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DESIGNING EXPERT SYSTEMS FOR EFFECTIVE DELIVERY OF EXTENSION PROGRAMMING

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ABSTRACT

Expert Systems offer potential to be important additions to the current methods used to deliver extension programming to clients. This paper discusses the design of such systems from the viewpoint of learning theory and cost effectiveness.

INTRODUCTION

The delivery of extension education programs to clients in commercial agriculture is a cornerstone of the extension service charter. Unfortunately, effective delivery of relevant extension programs has become more difficult as: 1) agriculture has become more technologically advanced; 2) relatively homogeneous family farms have been replaced by a mixture of large scale commercial enterprises and smaller part-time farms resulting in a very hetrogeneous mix of clientele, problems, and clientele resources available to solve problems; 3) institutional intervention in the form of regulations and government participation in agricultural markets has increased; and 4) extension budgets for commercial agriculture programs have decreased in real terms. To counteract the increased difficulty of delivering extension programing to commercial agriculture clientele, computer based expert systems, computer driven multi-media programs, and use of electronic media to replace or supplement the traditional one-on-one extension approach are often mentioned as means of improving the effectiveness of extension educational programs.

This study was developed to contribute to the discussion of this issue, focusing on the design of techniques to effectively deliver extension educational and problem solving services via computer based expert systems. Presentation of the findings is organized into five major sections. First, the objectives and methodology are discussed. Next, a brief definition of expert systems is presented. Third, an example is presented to illustrate the potential for use of expert systems in extension programming. This is followed by an analysis of expert systems compared to other teaching methods used in extension. Finally, conclusions and implications of the study are outlined and an estimate of the cost effectiveness of the example is presented.

Objectives and Methodology

The purpose of this paper is to critically evaluate the design of expert systems as a means of improving the delivery of extension program to agricultural clients. The educational impact model developed by Joyce and Showers will be used first as a model to guide the design of an expert system and then as a basis for a qualitative evaluation of the contents and expected effectiveness of expert systems compared to other extension teaching aids. In addition, preliminary results, including measures of cost effectiveness, of ongoing field tests designed to quantify the technique's actual educational impact will be presented.

Educational Impact Model

Joyce and Showers state that when students use what has been learned to solve problems they are demonstrating that their training has had the highest level of impact possible. Their research into teaching methods led to the following general rules to judge the level of impact a teaching program will have. They concluded that the level of impact is affected by the following training components:

1. **presentation of theory or description of skill or strategy,**
2. **model or demonstration of skills or models of teaching,**
3. **practice in simulated and classroom settings,**
4. **structured and open-ended feedback, and**
5. **coaching for application.**

Further, Joyce and Showers indicate that components one through five have increasingly greater levels of impact on students' abilities to solve problems. When all five components are included in a teaching program, up to 75 percent of students are able to apply what has been learned. The research by Joyce and Showers supports the notion that teaching techniques which incorporate more of the five components will have greater impact than techniques involving fewer training components. This conclusion and the conceptual framework of the five training components will be used as a guide to the following description and analysis of extension teaching methods.

EXPERT SYSTEMS

Expert systems are often described as a "black box" which can perform the function of an expert in providing advice about a particular subject area. Such a black box in the form of a computer system has potential to be a major channel for the delivery of extension programs to clients if, in fact, they can perform as "experts" and free up a portion the limited extension resource of experts, both specialists and agents, for expanded service to agriculture. The key to the effectiveness of an expert system augmenting human experts is designing systems that truly mimic what an extension "expert" really does.

Traditional Definition

A simple approach is to define an expert as one who gives correct, knowledgeable answers to questions. Rule-based expert systems emulate this limited definition of an expert. In a rule-based expert system the computer keeps posing questions for the user to answer until the information provided by the user, combined with the knowledge programmed into the computer, allows the computer to suggest a conclusion (see Forsyth for a detailed description of expert systems and Garson for a discussion of their use in the Social Sciences). Such systems are extremely useful for certain types of well-defined problems, like diagnosing diseases or trouble shooting problems with complicated machinery. Figure 1 displays a typical question that a system designed to provide advice about methods of cattle marketing might ask. Figure 2 displays the type of conclusion that such an expert system might come up with after asking a few questions of the type displayed in Figure 1.

