solving powers. They learn that mistakes are usually involved in their projects, that mistakes must be overcome and are not "failures" on their part. Molnar (1978, p. 15) concludes of Papert's work;

The significance of Dr. Papert's work is that it demonstrates that today's curriculum greatly underestimates the capacity of children to deal with complexity and arbitrarily postpones the introduction of problem-solving skill to a point so late in the curriculum that most children lose interest or become so dependent on guidance that they never master these skills.
As the utilization of the Logo language by classroom teachers has become more sophisticated, so also has the Logo research. Early Logo research tended to be anecdotal and usually was written by what some critics have called "overzealous" promoters. More recently, more valid research studies have supported the use of Logo. In a review of the Logo research, for example, Clements (1985) concludes that Logo has been shown to encourage social interaction, positive self-images, positive attitudes toward learning and independent work habits; to facilitate achievement gains in select areas (such as knowledge of geometric concepts); to encourage the development of specific problem solving behavior; and perhaps to enhance specific meta cognitive abilities and enhance creativity. Critics, who claim Logo has not lived up to the initial claims and suggest that it not be given so much attention, must realize that educators are only beginning to develop their uses of the language.

Tool software A similar model for educational applications of computers is the concept of tool software. Sheingold et al. (1983) suggest that software focus on information management skills and propose the idea of "software tools" in order to accomplish the development of these skills. Tools are those pieces of software which help users access, organize, manipulate, and communicate about
information (Sheingold, et al., 1983). Most kinds of tool software enable people to enter, revise, organize, and reorganize information (Sheingold et al., 1983). Tools help people accomplish tasks, yet do not specify the exact procedures involved in the task, in this way they are similar to pencil and paper and calculators.

Word processors, database management systems, music editing systems, spreadsheet packages, and graphics editors are examples of tool software. Of these, word processors are the most familiar. Word processors enable the user to manipulate text. Word processors in education allow teachers and students to approach writing the way professional writers do - creating, writing, rewriting, recreating, and rewriting. Word processors assist the revision process by eliminating the recopying or retyping that was necessary with pen and paper or typewriters. They free the writers from the drudgery of revision and enable them to spend more effort evaluating their own writing.

Data base programs allow for the collection, manipulation, and analysis of large amounts of information. Data bases in education can be used to encourage students to gather, categorize and operate on data so that some conclusions can be reached. Spread sheets are used in a similar manner. Formula templates allow the students to do
massive calculations on numerical data. The students, then, can make changes to any one variable and determine the variable's effect on the other aspects of the system. In these situations the computer "... eliminates many manual skills that are prerequisite to mastery and provides a powerful general problem-solving tool that permits students to cope with problems of complexity" (Molnar, 1978, p. 16).

**Microworlds** While teachers of language arts, social studies, and mathematics develop their utilization of Logo, word processing packages, data base management programs, and spread sheets, it is important for all educators to realize that similar software can be developed for many concepts taught in the various subjects. Currently, some educators have realized the potential of the computer for the development of microworlds. A microworld would typically:

1) represent the phenomena of the domain clearly; 2) eliminate irrelevant complexities from the microworld; 3) focus the students on aspects of their knowledge that need revising; 4) facilitate the use of problem solving heuristics; 5) encourage the application of relevant knowledge from other domains; and 6) encourage better ways of representing and thinking about the domain (White, 1984, p. 69).

White's (1984) example of a microworld for understanding the Newtonian laws of motion is a computer game. In this computer game, students must control a spaceship in order to hit some target or navigate the ship
through some maze. The difficulty level of the game increases as the student proceeds through the game. Strategies for achieving the goals utilize the student's intuitive understanding of how forces affect motion and various concepts in formal physics.

In another example, Brant (1983-84) creates a microworld for understanding Mendelian genetics. The goal of his lesson is to develop a pure recessive organism. Again, various levels of difficulty are represented. The student starts with one male and one female organism and through a breeding program of his or her choice attempts to develop the desired organism.

In an example of a microworld for a more limited concept, Thomas (1984) designed a lesson for understanding a computer's operation. In this microworld, students must manipulate one array of numbers in order to create another array with the same numbers in ascending order.

In each of these lessons, the individual student works toward a goal by manipulating the pieces of the total system. At each step, the student "sees" the results of the selected approach giving him or her insight into the faults of his or her understanding. These environments facilitate user control and through the encouragement of the student's evaluation of his or her own thinking, facilitate the
development of a more self-directed, heuristic approach to learning. It is with the development and utilization of software that encourages students to be more self-directed, to manipulate information, and devise their own models that the computer's potential for education will be better met.

Possible New Directions for Research

As described earlier in this chapter, a major problem of the currently available research regarding the effectiveness of computer uses in education is the reliance on evaluation techniques best suited for measuring factual recall and concept definition types of learning (Ellinger & Brown, 1979). And, while it has already been recognized that CAL has unique capabilities for concept learning and the development of general problem solving skills, research studies on computer uses in education typically compare a computer using group of students to students who receive traditional (usually lecture) instruction. These two situations bias the research outcomes and fail to encourage the development of new types of computer uses. Bredemeier and Greenblat (1981, p. 309) criticize the types of evaluations that are now prevalent by emphasizing "... the pointlessness of comparative assessments of effectiveness without clearer specification of any rationale for the outcome to be measured . . . ."
Needed are studies which attempt to determine what areas of the current curriculum could be improved with computer applications and to measure higher levels of cognition. Greenblat (1975, p. 7) pursues this theme;

We must not only teach people to SEE the forest and the trees, but we must show them HOW TO FIND THE WOODS and MOTIVATE THEM TO WANT TO MAKE THE SEARCH. In nonmetaphoric terms, we must develop ways of building motivation to learn - to explore, conceptualize, inquire, experiment, and critically analyze.

Howe's (1978) investigation of problem-formulating and problem solving skills in a Logo environment illustrates the type of research methodology that is needed. The study, conducted over a period of six years, investigates whether a Logo experience assisted children's learning in the normal classroom activities. The methodology consisted of;

. . . building an individual profile of each pupil, assessing changes in each pupil's mathematical skills, assessing general changes in each pupil's ability to communicate, assessing how each pupil's learning style (was) affected, and assessing gross changes in each pupil's behavior in the classroom, both academically and socially (Howe, 1978, p. 122).

Utilization of similar research methodologies would enable the design of more appropriate educational software and would provide more useful research results.
Summary

Although computers have been used in education for some time, the currently available research results do not strongly support the extensive efforts involved in providing CAL. At the root of this problem is the inappropriate utilization and evaluation of the computer by software designers, teachers, and researchers. Almost all of the presently available software consists of drill and practice and tutorial type lessons, and although the computer supports such uses, less expensive methods might provide equally positive results.

Recently, some educators have realized the potential of the computer to provide learning environments other than those of the drill and practice and tutorial type. Such learning environments consist of activities where students are actively engaged in model building, information processing, problem solving, or heuristics. With these new learning environments the computer will expand and enhance the current curriculum.

Although these ideas are beginning to receive greater attention, numerous current problems must be overcome before computer use can move forward into this new frame. A new classification system and more appropriate evaluative techniques for CAL comparisons are necessary. It is
suggested that the classification system focus on the learning objectives of the lessons that are being compared. In the development of software, detailed attention should be given to determining the effect of the lesson on individual student models. And, evaluative techniques, imposed only after thorough revisions based on field test data have been incorporated, must move away from only measuring achievement test scores and attempt to develop better measures of higher order thinking.
In this chapter, the planning and development of the preliminary form of the product, steps two and three of the research and development cycle identified earlier, are described. A problematic teaching area of the existing curriculum in animal science suitable for a computer application is identified. Following the identification of this problematic teaching area, a description of the computer simulation that was designed to facilitate teaching and learning in this area is given. A description of the developmental steps used in designing the simulation is then presented.

In the second major section of this chapter, the plan for the field test is given. The nature of the development project was to focus on the student's present state, the desired student state, and what the lesson would need to do in order to bring the student to this desired state. Specific attention was given to determining what types of models the students had regarding the concept and how the simulation could be designed to affect these various types of models. As cited earlier, the field test, done on a small scale, should provide a detailed look at each student who uses the lesson, the interactions that student has with the lesson, and how the lesson assisted the student in
perceiving the concept. The plan for this specific field test included a pre-test to determine what model of the concept each student had, observation of each student's interaction with the lesson, and a post-test that included open-ended questions designed to determine what the student learned from the lesson.

Development of the Simulation

Identification of problematic teaching area

In dairy herd management a fundamental concept requiring mastery is that the difference between herds in average milk produced per cow each year is due mainly to management factors. Although the numbers differ from study to study, it is evident that, today, anywhere from 85% to 95% of a cow's milk production is attributable to the management factors between herds. In fact, the formula presented in Table 1 is usually given in a beginning dairy management class.

Appropriate computer application

Yet, a common perception among dairy farmers is the idea that "if I had the cows belonging to the wealthy farmer down the road, I would be wealthy too." A most relevant learning experience would be to have these farmers switch cows, finding that the cows really would not make that much
TABLE 1. Formula for Predicting Milk Production Differences

\[
R = (C - A) + (0.15 \times (A - N)) + N
\]

- \( R \) predicted record for the cow in a new herd
- \( C \) cow's production record in her previous herd
- \( A \) average milk production of previous herd
- \( N \) average milk production of the new herd

An Example:

Cow A makes 18,000 lbs. in Herd A which averages 19,000 lbs.

New Herd's Average is 16,000.

\[
\begin{align*}
(18,000 - 19,000) + (0.15 \times (19,000 - 16,000)) + 16,000 &= 15,450
\end{align*}
\]

Cow A will produce 15,450 in the new herd

of a difference. Unfortunately, it would be an impossible task for the classroom teacher to provide herds of cattle to students so that such switching could take place. However, a computer simulation with its unique ability to compress time and duplicate real world phenomena that otherwise would require massive expenditures of effort and money could be used to simulate this situation. And, while it is not a new idea to propose the use of a computer simulation for dairy
Management classes, it is a new idea to suggest the use of a limited concept interactive simulation.

For years, agriculture classes utilized simulations of a typically batch nature. This batch processing usually consisted of students handing in decisions on paper that were later coded onto punched cards and submitted to the computer. Students received feedback about their decisions at a later date. In these batch simulations, students usually owned a theoretical herd of cattle and were responsible for the entire spectrum of herd related management decisions. The simulations usually ran the entire semester or year and focused on the "big picture." An attempt was made by the designers to closely resemble real world events, often encompassing as many variables as play havoc on the real dairy management environment.

In contrast, a limited concept simulation would focus on a smaller aspect of the total system thereby reducing the total number of variables that act on the larger system and would enable students to better understand each component part. A limited concept simulation is an example of how educators can utilize the computer to improve education rather than to simply fit the computer into what they do already. Instead of following the lead of business and major research centers in the development of simulations
that exactly simulate large systems, educators must explore
new uses of the computer that would be of more benefit to
their own discipline. "Complex systems can be modeled by
simplifying them to those elements and interactions of
greatest importance in generating the behavior that
interests us" (Fowler, 1982, p. 257).

In the case of the proposed simulation, students are
able to gain insight into a concept not normally accessible
to them by receiving immediate feedback in a structured
problem solving environment.

The intimate, intuition based interaction between
the theoretical system and a user can lead to a
creative form of model exploration . . . (the
user) can explore the model's behavior and the
role of each constraint . . . the assumptions
inherent in these realistic models can then be
tested by experimentation (Fowler, 1982, p. 257).

Depending on the present knowledge of the student, the
simulation could provide an organizing structure for the
learning to come, serve as a concrete example, or provide an
opportunity for the student to apply previous learning
(Thomas & Boysen, 1984).

The proposed simulation is of the experiential type as
described by Thomas and Boysen (1984), although it could
also be used as an integrating activity with more
experienced students, and is intended for major use with
students who have not yet mastered the main concept. It is
likely that these students will have just begun an initial dairy herd management course. The nature of the simulation is to confront students with their faulty perceptions. In this way, the simulation serves as a concrete example for the more experienced student and as an advance organizer for the less experienced student. This experience should cause the student to bring to mind all he or she knows about the particular concept. With this "mind set" the less experienced students should have a useful structure available to receive the concept when it is presented formally in lecture and the more experienced students should be able to incorporate the classroom knowledge with "real world" events.

Description of COWS: The experiential simulation

The simulation, named COWS, runs on the Courseware Authoring System (CAS) developed by Digital Equipment Corporation for their VAX computer. The system allows for an extremely interactive situation because of its use of the Digital Authoring Language (DAL), a language designed specifically for the development of educational software. The graphics, supported by the GIGI terminals, are of very high quality.

A student who uses COWS is first given an overview of the lesson and then asked to purchase four cows from the
FIGURE 5. COWS Title Display

FIGURE 6. COWS Main Menu Display
cattle sales offered by the computer that will increase his or her herd average (Figure 7). COWS randomly generates data about farm situations and provides a hypothetical farm to each user (Figure 8). The student can attend any number of sales where ten cows are offered per sale, each with a certain amount of record information (Figure 9). The student can then request additional information on a cow (Figure 10). To purchase a cow the student must out-bid the computer (Figure 11). When the student buys a cow the production records for the upcoming years in the student's herd are given (Figure 12). The student may request to see a production summary of his or her purchases at any time (Figure 13).

Although current prices and norm data were used for much of the simulation, some phenomena were exaggerated in order to present more of a "problem situation" for the learners. For instance, in generating sale cattle, attention was given to limiting the number of extremely high producing cows so that students were not able to increase their herd average simply by purchasing cattle with far superior genetics. Other items, such as calving interval and age, were held within limited bounds so that students would be more focused on the primary variable of difference from herdmates.
Simulation Description

OBJECTIVES:

1. To provide an opportunity to experiment with the selection and purchase of cows from other herds.
2. Discover the aspects that influence a purchased cow's profitability.

OVERVIEW:
This simulation allows you to practice the selection of dairy cattle. You will be given a theoretical dairy herd and must purchase four cows from the cattle sales offered by the computer.

YOUR GOAL is to buy cows that will increase your herd average.

Press RETURN to continue.

FIGURE 7. COWS Objectives/Overview Display

Your Herd Information

Current Herd Size 26
Optimal Herd Size 30
Average Milk Production:
M.E. 14097
Actual 11700
Calving Interval 13

Press RETURN to continue.

FIGURE 8. COWS Farm Information Display
### CATTLE SALE

<table>
<thead>
<tr>
<th>COW</th>
<th>LAST M.E.</th>
<th>LAST ACTUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12763</td>
<td>12625</td>
</tr>
<tr>
<td>2</td>
<td>14121</td>
<td>11720</td>
</tr>
<tr>
<td>3</td>
<td>9355</td>
<td>6329</td>
</tr>
<tr>
<td>4</td>
<td>12207</td>
<td>11296</td>
</tr>
<tr>
<td>5</td>
<td>15623</td>
<td>11331</td>
</tr>
<tr>
<td>6</td>
<td>22857</td>
<td>22457</td>
</tr>
<tr>
<td>7</td>
<td>13689</td>
<td>9919</td>
</tr>
<tr>
<td>8</td>
<td>16331</td>
<td>15614</td>
</tr>
<tr>
<td>9</td>
<td>14916</td>
<td>12399</td>
</tr>
<tr>
<td>10</td>
<td>10037</td>
<td>8380</td>
</tr>
</tbody>
</table>

**SALE MENU**
- More Information on a Cow
- Bid on a Cow
- Go to Another Cattle Sale
- See Summary of Purchases
- Get Help

Press `+` then `RETURN` to select. Press `Esc` when done.

---

**FIGURE 9. COWS Sale Display**

---

**FIGURE 10. COWS More Information Display**
FIGURE 11. COWS Bidding Display

FIGURE 12. COWS Purchased Cow Production Display
The developmental process

The developmental process consisted of: (1) defining the lesson objectives, (2) developing a model of the lesson, (3) determining the structural flow of the lesson, (4) actually coding the procedural units, (5) revising the product based on a preliminary field test, (6) field testing a target group, and (7) revising the simulation based on field test results.

Defining the lesson objectives proved to be a difficult task. The overall concept requiring mastery was for the student to understand that 85% to 95% of the production was
due to management. However, it became necessary to identify those related objectives that students would need in order to achieve this broad objective. The lesson objectives are presented in Table 2.

TABLE 2. Objectives of Unit That Would Include COWS

(1) The student will understand that 85% to 95% of a cow's milk production is due to her environmental conditions.

(a) The student will recognize that volume of milk is the most important source of profit from a dairy cow.

(b) The student will recognize what information is necessary in order to make sound decisions about the potential value of a particular cow.

(c) The student will be able to predict the amount of milk that a purchased cow will produce in another herd.

Once the objectives were specified, attention was given to how best to structure the simulation so that the students would receive the experiences necessary in order to achieve the overall objective. A model which described the general experiences that a user would need to have and what the computer would have to do in order to provide these
experiences was devised. Necessary inputs, outputs, and formulas were considered at this time. This model served as the source for determining the DAL code and data structures that would be required.

Also at this time, the graphic displays were designed and developed. The graphics editor available via CAS was utilized in order to produce the graphic displays. This editor facilitated the development of the graphics. The general procedure of the graphics editor was to describe to the machine what figure was desired, a box or text, the color, size, and placement, and the machine then would supply the actual DAL code that was necessary to produce the desired items.

Determination of the flow of program control was the next step. Thought was given to all procedural units that were required. Each unit was given a name and a description which included its purpose and any special required data structures. This determination of the necessary units and what they must do provided the framework for the structure of the total simulation into which more detailed code was added. Consideration was then given to the possible student responses, what options students might need, and what potential problems might exist.
Actual program code was only added after these initial steps were completed. With the determination of the necessary units and a description of what they entailed, the development of the actual instruction code was made easier. During the coding numerous items were recognized that would require revision to the previously described structure. These revisions were incorporated into the model of the simulation at the time of their recognition.

After the coding was completed, a preliminary field test was conducted using graduate students in a computer education course. Several run-time bugs were found during this field test. Suggestions for improvement of the program were requested (Appendix E). In general, the graduate students found the lesson to be in an acceptable form except for the run-time bugs. The lesson was revised after this preliminary field test before the scheduled field test with the target group.

The Pilot Study

A pilot study was designed in order to determine how animal science students would utilize the lesson and how the lesson could be improved.
Subjects

During the spring 1985 semester, the researcher contacted one senior and one sophomore Iowa State University Animal Science class for volunteers to participate in the simulation field test.

Procedures and instruments

Each of the eighteen volunteers was asked to schedule an hour and a half session during the two week period from May 6 to 17, 1985. Students participating in the field test signed a consent form (Appendix B), took a pre- and post-test, and evaluated the simulation.

The pre-test The pre-test, which consisted of three parts, attempted to identify the background experiences of each student, determine the student's present knowledge of the particular concept, and determine the student's computer knowledge (Appendix C). Part one of the pre-test asked students to list their previous dairy courses and describe their experience with dairy cattle and other related livestock. Part two of the pre-test asked students to rate their computer experience in terms of, general interest, present ability, computer anxiety, and the value of the computer to general education.