Figure 1

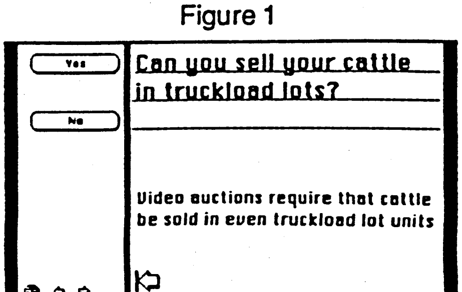


Figure 2

In general, rule-based expert systems are appropriate under the following conditions:

1) The problem is well defined. For example: "My tractor won't start. What is wrong with it?"

2) The user of the expert system has confidence in the ability of the expert system to provide correct answers. Such confidence can be acquired if the user is knowledgeable about the subject matter dealt with by the expert system and uses the system frequently. Doctors using disease diagnostic programs or mechanics using mechanical trouble shooting programs are examples of users which could easily develop confidence in an expert system after frequent use if the knowledge programmed into the system produces correct results.

Unfortunately, most of the questions asked of extension's experts would not satisfy either of the conditions above. The activity of extension experts is not simply solving diagnostic types of problems. Extension experts spend much of their effort in correctly defining problems. Once the problems are defined, extension experts spend time educating clients about the problems. Finally, extension experts do spend time solving problems. However, without the components of problem definition and education an expert system would be of only limited use in augmenting the resources of extension experts. Furthermore, since a large part of extension clientele do not use extension experts on a regular basis and/or do not have extensive knowledge in technical areas, their confidence in extension experts or expert systems must come from interaction. A computerized expert system which just asks a few questions and provides a solution to a problem without significant interaction with the client is not likely to generate the necessary level of confidence in the answers.

Therefore, traditional rule-based expert systems which simply ask questions and give advice are not well suited for most of the types of problems in which extension agents and specialists are involved.

Expanded Definition

Fortunately, it is possible to include functions of experts other than simple question asking and conclusion generation into computer programs. Specifically, it is possible to combine both a question asking/answering function with an educational function which presents informational material on the subject matter including specific information on the logic used by the expert system. Such a combination of educational material and a rule-based question answering system allows the user to develop confidence in the results of the system by making available to the user all of the logic used by the computer system in a format which encourages understanding of the results. Further, it is possible to include other computer programs such as simulations, data bases, spreadsheets, and hypertext information delivery into a single program by developing the expert system into a shell for providing appropriate analysis and educational material on a subject. It is this expanded definition of expert systems that we chose to use as a design target for developing a program to test the usefulness of expert systems in extension.

System Design

Using the expanded definition, an expert system was designed to provide extension programing to cattle ranchers. Problem areas of both marketing and production were included to make the test as realistic as possible. The problem areas in marketing included the type of marketing institution to use in selling cattle and the use of the commodity markets for hedging. The production problem areas included the nutritional management of the range cow herd, and the associated management of breeding and weaning timing. The goals of the system are to augment the abilities of Arizona ranchers to profitably manage their ranches. Specifically, operational goals were:

1. **increase the general knowledge level** of both cattle marketing and range cow nutrition;
2. **augment information availability** by providing access to statewide data bases on diets and forage nutrition;
3. **augment analytical tools** by providing pre-programmed spreadsheets on economic analysis of hedging and a pre-programmed simulation-based analysis model of range cattle nutrition.

The first test was to design the expert system to accomplish these goals in such a way that all of the components of learning described by Joyce and Showers were included.