Part three of the pre-test consisted of six questions that attempted to access the student's present model of the
concept. Question 1 asked students to rank four cows for their potential milk production in another herd. Students were given each cow's milk production in a previous herd, the previous herd's average milk production, and the milk production of the herd that the cow would be entering. A correct ranking of these four cows would have required a model that closely approximated the formula presented earlier in this chapter. Question 2 attempted to access the student's knowledge of what items made a cow valuable. In question 3, students were asked to specifically address how important environment and genetics were in determining a cow's milk production. Both questions 4 and 5 requested the students to cite what information is necessary in order to successfully predict a cow's milk production in a new herd. Question 6, which had three subparts, asked students to determine a cow's milk production in another herd when the cow's production, her previous herd's average production, and the new herd's average production were given. This question was similar to question 1, however, three different situations were presented and the students were asked to explain their answers.

The simulation experience The researcher observed each session in order to obtain information about how each student utilized the lesson and identify potential lesson
improvements. Each student individually ran the lesson while the researcher observed and took notes regarding their general use of the lesson. Specifically, the researcher observed which cows the student was interested in, whether he or she sought information about the cow, and his or her reaction to the cow's production in the new herd. In addition, the lesson itself provided data on each student's simulation session. A data file was saved for each volunteer. This file included the following information; the student's beginning and ending herd averages, the milk production of each purchased cow, and the price paid for each purchased cow.

The post-test The post-test differed from the pre-test only in the order of answers to the multiple choice type questions (Appendix D). Students were asked to re-work the questions (1 and 6) which asked them to rank cows for predicted milk production in another herd. Students were told to re-work the remaining questions (2, 3, 4, and 5), that addressed their foundational knowledge in this area, only if they desired to change or add to their pre-test answer. The students were not allowed to view their pre-test, however, when completing the post-test.

The simulation evaluation On the evaluation sheet the students wrote or were asked verbally to determine
specific problems or improvements for the simulation (Appendix E). Attention was focused on the lesson instructions, the terminal operations, program execution problems, and suggestions for lesson improvement. Also, the students were asked to state what they had learned from the lesson and to give advice that would enable another student to do well.

Summary

An experiential computer simulation was designed and developed in order to facilitate the teaching and learning of a problematic conceptual area in the traditional dairy herd management curriculum and to serve as an example of the type of model building software that has been called for in the present educational literature. The simulation puts the student in an active role where he or she makes decisions, sees the results of those decisions, and on the basis of the results gains insight into his or her model of the concept. A field test was designed to obtain information about the initial models of animal science students, how the simulation affected the students, and how the simulation might be improved. The upcoming chapter presents the results of this field test.
CHAPTER FOUR: RESULTS

This chapter presents the results of the preliminary field test with animal science students. In keeping with the nature of the research and development cycle and the need for more descriptive research on individual student models, the presentation of results is very detailed. Each pre-test question is addressed separately with each student's response indicated. After a summarization of the student models that were identified by the pre-test results, outcomes of the simulation experience are presented. Then, post-test results are given. And, finally, the results of the students' evaluations of the simulation and suggestions for lesson improvement are presented.

Background Dairy Experiences and Education

Seniors

The background dairy related experiences of the six male seniors were quite rich. Four of the six had lived on home dairy farms. And, although the remaining two (S2, S4) students claimed very little dairy experience, they each had had experience with other types of livestock. One student (S6) was operating his own farm and had previously worked as a herdsman for a registered Holstein breeder. One other senior (S1) claimed experience with registered animals; his experience included showing and judging cattle.
All six of the volunteering seniors were majors or co-majors in Dairy Science. Therefore, the results obtained from asking the volunteers to list their previous coursework were quite similar. In general, three upper-level dairy production and/or management classes were cited. One student (S5) listed two courses and another (S3) listed four; some variety might be accounted for by recognizing that some students listed dairy courses of a marketing nature when others did not.

**Sophomore males**

The background experiences of the sophomore males were also quite rich. Six of the seven sophomores claimed experience with a home dairy farm. The remaining student (S12) had owned and operated a dairy farm for six years. Five of the six students from dairies had also been involved in showing cattle. Two (S9, S11) had worked at the ISU farm. And, one (S9) had also worked on a registered Holstein farm in California.

Again, the educational backgrounds in terms of dairy courses were similar among the students. In general, the sophomores had had two college-level dairy courses. Three (S7, S8, S11) of the students also reported involvement in a dairy judging course. And, one student (S7) listed high school coursework.
Sophomore females

The female sophomore volunteers did not have as many background experiences as the males. Only one student (S18) had lived on a home dairy farm. One student (S14) claimed no dairy experience. The remaining three cited work experience on one or two dairy farms; one (S16) of these had spent one year as a herd manager for a 40 cow dairy.

The educational backgrounds of the females were quite similar to those of the male sophomores. Four (S14, S15, S16, S17) of the five reported two college level courses (the same courses that most of the male sophomores listed). The remaining student (S18) claimed five dairy courses and some high school dairy experience.

Computer Experience

The overall average of the Likert items regarding computers were fairly positive (mean = 3.34). The students reported slightly below average computer ability (mean = 2.61) and just above average computer interest (mean = 3.38). The highest overall average score was given to the scale indicating the value of computers to education (mean = 3.83); seven of the eighteen students scored the high option for this item. The students reported medium low computer anxiety (mean = 2.44); one student was at the high end of the scale while six were at the low end.
The Pre-Test Results

Question 1

The first pre-test question gave information about four cows and asked the student to rank these cows for milk production in a new herd. The correct ranking was 1, 4, 3, 2. The results obtained from this question are discussed in the following paragraphs and summarized in Table 3. A working knowledge of the formula, with more weight given to environmental effects, would have been necessary for a correct ranking.

TABLE 3. Frequency of Responses When Asked to Rank Cows for Predicted Milk Production in a New Herd

<table>
<thead>
<tr>
<th>GROUP</th>
<th>CORRECT</th>
<th>HALF CORRECT</th>
<th>INCORRECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seniors N=6</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sophomores Males N=7</td>
<td>6</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Females N=5</td>
<td>-</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total N=18</td>
<td>9</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>
Seniors Three of the six seniors answered correctly; one scored half correct; and two were incorrect. Each of the three seniors (S1, S2, S3) who ranked the cows correctly (1,4,3,2) had marked the cow's difference from her herd average on his paper in order to rank the cows. The student (S4) who received half credit (with a ranking of 1,4,2,3) got the best and last cows correctly ranked; however, he reversed the second and third cows indicating that his belief of the concept waned with cows from lower producing herds. Of the two seniors who answered incorrectly, one (S5) ranked the cows according to highest production (1,3,2,4), placing Cow A over Cow D but not continuing with herd average differences. The other senior (S6) who answered incorrectly (2,3,1,4) lacked a consistent pattern in his rankings.

Sophomore males Of the seven sophomore males, one was incorrect and the others answered correctly. The student (S7) who answered incorrectly (1,3,2,4) ranked the cows according to highest production, placing Cow A over Cow C but not continuing with herdmate differences.

Sophomore females Not one of the five female sophomores ranked the four cows correctly. Two students (S15, S18) were half correct and three (S14, S16, S17) were incorrect. One student (S15) who received half credit
(1,4,2,3) ranked correctly the first and last place cows but inverted the order of the second and third place cows, indicating that her belief of the concept waned with low producing herds. The other student (S18) receiving half credit (2,4,3,1) switched the order of the first and second place cows. One student (S14) who answered incorrectly (1,3,2,4) ranked the cows according to the highest producer, placing Cow A over Cow D but not continuing with herdmate differences. Another student (S16) who scored incorrectly (3,2,1,4) ranked the cows according to their herd average without respect to the individual cow's deviation from her herd average. The researcher was unable to discern the pattern of the remaining student's (S17) incorrect answer.

**Question 2**

The second pre-test question asked each student to list the items that he or she felt made a dairy cow valuable. A discussion of these results is given in the following paragraphs and Table 4 summarizes the items that were cited. This question was posed to determine how much weight the students gave milk production.

**Seniors** All of the six seniors cited milk production as an important item. Four students (S1, S2, S3, S6) cited type and three students (S3, S4, S6) listed depth of pedigree. Two students (S2, S5) listed health as an
TABLE 4. Frequency of Items Cited When Asked to List Items That Make a Dairy Cow Valuable

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Seniors</th>
<th>Sophomores</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk Production</td>
<td>6</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Type</td>
<td>4</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Depth of Pedigree</td>
<td>4</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Reproductive Efficiency</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Health</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Fat and Protein</td>
<td>-</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Disposition</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
</tbody>
</table>

important item. And, one citation was given to each reproductive performance and disposition by one student (S5).

Sophomore males Type was cited by each of the seven sophomore males. Milk production was next in frequency of citation with six listings (S7, S8, S9, S11, S12, S13). Depth of pedigree was listed three times (S8, S10, S13) and
longevity, reproductive efficiency, and fat test were all listed once by (S11, S11, S8), respectively.

**Sophomore females** Milk production was cited by all five sophomore females. Depth of pedigree and sound type were listed by three students (S15, S17, S18). And, reproductive efficiency, and fat test were listed twice by (S14, S18) and (S15, S18) respectively.

**Question 3**

Pre-test question three asked students to explain how important genetics and environment were in determining a cow's milk production. Table 5 summarizes the results, and a discussion of the student responses follows. In posing this question, an attempt was made to identify those students who had a basic understanding of the concept.

**Seniors** Five of the six seniors (S2, S3, S4, S5, S6) indicated that both genetics and environment were important in determining a cow's milk production without assigning a greater importance to either. The remaining student (S1), however, indicated that environment was more important than genetics; he wrote "... production is 20% genetics, (and) 80% environmental ... ."

**Sophomore males** Two students (S7, S12) indicated that genetics and environment held equal importance in determining a cow's milk production. Two other students
TABLE 5. Frequency of Responses When Asked to Explain the Importance of Environment and Genetic Effects on Milk Production

<table>
<thead>
<tr>
<th>GROUP</th>
<th>ANSWER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E = G</td>
</tr>
<tr>
<td>Seniors N=6</td>
<td>5</td>
</tr>
<tr>
<td>Sophomores</td>
<td></td>
</tr>
<tr>
<td>Males=7</td>
<td>2</td>
</tr>
<tr>
<td>Females=5</td>
<td>3</td>
</tr>
<tr>
<td>Total N=18</td>
<td>10</td>
</tr>
</tbody>
</table>

(S11, S13) thought both were important but that genetics were more important; one stated "The genetics are the primary importance . . . ", and the other wrote "I would say genetics has twice the importance of management." Two other sophomore males (S8, S10) felt both genetics and environment were important but that the environment was more important. One of these students (S8) stated " . . . environment is probably more important." The other (S10) included the statement "Environment is 75-80% of milk production" in his answer. The remaining student (S9) mis-interpreted the question.
Sophomore females Three students (S14, S16, S17) indicated that environment and genetics were of equal importance. These students stated that genetics were "very important" and followed that by saying the environment was also "very important." No attempt was made by these three students to indicate if one was more important than the other. One student (S15) only mentioned genetics as important; no reference to the effects of environment was given. The remaining student (S18) indicated that environment was more important than genetics; she stated: "Personally, I feel that environment is the greatest factor influencing milk production."

Question 4

Pre-test question four suggested that cattle buyers had no more ability to predict success from a purchased cow than did used car buyers. The student responses to this question are presented in the following paragraphs.

Seniors Of the six seniors, four students disagreed with the quote and two agreed. Each of the four students (S1, S2, S3, S5) who disagreed felt that cattle buyers had more reliable information available than did buyers of used cars. Two of these students indicated the specific items a cow buyer should utilize - the reputation of the seller, the cow's production records, and the pedigree of the cow. The
two students who agreed with the quote each gave a different explanation. One (S4) stated; "True, pedigrees can make a cow look good on paper, but it is really the way that she performs in the parlor that's important to the farmer." The other (S6) wrote; "... a cow could perform in one herd, but if moved and placed under different environment and different background schemes the cow's production could suffer."

**Sophomore males** Five of the sophomore males (S8, S9, S10, S11, S13) disagreed with the quote; they all stated that past production records and the difference from herdmates could adequately predict successful purchases. Two students (S7, S12) agreed with the quote if the cow was not on production test. One of these (S7) felt a cow must be in your own operation before you could determine if she was a good buy; however, he stated that a dairy farmer had more certified records available than a used car buyer had.

**Sophomore females** Two females agreed with the quote; while three disagreed. One (S16) student who agreed with the quote felt that the buyer could not tell how the cow would milk until she produced in the new herd. The other student (S14) who agreed suggested that the farmer attempt to identify the conditions of the previous farm. The three students (S15, S17, S18) who disagreed felt that
with previous production records, pedigrees, and type, the buyer should be able to adequately judge the cow.

Question 5

Pre-test question five asked students to list the items that were necessary to ensure successful dairy purchases. The frequency of items cited are summarized in Table 5, and an explanation of the student responses is presented in the following paragraphs. Here, students were prompted to respond by indicating how this situation could be true or false.

**Seniors** Only one senior (S4) failed to mention production records as an item for a cattle buyer to know. The next most frequently cited items, with four citations each, were the cow's pedigree (S1, S3, S4, S6) and information on the cow's relatives (S1, S4, S5, S6). Two students (S3, S4) listed knowledge of the previous herd environment. And, one citation was given for each of the following: reproductive history (S2), price (S2), reputation of the seller (S5), health records (S3), and registration (S3).

**Sophomore males** Again, only one student (S10) failed to mention the cow's production records as a necessary item for predicting sound dairy purchases. Four students cited the cow's pedigree (S7, S10, S12, S13) and
TABLE 6. Frequency of Items Cited When Asked to List Items Necessary to Ensure Successful Dairy Purchases

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Seniors</th>
<th>Sophomores</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M  F</td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>6</td>
<td>6  5</td>
<td>17</td>
</tr>
<tr>
<td>Pedigree</td>
<td>4</td>
<td>4  4</td>
<td>12</td>
</tr>
<tr>
<td>Relative Information</td>
<td>4</td>
<td>3  2</td>
<td>9</td>
</tr>
<tr>
<td>Herd Environment</td>
<td>2</td>
<td>2  2</td>
<td>6</td>
</tr>
<tr>
<td>Reproductive Performance</td>
<td>1</td>
<td>2  3</td>
<td>6</td>
</tr>
<tr>
<td>Reputation of Seller</td>
<td>1</td>
<td>1  1</td>
<td>3</td>
</tr>
<tr>
<td>Health</td>
<td>1</td>
<td>1  -</td>
<td>2</td>
</tr>
<tr>
<td>Price</td>
<td>1</td>
<td>-  -</td>
<td>1</td>
</tr>
<tr>
<td>Registration</td>
<td>1</td>
<td>-  -</td>
<td>1</td>
</tr>
<tr>
<td>Lactation Stage</td>
<td>-</td>
<td>1  -</td>
<td>1</td>
</tr>
</tbody>
</table>

her type score (S7, S8, S9, S13). Three students (S8, S11, S13) listed information on the cow's relatives. And, reproductive performance (S8, S10), the environment of the previous herd (S9, S11), and a visual inspection of the cow
(S11, S12) each received two citations. Health records
(S10), reputation of the seller (S11), and stage of
lactation (S8) received one citation each. The one student
(S10) who failed to list the cow's production did suggest
knowing the Cow Index.

**Sophomore females** All five sophomore females said
that a buyer should learn the cow's milk production. Four
students (S14, S16, S17, S18) cited depth of pedigree, and
three (S15, S17, S18) listed reproductive performance. Two
citations were given to each relative information (S15, S17)
and the previous environment of the cow (S14, S18). In
addition, one student (S16) listed the reputation of the
seller as an important factor.

**Question 6**

Pre-test question 6 was similar to the first pre-test
question in that students needed to predict the milk
production of a purchased cow in a new herd. However,
question 6 presented three different situations rather than
one and asked the students to explain their answer. Correct
responses were above average for 6a and 6b, and can't tell
for 6c. The overall results from this question are
summarized in Table 7.

**Seniors** One senior (S1) correctly answered each of
the three subparts of pre-test question 6. In his
TABLE 7. Responses When Asked to Judge a Cow for Predicted Milk Production in a New Herd

<table>
<thead>
<tr>
<th>GROUP</th>
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<tbody>
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<td></td>
<td>6a</td>
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<td>6b</td>
<td></td>
<td>6c</td>
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<td>C</td>
<td>C</td>
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<tr>
<td>S2</td>
<td>C</td>
<td>H</td>
<td>C</td>
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<td></td>
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<tr>
<td>S3</td>
<td>I</td>
<td>I</td>
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<tr>
<td>S4</td>
<td>I</td>
<td>C</td>
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<td>S5</td>
<td>I</td>
<td>I</td>
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<tr>
<td>S6</td>
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<td>S18</td>
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<td>C</td>
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</tbody>
</table>

explanation, he stated that the cow in 6a "is +2,000 lbs. from herd"; in 6b he wrote "... this cow has the ability
to produce above herdmates"; and for 6c he wrote "... this depends upon how well that cow is producing in the other herd." Another senior (S2) correctly answered two of the three subparts and received half credit for the remaining subpart. In explanation for his answer to 6a, he wrote "... the management between the two farms is comparable, therefore the cow must have the ability to produce at an above average rate." On 6b where he received half credit, he circled the average production option but wrote in beside this answer "or better." For 6c, he mentioned that production could not be predicted because the herd reference was missing. Another student (S4) answered subpart 6c correctly and the remaining two parts incorrectly. His reasons for the given responses did not seem to follow a particular pattern. For 6a, he suggested the cow would only make average production because of the different environment. But then in 6b, he thought the cow would produce above average because "... she must have the genetics to be producing that amount of milk." And, he also thought the cow in 6c would produce above average. The remaining three seniors (S3, S5, S6) answered each subpart incorrectly. They all felt that production could not be predicted because not enough information was given. Although the correct response to 6c was "can't predict",
these students failed to receive correct answers because their explanations were incorrect.

**Sophomore males** Three (S8, S10, S12) of the seven sophomore males correctly answered each subpart. For 6a, they each explained that the two herds were comparable and the cow was above average. Also for 6b, the students cited the cow's ability to produce above her herd's average production. And, for 6c, they each said the production could not be determined because no herdmate comparison was given. Two students (S11, S13) correctly answered 6a and incorrectly answered 6b and 6c. In 6a, they wrote that the cow was superior to the average animals of both herds. For 6b, they each explained that the cow did not have the ability to produce above herd average; one (S11) wrote "... her production ability is well below the herd average and the environment will not compensate that much." The other (S13) wrote "... part of the difference in the herds may be genetic." Two students (S6, S7) answered each subpart incorrectly. One (S7) explained in 6a and 6b that you could not predict the cow's production "... because the management and genetics haven't been given." Yet in 6c, he stated "... production is high enough above average to assume above average production."
Sophomore females One student (S18) answered each subpart correctly. She explained that the cow was "... better than the herd" in 6a and 6b. For subpart 6c, she wrote "... don't know the cow's comparison to her herd average." Two students (S16, S17) correctly answered subpart 6a; one (S16) wrote "... both herds are at 14,000 and the cow's production is 16,000 therefore she will be above average in both herds." Their answers to the remaining two parts were also identical. Each felt the cow in 6b would produce below average; one (S17) stated "... it doesn't matter what the previous herd average was ... 12,500 is below my 14,000 average." For 6c, they each thought the cow would be above average. The remaining two students (S14, S15) answered each subpart incorrectly. They circled "can't tell" for each part. In 6a, one student (S14) wrote "... need to know environmental conditions and information about feeds, etc." Although "can't tell" was a correct response to 6c their explanations indicated that their perceptions of the concept were wrong. For instance, one (S14) wrote "... the cow will produce the same ... however, if my management is good she will probable produce higher."
Summary of student models

The students' models seemed to fit into four categories; correct, incorrect, mixed but mostly correct, and mixed but mostly incorrect. Four students, one senior and three sophomore males, exhibited correct models of the concept as determined by their pre-test responses. Four other students, two seniors, one sophomore male, and one sophomore female, exhibited incorrect models of the concept as determined by the pre-test. Four students were mostly correct in their pre-test responses and six students were mostly incorrect.