The first stage, **presentation of theory,** is accomplished by an introductory component which includes definitions of terms and concepts, and short courses in: alternative cattle marketing techniques, hedging using futures contracts, hedging using options, range cow nutrition, cow diets, and range forage nutritional values. The specific computer techniques used included presenting text on the screen with bold faced text linked to further explanatory sections. This specific computer technique is commonly called hypertext in the computer literature (see Blank and Gum for more detail on hypertext applications for expert systems). For example, in the section introducing the alternative livestock marketing technique of video auctions reference is made to the concepts of futures and options which are presented as bold faced words. By selecting the words, moving the cursor over them and clicking with the mouse the user is presented with the index of the detailed section on hedging which includes both text and working spreadsheets to calculate the results of hypothetical examples. The user can select any of the index items to have the computer display the screens relevant to those items. If for example, the user selects the option calculator a working spreadsheet appears which allows the user to calculate the expected results of a hedge using option contracts. The specific computer screens are displayed in Figures 3 to 5. The user, if he chooses to obtain the detailed information on hedging and use the spreadsheets, has at this point been exposed to the theory of hedging (stage one of the Joyce and Showers model) and been presented a working example of how to calculate the results of a hedge (stage two of Joyce and Showers). Further, the hypertext approach makes effective use of the user's time as they are in complete control of choosing the material to be displayed on the computer screen. If a rancher is not interested in using the futures markets to hedge, the computer does not bombard them with screens and screens full of material on futures that must be paged through to get to the information in which they are interested. Using such a free choice system of presenting material effective presenting theory can be effectively presented.

Figure 3

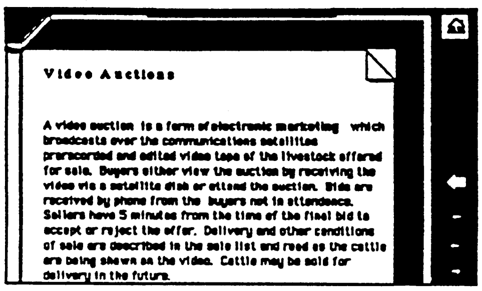


Figure 4

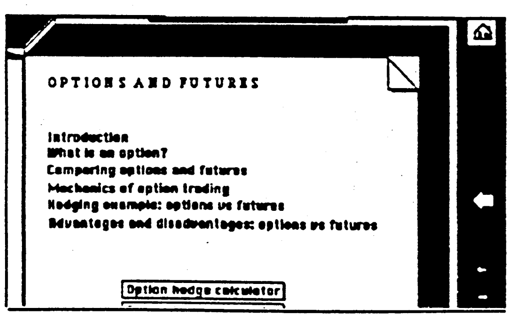
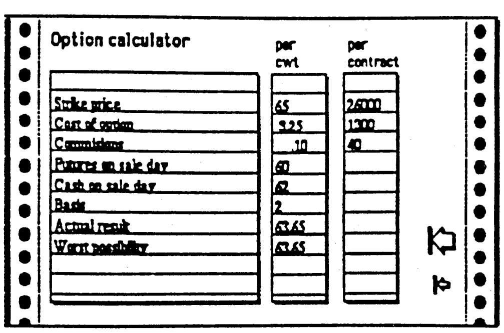


Figure 5



The second stage, **model or demonstration of skills**, is implemented with a walk through of a typical Arizona range cow annual production process. This is implemented with computer graphics illustrating the nutritional links to the range cow production processes using a simulation model as a basis. Animated graphical displays present the results as several annual range cow production cycles are simulated. Non-animated representations of these are displayed in Figures 6 and 7.

Figure 6

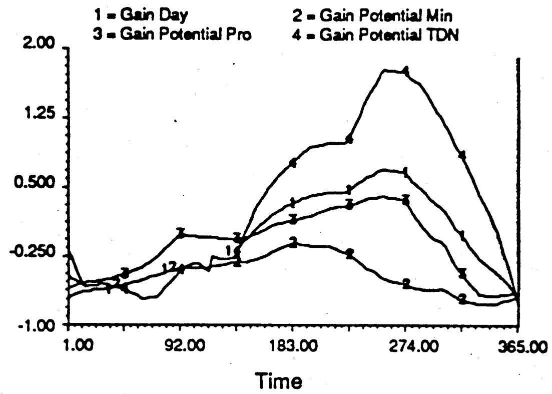
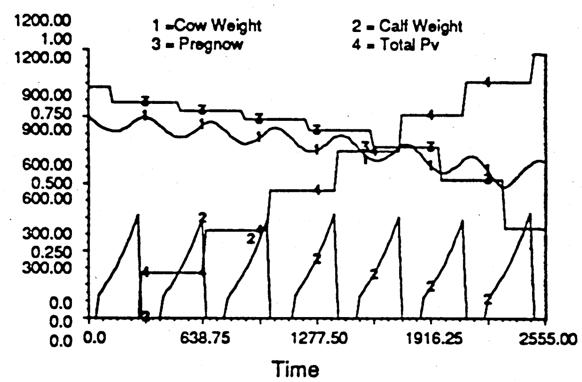


Figure 7



The third stage, **practice in a simulated setting**, is implemented by first guiding the rancher through the process of modifying the computer simulation model to reflect their own ranching situation, and then guiding the rancher through the process of simulating, and thus, evaluating different management alternatives.