Three (S1, S8, S10) of the four who exhibited correct models indicated that the environment was more important than genetics in determining milk production. Two of these cited percentages; their percentages differed slightly with one saying environment was 80% and the other saying it was 75%. The same three (S1, S8, S10) also thought it was important to find out the difference of the cow from her herd average. The remaining student (S12) mentioned difference from herd in explanation of his answers to question 6.

All four of the students (S5, S6, S7, S14) who exhibited incorrect models indicated that environment was equal to genetics in determining milk production. These
students typically ranked cows for milk production based on which cows produced the most milk without regard to her herd's average production. However, three (S5, S7, S14) of the four did regard herdmate difference when two cows had equal production records. All four felt that you could not predict milk production when given the cow's production, her herd production, and the average production in the new herd. In explanation, these students typically said "... the management and genetics have not been given."

The four students (S2, S9, S13, S18) with mostly correct models all utilized the basic concept. However, when it came to predicting the production of a low producing cow with a large positive deviation from her herd average, their use of the model lessened. In this case, these students seemed to overestimate the effect of the genetic effects on milk production. Yet, only one of these students (S13) stated that genetics were more important than environment in determining milk production.

Five of the six students (S3, S4, S11, S15, S16, S17) who exhibited mostly incorrect models, stated that environment and genetics held equal importance in determining a cow's milk production. The remaining student (S11) thought that genetics were more important than environment. All six thought that milk production could not
be determined when a cow's milk production, her herd average, and the new herd average were given.

The Simulation Experience

The simulation experience consisted of each student running the COWS lesson and purchasing four cows from the cattle sales offered by the computer. The student's task was to purchase cows that would increase his or her herd average. A description of the student experiences follows and the overall changes to each student's herd average are presented in Table 8. It should be noted that the lesson was modified after the first few students ran the lesson. The modification consisted of limiting the number of outstanding producers, since students were making large herd average gains without utilizing correct selection procedures.

The four students (S1, S8, S10, S12) who exhibited correct models made large herd average gains when using the simulation. Only one of these students (S10) ran the lesson before the program change limiting the number of outstanding milk producers was incorporated. All four looked at high producing cows at the sales. Only two of these students (S1, S8) were asked to give advice to fellow students regarding the simulation. Both suggested that the fellow
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<th>Cow 3</th>
<th>Cow 4</th>
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<td>Cow 3</td>
<td>Cow 4</td>
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<td>169</td>
<td>176</td>
<td>509</td>
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<td>533</td>
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<td>46</td>
<td>65</td>
<td>72</td>
<td>317</td>
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<td>171</td>
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<td>171</td>
<td>80</td>
<td>148</td>
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<td>-39</td>
<td>51</td>
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</tr>
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<td>133</td>
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</tr>
<tr>
<td>S18</td>
<td></td>
<td>42</td>
<td>85</td>
<td>108</td>
<td>119</td>
<td>354</td>
</tr>
</tbody>
</table>

*** Indicates use of lesson before lesson change that limited the number of outstanding producers.

The student finds the largest difference of a cow from her herd average and a cow with milk production better than the student's herd.
Of the four students (S5, S6, S7, S14) exhibiting incorrect models, one student (S5) decreased his herd average slightly, one student (S14) increased her herd average, and two students (S6, S7) greatly increased their herd averages. Two (S5, S7) of the four students with incorrect models improved responses to question one. Two (S5, S14) students also changed answers to question 6, although one student (S5) was still incorrect. Three (S5, S6, S7) looked at highest producers at the sales. The other student's (S14) selection pattern was not determined. Only one student (S7) advised fellow students to check the cow's herd average. S5 said after the simulation that he had learned "Just because a cow is a high producer does not mean it will help your herd average."

Three (S2, S9, S18) of the four students with mostly correct models had large herd average gains. The remaining student (S13) had an overall change of zero after his purchases. These students typically said in advice "... select highest producing individuals and review them for herdmate deviations." The students typically looked at only the high producers at the cattle sales.

Two (S4, S11) of the six students who had mostly incorrect models, had large herd average gains, however, these students used the simulation prior to the
incorporation of the variable that limited the number of outstanding milk producers. Two other students (S16, S17) had fairly large positive gains and the remaining two students (S13, S15) slightly improved their herd averages. These six students differed in the selection patterns used during the simulation. Most of these students (S4, S11, S15, S16, S17) did look for high producing cows at the cattle sales. A few of them did seem to gain some understanding from the lesson. For instance, S16 said that she learned "Records can't tell a lot . . . a high producing cow won't actually produce more in your herd."

The Post-Test

Basically, the students who were correct on the pre-test showed no answer changes on the post-test and the students who had incorrect pre-test responses showed some improvement on the post-test. The students who had some correct and some incorrect pre-test responses had the most improvements. A summary of the pre- and post-test differences is presented in Table 9.

One senior (S1) and three sophomore males (S8, S10, S12) correctly answered questions 1 and 6 on both the pre- and post-tests. No changes were seen in their explanations, although the senior (S1) added the following item to his question 2 response " . . . difference from herdmates."
TABLE 9. Pre and Post-test Differences for Questions One and Six by Student (A=Pre, B=Post)

<table>
<thead>
<tr>
<th>GROUP</th>
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<th>6c</th>
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<td>A B A B</td>
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</tr>
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</tr>
<tr>
<td>S1</td>
<td>C - C C - C</td>
<td>C - C C - C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>C - C H - H</td>
<td>C - C C - C</td>
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<td></td>
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<tr>
<td>S3</td>
<td>C - C I - I</td>
<td>I - I I - I</td>
<td></td>
<td></td>
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<tr>
<td>S4</td>
<td>H - H C - I</td>
<td>I - I I - I</td>
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<td></td>
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<td>S5</td>
<td>I - C I - I</td>
<td>I - I I - I</td>
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<td>S7</td>
<td>I - H I - I</td>
<td>I - I I - I</td>
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<tr>
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<tr>
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<td>I - I I - I</td>
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<tr>
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</tr>
<tr>
<td>S14</td>
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<td>I - I C - C</td>
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<tr>
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<td>I - I I - I</td>
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<td>S17</td>
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<td>I - C I - I</td>
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<tr>
<td>S18</td>
<td>H - H C - C</td>
<td>C - I C - C</td>
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</tr>
</tbody>
</table>

Of the four students who incorrectly answered pre-test questions 1 and 6, one student (S6) showed no change and three students (S5, S7, and S14) showed some improvement. S5 improved his answer to question 1 but continued with
TABLE 10. Overall Change from Pre to Post-test for Questions One and Six by Student

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<tr>
<td>S8</td>
<td>0</td>
</tr>
<tr>
<td>S9</td>
<td>0</td>
</tr>
<tr>
<td>S10</td>
<td>0</td>
</tr>
<tr>
<td>S11</td>
<td>-</td>
</tr>
<tr>
<td>S12</td>
<td>0</td>
</tr>
<tr>
<td>S13</td>
<td>+</td>
</tr>
<tr>
<td>Females</td>
<td></td>
</tr>
<tr>
<td>S14</td>
<td>+</td>
</tr>
<tr>
<td>S15</td>
<td>+</td>
</tr>
<tr>
<td>S16</td>
<td>-</td>
</tr>
<tr>
<td>S17</td>
<td>+</td>
</tr>
<tr>
<td>S18</td>
<td>-</td>
</tr>
</tbody>
</table>

0 = no change
+ = positive change
- = negative change

incorrect responses to question 6. In explanation for his selections to question 6 he wrote "... that is what happened when I used the computer." S7 also improved his
answer to question 1 but remained incorrect on each of the three subparts to question 6. S14 improved her response to 6b and 6c but continued to rank the cows incorrectly in question 1.

Four other students who were mostly correct in their pre-test responses, had different reactions to the post-test. Two of these student (S2, S9) had no change in their responses, one student (S13) did slightly better on his post-test and the remaining student (S18) did worse.

Six students were mostly incorrect on their pre-test responses. One of these (S3) had no differences in his post-test responses. Two students (S4, S11) did worse on the post-test. And two other students (S15, S17) improved their responses on the post-test. The remaining student (S16) did better on question 1 (although it was still incorrect) and worse on question 6.

The Simulation Evaluation

All (18) of the volunteering students felt that the program instructions were clear. Although none of the students cited a problem with the instructions that were given, several of the suggestions for program improvement focused on the instructions. Specifically, the use of the "PF4" key was discouraged and an explanation of the number
of sales that could be attended along with an explanation of mature equivalent (M.E.) were desired.

Three of the students cited problems with the terminal operations. Two of these problems were associated with the use of the "PF4" key. And, the other student wrote "... typical VAX problems ... the program runs alright." No explanation was given regarding the "typical" VAX problems. The remaining fifteen students cited no problems with the terminal operations.

Several program execution problems were addressed by the students. As before, the "PF4" key was labeled problematic. One student found its use "confusing." And two other students had problems with holding the key down too long when they wanted one "PF4" and got numerous "PF4"'s which took them through the lesson in ways they didn't want to go. One student did not like the way the program returned to the main menu after seeing a summary of his purchased cows.