The fourth stage, **structured and open-ended feedback**, is accomplished by the computer system asking the rancher a series of evaluation questions about the system and allowing the rancher to comment, discuss, or question the system and/or the results generated by electronic communication to the specialists who designed the system.

The fifth stage, **coaching for application**, is accomplished by the computer suggesting economically reasonable alternatives to the ranchers current method of operation, if any can be found, and by the specialists communicating their opinions and observations to the rancher over the electronic network.

Monitoring and Evaluation

At present, the system has been designed and is in the initial stages of field testing. The initial reaction to the system has been very positive. A formal evaluation program for the system has been designed as an integral part of the system and will be implemented as the system is used throughout the state. The design of the formal monitoring and evaluation is based on: 1) observing the time a rancher spends in each segment of the system; 2) recording the exact path the rancher uses to interact with the system including recording the responses to computer prompts asking if the rancher wishes on-line help in explaining or reviewing concepts, or operations, and recording the response to computer prompts asking if the rancher agrees with the results presented; 3) rancher responses to a pre-use and post-use evaluation questionnaires which are built into the system; and 4) a questionnaire to agents about their impressions of the rancher computer interactions and their subjective comments about its usefulness and its impact on actual ranching decisions. A statistical analysis will be performed on several alternative measures of learning accomplishment to test hypothesis about both the level of overall learning and about the relative contribution of the different educational components to the total learning experience.

COMPARISON TO OTHER APPROACHES

While the complete set of evaluation data will not be collected and analyzed until 1991, when the system will have been operational for 12 to 18 months, the programming method can be compared to alternative approaches using the Joyce and Showers training components framework augmented by informal observational data. Likely candidates for comparison are presented in the following table along with the learning components associated with the technique.

The table illustrates the commonly observed fact that traditional extension outreach techniques break down into those designed for general audiences which stress the presentations of theories and concepts and general models of the applicability of a potential practice, and those which work directly with an individual in real world

Learning Components

Approach	1	2	3	4	5
Extension Bulletins	x	x			
Spreadsheets			x		
Agent/Specialist "One-on-One"				x	x
Agent/Specialist Workshops	x	x	x		
Video Tape		x	x		
Interactive Video Disk	x	x			
Traditional Expert Systems				x	
Expanded Expert System	x	x	x	x	x

problem solving. Currently only extension programs designed using a mixture of techniques include all of the components. The approach described above, using the extended expert system concept, offers the advantage of including all of the learning components. Thus, based on the educational impact model research of Joyce and Showers the expanded expert system approach would be expected to provide a more effective means of information delivery.

Observations of users of the expert system revealed:

1. Significantly more interest in the nutrition components than in the marketing components. This is likely because there are no noncomputerized alternatives which are as effective as the computerized nutrition simulation model in analyzing nutrition management, while non computerized alternatives do exist for analysis of marketing decisions. This observation supports the hypotheses that the analytical abilities of the ranchers have been augmented by the expert system.

2. Acceptance of the computer as a useful tool when a user friendly interface was used. Ranchers simply do not have the time or interest to spend time learning how to run the computer. The use of HyperCard and the user friendly graphical interface with numerous on-screen prompts allowed the ranchers to overcome their fear of computers and get on to the important task of using computers as a tool.

3. Presentation of the results of the simulation model as an animated graph depicting important nutritional variables as they change over time kept the attention of the users while the rather time intensive simulation ran.