The students gave numerous suggestions for lesson improvement. The most frequently cited item was to incorporate the price paid variable in order to provide more feedback on the cattle selections. A summary of the student suggestions appears in Table 11.
### TABLE 11. Student Suggestions for Lesson Improvement

<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>SUGGESTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>?</td>
<td>1 allow deletion of purchased cows</td>
</tr>
<tr>
<td>*</td>
<td>5 incorporation of price in evaluation of purchased cows</td>
</tr>
<tr>
<td>*</td>
<td>3 only use &quot;PF4&quot; to exit lesson</td>
</tr>
<tr>
<td>?</td>
<td>1 incorporate a genetic index</td>
</tr>
<tr>
<td>-</td>
<td>2 give more information on dam and sire</td>
</tr>
<tr>
<td>*</td>
<td>1 have people bring pencil and paper</td>
</tr>
<tr>
<td>*</td>
<td>1 include instructions regarding total number of sales</td>
</tr>
<tr>
<td>*</td>
<td>1 give explanation of overlooked cows</td>
</tr>
<tr>
<td>?</td>
<td>2 have more information available</td>
</tr>
<tr>
<td>*</td>
<td>2 explain mature equivalent (M.E.)</td>
</tr>
<tr>
<td>*</td>
<td>1 shorten the response time on the more information requests</td>
</tr>
<tr>
<td>*</td>
<td>1 allow return to same sale after summary</td>
</tr>
</tbody>
</table>

* should be incorporated

? unsure about inclusion

- should not be incorporated

### Summary

Results of the preliminary field test with animal science students indicated that the simulation could provide a needed addition to the existing curriculum. Many of the students had difficulty with the concept, even those students who exhibited correct models on paper failed to utilize their knowledge to the fullest extent. Numerous simulation changes and additions, however, were identified
as necessary. In the following chapter, then, generalizations discerned from the results summarized in this chapter are presented. And, attention is given to the needed lesson revisions and future research work with the simulation.
CHAPTER FIVE: DISCUSSION

After reviewing the literature regarding the use of computers in education, the researcher identified a gap between state-of-art educational research and current educational practice; the majority of the presently available CAL software lacked appropriate design features that would enable the computer to meet its potential for the infusion of problem solving, information processing, and model building skills into the existing curriculum. With this gap in mind, the researcher proposed the development of a CAL lesson that could serve as a model of one type of computer use that better met the need for infusion of higher order thinking skills into the curriculum and also to serve as a model of how to develop software with these goals in mind. After designing the lesson, the researcher undertook a field test of the product in order to identify needed lesson revisions. In the preceding chapter, a presentation of the results of this field test were given.

In this chapter, the researcher makes generalizations about the results and, on the basis of these results, suggests needed lesson revisions. In the first section of this chapter, a review is given of the types of student models that were identified, with attention given to identifying flaws in the student models from pre- and post-
test answers and observations from the student interactions and outcomes of the simulation experience. After this, recommendations for lesson improvements are presented. And, in conclusion, a review is given, in terms of developmental caveats, of how the procedures utilized in this project reflect the needs identified in the review of literature and how the developmental process might be generalized.

Conclusions

Conclusions about the research questions that were identified in Chapter One are presented in the following paragraphs. Of primary importance was the usefulness of the simulation as a learning tool. In order to access this usefulness several secondary research questions were posed; these questions addressed the types of models of the concept that students had, the kinds of interactions that the students had with the simulation, and the outcomes of the simulation in terms of student perceptions about the concept of interest. Results from each of these questions are addressed below.

In general, the students had difficulty with the concept of environmental versus genetic effects on milk production. The pre-test identified four students with correct models, four students with incorrect models, four
students with mostly correct models, and six students with mostly incorrect models. More than half of the students did not understand the basic concept. Even though these students might have believed that environment was an important factor in determining milk production, they were not able to utilize this information for a "real world" application. In response to question 6 on both the pre- and post-test, these students typically circled the "can't tell" option and explained that the "... management (environment) and genetics have not been given." However, many of these students indicated on 6c that, even though the environmental and genetic factors had not been given, the production could be predicted since the cow's production was so high previously. These responses indicate the lack of a connection with herd average as an estimate of the environment and the overestimation of the genetic effects on milk production.

Student interactions with the simulation indicated that, even the students who typically scored correct responses (approximately one fourth of the students) to the pre- and post-test questions exhibited flawed conceptual models when using the simulation to actually purchase cows. These students, some of whom even quoted the exact conceptual idea that "production is 80% environment and 20%
genetics", evaluated cows on the basis of high production records along with the difference from herdmates.

The search procedures of the students exhibiting correct models usually consisted of attending many different cattle sales in order to identify high producers with positive deviations from their herdmates. Rarely did these students obtain herdmate deviations on the remaining cows at the attended sales. While the cows that they selected did enable herd average gains, equal overall increases to herd average could have been made with the purchase of initially lower producing cows which had larger deviations from their herd averages. And the cost of these cows would have been less. This provided another example of the lack of "real world" application of their knowledge. Even though these students correctly focused on cows with positive deviations from their herd averages, the students clinged to the "genetic" effects - high milk production (equated with genetics) seemed to guarantee positive gains for these students.

The background experiences of the students predicted some success on the pre- or post-test. Two (S2, S4) of the six seniors and four (S14, S15, S16, S17) of the five sophomore females had limited experience. All four of the sophomore females with limited experience exhibited mostly
incorrect models of the concept on the pre-test. One of the two seniors with limited experience also was identified as having a mostly incorrect model. The other senior, though, exhibited a mostly correct model.

When using the simulation, the four sophomore females who had the most limited experiences made herd average gains well below the average gains of the other students. The two seniors with limited dairy experience, though, did well on herd average gains with the simulation. In general, experience had some influence on positive responses and cattle selections. The sophomore males, as a group, did better on the pre- and post-tests and on the simulation than did the seniors. As a group, the sophomore males exhibited the most related background experiences.

The field test volunteers all were able to follow the lesson instructions and commands. In general, the students enjoyed using the lesson; they typically asked the researcher "did I get the highest gain?" One student who had not signed the initial volunteer sheet, simply came to run the simulation with a friend who had volunteered. When asked why he had decided to volunteer, he stated that he had "heard his friends discussing their experiences with the simulation" and on the basis of the conversation decided to try the lesson himself.
These comments indicate that the lesson did encourage students to think about their own model of the concept. However, the present form of the lesson failed to indicate to some students that their models had some faults. In these cases, the lesson failed to be a tool for the students to evaluate their own thinking. Later, attention will focus on the lesson improvements that need to be incorporated in order to alleviate these lesson flaws.

Two students who had very limited dairy experience felt that they needed another simulation session to try pulling their ideas together. They each asked to schedule a second session, and one returned for a third session. For them, the simulation indicated faulty logic on their part. Other students also realized problems with their models. As identified in Chapter Four several students with mixed models improved their post-test responses. And, a few students verbalized their insights. One student indicated a model reflection, he wrote "(I learned) just because a cow is a high producer does not mean it will help your herd average." Another student echoed this idea, she wrote "... a high producing cow won't actually produce in your herd." Again, the simulation showed some potential for pointing out inadequacies in student models. Of major concern, though, is the need for more illustrative feedback
regarding student choices, since a large number of the students who made large positive herd average gains, were given no indication of their model faults. The lack of further discussion regarding the students' attitudes about the simulation, makes it difficult to determine if the students felt the simulation reflected the real world situation.

Recommendations

**Suggested lesson improvements**

The most needed lesson revision was for the provision of more evaluative information to the user. In the present version of the lesson, not all faulty student models are discouraged and even when they are discouraged, the student may not receive enough negative feedback in order to realize that a problem exists in his or her model of the concept. For instance, numerous field test volunteers garnered large herd average gains simply by going to many cattle sales in search of "outstanding" milk producers. And, although high milk production alone does not ensure a herd average gain, the generation method used in the simulation ensured that any cow whose production was above 18,000 was also above herd average and, therefore, was a "good buy". In effect, the lesson encouraged the use of this incorrect model by
allowing the possibility of such positive results when this procedure was used. A mechanism that evaluates each student's cattle purchases on the basis of how his or her selections compare to the best possible case would alleviate this lesson problem.

One method of providing this mechanism would be to limit the number of sales that could be attended during one simulation session. Sale cattle would still be generated randomly so that a sale was never repeated but, limiting the number of sales would facilitate the identification of the best "buys" and the ability of the student to utilize this information. If, for instance, only five cattle sales were available during a simulation session the student would make his or her cattle selections and the lesson would go back to each sale and identify the four best cows at that sale.

Limiting the number of sales would not only make it easier to provide this evaluative mechanism, it would also encourage the student to look for cows with large positive deviations from their herdmates. Since only five sales would be available at a time, the chances of finding several "outstanding" producers would be minimized.

Since almost all of the students were able to purchase "outstanding" producers and on average make large herd average gains, a further measure should be taken in order to
discourage the use of this faulty selection model. In the random generation of the sale cattle, the lesson could recalculate the herd averages of a portion of these "outstanding" producers in order to minimize the percentage of those cows that were above herd average. In fact, during the field test this lesson change was identified and incorporated when it became obvious that the lesson failed to discourage this particular faulty selection strategy.

Another lesson revision that would provide more evaluative feedback on each student's cattle selections regards the incorporation of the price paid variable. In the present lesson, students bid against the computer on selected sale cattle. If the student exceeds the programmed sale value of the particular cow that he or she is bidding on, the cow is then, in effect, bought by the student, and the cow's production records in the students' herds are presented. An evaluation of the price that was paid for any cow is not given, nor is the student limited in the amount of money that he or she has available to spend. So, a student could buy a cow for $10,000.00 when the cow's sale value was only $950.00 and the lesson would not indicate that the price paid was too much.

Several options might be taken to improve the lesson in this respect. One option would be to eliminate altogether
the bidding on cattle. Students would simply pick the cows that they liked and find out how the cows performed in their herds. Another option would be to give the student a fixed number of dollars that he or she could spend to buy as many cows as he or she could with that amount. Or, in the evaluation of a student's cattle selections the lesson could present a dollars spent per unit of milk production change measure.