CONCLUSIONS AND IMPLICATIONS FOR EXTENSION

In addition to advantages in terms of learning, the expanded expert system approach offers a cost effective means of extension program delivery. Specialists can make efficient use of their limited time and travel resources by interacting one-on-one with clients through the computer network connections. They can utilize training materials for multiple clients as the computer system has to be developed only once. In addition, once developed, the expert system can serve as a focus for the collection and organization of information, knowledge, and analytical tools relevant to a subject area. Such a focus serves to facilitate the interaction of specialists in different disciplines towards multi-, inter-, and cross-disciplinary approaches to problem solving. Because of this broad range of advantages, the development of expanded expert systems for delivery of extension programs will be a popular activity for extension faculty in the future. Whether these systems are called expert systems, computer driven multi-media programs, or the newly popular "hyper something or other", only sound design based on proven learning techniques will result in truly effective improvements in the delivery of extension programming. The expanded expert system described above demonstrates the possibilities of developing educational programs which include the full range of educational techniques. Both educational theory and the initial reaction to the system suggest that this approach holds great promise for improving the effectiveness of extension.

The bad news is that there is not a simple evolutionary path between the current way of providing extension programming and large scale use of expert systems. This is typical of so called "lumpy" technologies where major changes are needed to use them at all. Since expert systems are a lumpy technology, extension operations without the financial flexibility to invest in the human and computer resources necessary to develop and use these new techniques will continue to fall behind in their ability to deliver relevant and effective programs to their clientele. The chance exists that the lumpy nature of this innovation will not be recognized and resources will be diverted into the development of expert systems with restraints attached. For example, any systems developed work with the existing installed base of extension computers. These restraints may reduce the likelihood of being able to develop truly effective expert systems may be required. This leads to the issue of the optimum path of adoption of expert systems. How many resources, if any, and when, if ever, should extension invest in this new technology. A way of answering this question is to perform a Fermi approximation to a cost effectiveness analysis. The Fermi approach named after the Nobel Prize winning physicist Enrio Fermi is a method of finding easy solutions to problems that, at first glance, seems very difficult (see von Baeyer).

The costs for the range cattle project described above can be approximated as:

Computer hardware $4,000 per unit

Unfortunately, the expert systems of the type described above require powerful micro-computers. A reasonable computing platform for the system described would be a Macintosh SE 30 with 40 meg hard disk and 2 meg of memory, 2400 baud modem, and printer.

Computer software $600 per unit

The expert system requires HyperCard™ (the hypertext all-purpose program which was used as a shell to put together the necessary parts of the expert system) and is bundled with all Macintoshes, Stella™ (the graphically based simulation program), and Timbuctu Remote™ (the communication program to allow remote control of the expert system).

Development costs $20,000 one time

The development cost must be divided between the effort necessary to develop information and do applied research on the areas covered by the expert system and the additional costs to package the results of the applied research into an expert system format. The additional costs are estimated to be $20,000 for the cattle ranching expert system.

Maintenance and training costs $5,000 per year

Any complicated system needs to be kept up to date and new personnel trained in its use.

The present value of these cost streams, assuming a five year life of the expert system and associated hardware, is approximately $44,000 for one unit and $52,500 for three units.

The benefits:

Rancher savings $10 per head per year due to changes in management suggested by expert system. For a ranch with 200 mother cows this would mean an increase in profits by $2,000 per year. This may be an underestimate as savings of over $70 per head have been reported as the result of similar integrated management programs (see Eftink and Walter).

A similar level of increase could likely be obtained by quarterly visits by a specialist. Thus the extension savings would equal $250 per day of specialist time and travel saved or $1,000 per year per ranch.

The break even for extension in terms of cost effectiveness can be roughly calculated as the number of ranches per year using the model which would pay for the model by reducing extension travel expenses. With just one system in operation approximately 10 ranchers are needed to participate. However with three systems in operation only an additional two ranchers are necessary. At the first meeting with ranchers, at which the basic components of the system were introduced, over 10 ranchers indicated a strong interest in utilizing the system. Thus, the likelihood of having enough ranchers statewide participate in using the expert system seems very good from initial observations. With additional systems located in county offices around the state the odds of the system being a very cost effective educational tool for extension are extremely high.

The Bottom Line

The preliminary analysis both in terms of learning efficiency and in cost effectiveness strongly suggest that the concept of enhanced expert systems should be an important new addition to the toolbox of extension. If extension is to be an agent of change in the effort of making the agricultural sector more efficient, then advances in technology, which have the potential for making extension itself more efficient, need careful consideration and evaluation. While mass conversion of extension delivery techniques to the expert system approach cannot be justified at present, the initial results of our test certainly would suggest that development and implementation of expert systems should proceed and be closely monitored to test their long range effectiveness in delivering extension programming.

REFERENCES

Blank, Steven C. and R. L. Gum. "Expert Systems for Choosing Between Livestock Marketing Alternatives in Maintaining the Cutting Edge." Mitchell, C. and K. Anderson (eds.), American Agricultural Economics Association, 1987, pp. 249-261.

Eftink, Bill and J. Walter, "IRM Helps Ranchers Focus on the Big Picture". Successful Farming (February, 1988):42-42.

Forsyth, R. "Expert Systems: Principles and Case Studies". Chapman and Hall, Ltd.: London, 1984, Chapter 2.

Garson, G.D. "The Role of Inductive Expert Systems Generators in the Social Science Research Process". Social Science Microcomputer Review 5(1987):11-24.

Joyce, B. and B. Showers, "Improving Inservice Training: The Message of Research." Educational Leadership 37(1980): 379-385.

von Baeyer, Hans Christian, "The Easy Solution of Difficult Problems — The Fermi Approach". Italian Journal, 2(1988):32-35 (reprinted from The Sciences, Sept./Oct. 1988, The New York Academy of Sciences).

A Practical Way to Obtain Near-Optimal Solutions (NOS) in Linear Programming

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The nature of agricultural production is such that the functional relationships that describe technology and resources requirements cannot always be modeled adequately in a deterministic way. These functional relationships, along with the objective functions that are associated with them can be linear or nonlinear and continuously differentiable (smooth) or nondifferentiable (nonsmooth). In addition, the decision variables may be continuous, restricted to integer values, or in certain situations, both. Also, production may take place at a fixed point in time (static) or during an interval of time (dynamic). Even with these complexities many agricultural model builders have opted to represent farm problems using linear-deterministic-smooth-continuous-static models (LP). Mathematical linear programming (LP) also assumes additivity, divisibility, finiteness, and single-valued expectations. The use of LP in agriculture offers an indispensable degree of operational simplicity.

Using this optimization technique, the researcher approaches a complex decision problem by concentrating on a single objective designed to quantify performance. This one objective is minimized (or maximized) subject to the constraint set. If one can isolate and characterize a problem by one objective, be it net returns or net loss in a farm situation, transferring resources or farm commodities between various locations, or social welfare in the context of government planning, LP may provide a useful procedure and basis for analysis.

It is, however, a rare situation in which the model builder can fully represent all the complexities of interactions, constraints, and appropriate objectives when faced with a complex decision setting such as agriculture. Thus, as with all quantitative techniques of analysis, a particular LP formulation should be regarded only as an approximation (Luenberger). This has caused many practical farm planners to reject the idea of a single unique optimal solution to a linear programming model of a particular farm situation. Instead, these planners prefer to compute a number of solutions for the farmer's consideration. According to Powell and Hardaker, the most restrictive assumption of LP is its deterministic nature. The authors also assert that LP has the limitation of permitting only one objective function - normally maximum expected profit. They point to the work of Officer, Halter, and Dillon who have indicated the importance of higher order moments of the profit criterion and the importance of risk attitudes in farmers' decisions. Based on research by others, Powell and Hardaker indicated that the farmer's utility function may be multidimensional, perhaps nonlinear, or even impossible to represent adequately using an LP formulation. In addition, according to the authors, farmers may have difficulty in articulating their objectives precisely enough to be incorporated into any formal model, but may be able to determine which of a set of plans suits their needs the best. Based on a study by Renborg, the authors indicate that the solution space is often relatively "flat" in the optimum region. This will often signify that solutions exist which would enable the farmer to satisfy better some secondary objective at the expense of relatively little reduction in expected earnings.

With some modification, a range of suboptimal solutions that are of interest to farmers can be generated using procedures that are described in