Perhaps, this revision would best be made by providing two levels of difficulty in the lesson. The first level would disregard the price variable altogether. Students, as suggested earlier, would simply select those cows that were desired for their herds and receive feedback regarding which were the best cows at each sale. The second level of difficulty would incorporate the price variable. Here, each student would bid on selected cows, and in the evaluation information the cow's estimated value and the price that the student paid for one unit of milk production change would be presented. In addition, the lesson would present the best possible combination of sale cattle and selling price.

Another needed revision was to provide students more freedom of movement through the various subportions of the lesson. In the present version of the simulation, a student might attend a cattle sale, buy one cow, and then select the
option "See Summary of Purchases." Then, much to the student's surprise, rather than being returned to the sale he or she just left, the student is returned to the main menu. Here, the student can select "attend a cattle sale" but, is not able to return the particular sale he or she just left. The student might have wanted to buy another cow at the first sale but, is now unable to. What is needed is a better mechanism to support the student's ability to answer the following questions; Where am I?, What can I do here?, How did I get here?, Where else can I go? How do I get there? (Nievergelt, 1980). It seems the most logical sequence would be to always return the student to where he or she left off and allow the student make the choice of where he or she wants to go. The screen graphics and menu options should have options for each of the places that a user might like to go.

The sale menu is particularly inappropriate in this manner. For instance, a student can not in the present lesson version attend a cattle sale, request to review see his or her farm information, and then return to the same sale. At least once, a field test volunteer wished to do just that. Limiting the number of available sales along with allowing students to attend, leave, and re-attend the same sale would also assist overcoming this present lesson
problem. Then, all conceivable options could be selected without the loss of the present selection. Students could see summary information on a cow by cow basis rather than a sale basis, and student time would not be wasted by reviewing one sale's cows, selecting to review farm information and then realizing that you could never get back to that sale.

In particular, the lesson menus could be redesigned to accept the first letter of an option rather than relying on the use of the up arrow, down arrow, and return keys. This would streamline the student selection process. The more information menu provides the clearest example of this needed revision. Here, a student is able to receive information on a selected cow. There are five pieces of information that are available for the student to review. The up arrow and down arrow keys are used to select which one of the five pieces of information the student would like to see displayed. If the student happens to want to see the cow's herd average (the last item on the menu) he or she must press the down arrow five times and then press the return key. If the student wished to see all the available information on a cow, he or she must press return for the first item, wait for the item to print to the screen, then use the down arrow key to select the second choice and press
return, wait for this item to print out on the screen, use
the down arrow to select the third item and press return,
wait for the item to print, use the down arrow to select the
fourth option, etc. Obviously, this is a tedious process
that wastes the user's time. Certainly, this menu could
simply display all options, including an option for all the
information, and the user could simply type the first letter
of any option in order to have that particular piece of
information displayed. Using one character and a return as
selection input would also be useful on the other lesson
menus. Such a menu operation would eliminate the use of the
up arrow and down arrow keys which are not only difficult to
find on the keyboard but, are an extra step in making a
selection.

A similar problem exists with the use of the "PF4" key,
several field test volunteers identified the present use of
the "PF4" key as problematic. Instead of using "PF4" to
exit all menus, an exit option should be incorporated into
the menu choices and the use of the "PF4" key should be
reserved for the one time function of exiting the entire
lesson.

More instructions about the nature of the simulation
experience should be given initially and be available for
review if requested at a later time. Specifically, more
elaborate instructions regarding what the student should expect during the simulation experience need to be provided. A description of the number of cows to buy, the use or non use of money, how many sales can be attended, and how one controls movement through the lesson should be given. Help units that address specific problem areas should be incorporated. For instance, one help section might provide an explanation of the terminology used in the lesson. Help that assists the user in understanding the lesson instructions should also be provided. A general input for help should be able to be called at any point in the lesson. And, from this point the students should be able to access more specific help for the particular topic that they are having problems with.

Another item that would improve the lesson would be a mechanism that enabled the student, after he or she had purchased four cattle and before viewing the explanation of the best buys, to delete a cow or purchased cow or cows from his or her herd and allow the student to purchase a different cow in place of the deleted cow. The most notable reason for this option is to eliminate the results attributable to mistakes. For instance, a student might think that he or she was bidding on cow 1 when in fact he or she had input a 2, the student could then delete cow 2 and
get cow 1 as was initially desired. Also, it would allow students who think they learned something from seeing the production records of a purchased cow to try a new selection model. Incorporation of this item would be restricted to use prior to getting the evaluative information. Students who would like to improve on their purchases after viewing the evaluative information would not be able to return to any of the previous sales. They could delete their purchased cows and attend other sales but not return to the same sales and buy the cows that were indicated as the best by the lesson.

The data file saved by the machine should be expanded. More information should be saved so that a more thorough review of each student's simulation experience could be collected. Specifically, the herd averages of all purchased cows, the number of cows the student sought information on or bid on, how many sales were attended, and any uses of the help information could be saved.

Revised lesson version

Many of the suggested lesson improvements presented above were incorporated into a new version of the lesson. The main menu was expanded to include several additional options (Figure 14). The overview display was also expanded to provide more information to the user about the nature of
the simulation (Figure 15). Each simulation session now has only thirty cows available for review and purchase. Although only ten cows can be seen at one time, the user may request which ten of the thirty he or she would like displayed (Figure 16). The more information menu was eliminated. Students who select to receive more information on a cow are simply presented with all the available information (Figure 17). In addition to the summary of purchases that can be reviewed at any point in the lesson, a display of the best four cows is available to the student after he or she has made four selections (Figure 18).

**FIGURE 14. Revised COWS Main Menu Display**
Simulation Description

OVERVIEW:
This simulation allows you to practice the selection of dairy cattle. As the owner of a theoretical dairy herd you will be able to select and purchase cows from a cattle sale offered by the computer. There are thirty cows available for purchase. You can spend any amount of money that you want for a cow -- although each cow has a set sale price and your purchases will be evaluated upon completion of this lesson.

You need to purchase four cows. YOUR GOAL should be to purchase the four cows that will increase your present herd average the most. Upon completion of your purchases the computer will present the four cows that would have increased your herd average the most.

Movement through the lesson is controlled by selections from the menu available on the screen at any time. A typical lesson session would consist of reading these instructions, viewing your herd information (you might want to copy your farm data onto paper), attending the cattle sale, viewing a summary of your purchases, seeing which cows were the best, and saving your work.

Press RETURN to continue.

FIGURE 15. Revised COWS Overview Display

CATTLE SALE

<table>
<thead>
<tr>
<th>COW</th>
<th>LAST M.E.</th>
<th>LAST ACTUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11528</td>
<td>8415</td>
</tr>
<tr>
<td>2</td>
<td>19082</td>
<td>8376</td>
</tr>
<tr>
<td>3</td>
<td>22087</td>
<td>20992</td>
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<tr>
<td>4</td>
<td>18121</td>
<td>16121</td>
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<td>10540</td>
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<td>13537</td>
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<td>13330</td>
</tr>
<tr>
<td>10</td>
<td>14577</td>
<td>10641</td>
</tr>
</tbody>
</table>

SALE MENU
- More Information on a Cow
- Bid on a Cow
- See Sale Cows 1 - 10
- See Sale Cows 11 - 20
- See Sale Cows 21 - 30
- See Summary of Purchases
- Exit Return to Main Menu

Press < or > then RETURN to select.

FIGURE 16. Revised COWS Sale Display
FIGURE 17. Revised COWS More Information Display

FIGURE 18. Revised COWS Best Cows Display
Possible future research projects

With the present revised version of the lesson, main field testing is now possible. Main field testing would consist of infusing the lesson into existing curriculum in animal science and conducting a larger scale evaluation of the lesson. In particular, the researcher suggests the exploration of the simulation as an advance organizer. Under and upper-class animal science students would participate, either receiving the lesson prior to or after the traditional classroom instruction. Also, the effect of incorporating a discussion regarding the simulation outcomes might be explored. The emphasis would be on how the simulation assists the traditional instruction. Therefore, in addition to the collection of quantitative data, more descriptive evaluation techniques should still be used. Data collected would include test scores, background experiences and attitudes, a measure of the student's simulation experience (perhaps the data file), and the instructor's perceptions regarding the usefulness of the lesson.

Developmental caveats

The need for educational materials that emphasize problem solving, information processing, and model building has received great attention lately in educational
literature (National Commission on Excellence in Education, 1983; National Science Board, 1983; National Science Foundation, 1983). A large portion of the research regarding the effectiveness of teaching problem solving skills suggests that thinking and problem solving skills should be taught as part of an interactive process between these cognitive abilities and the acquisition of domain specific knowledge rather than as add ons to knowledge (Glaser, 1984). The computer has been identified as a mechanism rich for such infusion of problem solving skills into the existing curriculum. However, in order for educational software to meet this goal several changes in the way software is currently developed must take place.

First, movement must be made away from simply using the computer as a method for drill and practice and tutorial instruction. Although appropriate in some instances, this type of use neither improves the present curriculum or utilizes the unique capabilities that the computer has to offer. Nor, must the existing curriculum be totally revamped. As a first step in the development of educational software, attention should be focused on the problematic areas of the existing curriculum. Kutz (1984, p. 27) summarizes these ideas;

One need not rethink schooling from a zero basepoint to see if computers end up in the classroom. The beginning question should be, What
can the computer do well that schools need to be doing? This focuses on the strengths of the machine and the weaknesses in the curriculum. Where the two exist simultaneously - an area where the computer can do something particularly well, and where schools need to be doing better than they currently are - is the place to look for effective, perhaps exciting, utilization of computers.

This methodology necessitates the involvement of teachers. Yet, the training of teachers regarding the use of computers in education is a major weakness in our current system (Bork, 1984). Not only do many of the presently available computer lessons not make full use of the computer, but teachers themselves have not made full use of some effective CAL materials that have been developed.

Professional associations and federal agencies suggest that the application of computers by educators can improve the quality of education. However, actual adoption depends upon the decisions of individual teachers. Teachers must experience and interact with computers if they are to both adopt and intelligently use computers in their classrooms. Teacher educators can respond to this challenge by helping preservice teachers acquire an experiential base upon which to adopt and implement decisions. In particular, preservice teachers must experience the various instructional applications of computers from both student and teacher perspectives. Failure to continually update preservice teacher education programs and keep pace with the advances in information technology will, at best, result in the squandering of an opportunity to improve education. At worst, it may result in the uncritical use of computers in classrooms - a state of affairs which would represent a setback in the offering of quality teacher education (Bush & Cobb, 1983-84, p. 13).
Attention must be given to developing the CAL software models of pre-service and in-service teachers so that they will be better able to identify those areas of the present curriculum which would benefit from the incorporation of computer software and to effectively use the new types of CAL in the classroom.

Even when teachers perceive the new types of software that can be designed, they will not single-handedly develop the needed software. Most effective CAL developmental projects require massive amounts of time. Although a few talented teachers have developed exemplary software, the reality for most teachers is that they simply do not have the time to invest in learning an authoring system and, designing and programming a lesson. Nievergelt (1980) suggests that anyone starting a CAL developmental project should anticipate several years of effort before the lesson will begin to pay off.

As this project illustrates, very detailed field test results must be utilized throughout the long developmental process in order to eventually provide lessons that meet design goals. Too often, revision based on detailed descriptions of student models, how the students used the software, and the software's effects and shortcomings are not present. Many developers simply get the lesson to a
stage where "it runs" and then put it on the market. This type of development is one reason why a large portion of the currently available software is so poor.

Creating software that expands the current curriculum, especially in the area of problem solving and information processing skills, will require collaborative efforts among teachers, technical specialists, computer programmers, and educational researchers. Bork (1982) states that developing good courseware is an expensive, time-consuming enterprise, not to be undertaken casually by individual teachers who know a bit of programming. Bork (1982) suggests division of labor: instructional designers, teamed with professional programmers who have the advanced technical skills needed to make the courseware flexible, sophisticated, transportable, and capable of tapping the full resource of the machine. Exemplary software from all disciplines is needed to provide the insights necessary for teachers to realize what type of software is needed.

With these caveats said, many educators are asking; Is it worth it? Wyer (1984, p. 190) responds to this question;

So, is it worth it? Probably yes. The computer's potential for accomplishing truly worthwhile things is virtually untapped. Education and learning on all levels are wildly in need of a transfusion. The problems are: Can we think and design creatively enough? And can we find a way to pay for it?
Summary

The project described in this paper illustrates one type of software that could serve as an example of what the computer could accomplish in terms of infusing problem solving, information processing, and model building software into the existing curriculum and provides a measure of the type of effort that is needed to adequately develop a lesson (product revisions based on field test data) that will eventually be a useful learning and research tool. An experiential computer simulation was designed, using a state-of-the-art software development system, to enhance teaching and learning of a limited concept in animal science. A field test was undertaken with animal science students in order to determine lesson revisions needed to ensure the lesson adequately interacted with the varying student models. Results indicated that this lesson could enhance the existing curriculum, and that much attention throughout the developmental process must be focused on the possible student models and how the lesson can provide appropriate feedback for each student.


APPENDIX A: HUMAN SUBJECTS APPROVAL

The Iowa State University Committee on the Use of Human Subjects in Research reviewed this project and concluded that the rights and welfare of the human subjects were adequately protected, that risks were outweighed by the potential benefits and expected value of the knowledge sought, that confidentiality of data was assured and that informed consent was obtained by appropriate procedures.
APPENDIX B: CONSENT

Dear Student:

You have volunteered to evaluate a recently completed computer simulation regarding dairy cattle management. During the course of this evaluation you will be asked to; (1) take a pre-test, (2) schedule a session to use the simulation and give feedback about your use (approximately one hour of time), and (3) take a post-test. Some of the sessions with the simulation will be videotaped.

The data collected from this experience will be used to make further revisions to the simulation. It will not effect your grades in any way. Any reports of the project will not include the use of individual names and any videotapes will be erased shortly after the post-test.

Your signature below will indicate your willingness to allow the use of data collected during this experience.

Thank-you for your cooperation.

(Signature of Student)
APPENDIX C: PRE-TEST

Part I

Name ________________________________
Major ________________________________
Sex (Please Circle) Male Female

1. Briefly describe length and content of previous dairy courses (or parts of courses) you have taken in high school or college.

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Length</th>
<th>School</th>
<th>Topics</th>
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(continue on back of sheet if necessary)

2. Briefly describe any other experiences you have had working with dairy cattle. For instance, you may have lived on a dairy farm, owned, bred, or purchased cows, etc.

3. Briefly describe any other relevant experiences that you have had. For instance, you may not know about dairy cattle but have experience with beef cows, etc.
Part II

Please record your reactions to the following items.

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<thead>
<tr>
<th></th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
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</thead>
<tbody>
<tr>
<td>a. GENERAL INTEREST.</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Compared to other students you associate with at the university, how do you rate own interest in computers?</td>
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| b. PRESENT ABILITY. | 1   | 2      | 3    | 4    | 5    |
|                     |     |        |      |      |      |
| Compared to other students, how do you rate your present knowledge and ability when it comes to computers? |

| c. COMPUTERS AND GENERAL EDUCATION. | 1   | 2     | 3    | 4    | 5    |
|                                     |     |       |      |      |      |
| How important or valuable do you feel computers are as a part of general education for a college student like yourself? |

| d. COMPUTER ANXIETY. How | 1   | 2    | 3    | 4    | 5    |
|                          |     |      |      |      |      |
| would you rank your anxiety, fear, or general feeling of helplessness when it comes to dealing with computers? |
1. You own a dairy herd that has a herd milk average of 14,000 lbs/cow. Rank the following sale cattle (from highest to lowest) for their predicted milk production in your herd.

Rank
- Cow A makes 16,000 in a herd that averages 14,000
- Cow B makes 15,000 in a herd that averages 16,000
- Cow C makes 16,000 in a herd that averages 15,000
- Cow D makes 13,000 in a herd that averages 11,500

2. List the items (in order of importance) that you feel make a dairy cow valuable.

3. How important are genetics in determining a cow's milk production? Environment? (Explain your views.)
4. Respond to the following quote;

"Buying a cow is somewhat like buying a used car. The farmer doesn't know until s/he gets the cow home whether it is a good buy or a lemon."

5. What information is necessary to obtain in order to make sound dairy purchases?
6. Your herd average is 14,000 lbs. In each of the following situations circle the correct response.

A) A cow that makes 16,000 in a herd that averages 14,000 will produce how in your herd?
   a) above average
   b) average
   c) below average
   d) can't tell

Explain why you answered the way you did.

B) A cow that makes 12,500 in a herd that averages 10,000 will produce how in your herd?
   a) above average
   b) average
   c) below average
   d) can't tell

Explain why you answered the way you did.

C) A cow that makes 17,000 in another herd will produce how in your herd?
   a) above average
   b) average
   c) below average
   d) can't tell

Explain why you answered the way you did.
1. You own a dairy herd that has a herd milk average of 14,000 lbs/cow. Rank the following sale cattle (from highest to lowest) for their predicted milk production in your herd.

Rank

_____ Cow A makes 13,000 in a herd that averages 11,500
_____ Cow B makes 16,000 in a herd that averages 16,000
_____ Cow C makes 15,000 in a herd that averages 16,000
_____ Cow D makes 16,000 in a herd that averages 14,000

2. List the items (in order of importance) that you feel make a dairy cow valuable.

3. How important are genetics in determining a cow's milk production? Environment? (Explain your views.)
4. Respond to the following quote;

"Buying a cow is somewhat like buying a used car. The farmer doesn't know until s/he gets the cow home whether it is a good buy or a lemon."

5. What information is necessary to obtain in order to make sound dairy purchases?
6. Your herd average is 14,000 lbs. In each of the following situations circle the correct response.

A) A cow that makes 12,500 in a herd that averages 10,000 will produce how in your herd?

   a) above average
   b) average
   c) below average
   d) can't tell

   Explain why you answered the way you did.

B) A cow that makes 16,000 in a herd that averages 14,000 will produce how in your herd?

   a) above average
   b) average
   c) below average
   d) can't tell

   Explain why you answered the way you did.

C) A cow that makes 17,000 in another herd will produce how in your herd?

   a) above average
   b) average
   c) below average
   d) can't tell

   Explain why you answered the way you did.
APPENDIX E: SIMULATION EVALUATION

1. Were the instructions clear? (yes or no)
   If no, which instructions caused you problems?

2. Did you have any problems with the terminal operations? (yes or no)
   If yes, describe the problem(s).

3. Did you have any problems with the program? (yes or no)
   If yes, where in the program were you and what happened?

4. What did you learn from the program?

5. Please make any further suggestions that you have regarding this lesson.
ACKNOWLEDGEMENTS

I wish to express my appreciation to Dr. Ann Thompson for her assistance in the conceptualization and actual writing of this paper. Her knowledge of the area and general good nature played a large role in my completion of this project. Also, I wish to thank Dr. Elaine Jarchow for her thoughtful critique of the structure and ideas expressed in this paper. I am also grateful for the assistance given by Dr. Rex Thomas in the development of the lesson and the ideas expressed herein. And, I thank the remaining members of my graduate committee, Dr. William Wunder, Dr. Pete Boysen, and Dr. Stanley Ahmann, for their assistance at various times during this project.