Designing Expert Systems for Effective Delivery of Extension Programming

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Expert systems offer potential as 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 assesses the cost effectiveness, relative to standard extension programming approaches, of a sample system developed for use with/by cattle ranchers. Results indicate that hybrid expert systems have greater educational impact than traditional programming methods and are more cost effective.

Key words: expert systems, extension, simulation.

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difficult as (*a*) agriculture has become more technologically advanced; (*b*) relatively homogenous family farms have been replaced by a mixture of large-scale commercial enterprises and smaller part-time farms resulting in a heterogenous mix of clientele, programs, and clientele resources available to solve problems; (*c*) institutional intervention in the form of regulations and government participation in agricultural markets has increased; and (*d*) extension budgets for commercial agriculture programs have decreased in real terms. To counteract the increased difficulty of delivering extension programming to commercial agriculture clientele, new approaches are being sought. For example, computer-based expert systems (hereafter ES), computer driven multimedia 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 programming.

This study contributes to the discussion of this issue by evaluating the potential for designing computer-based expert systems as a means of improving the delivery of extension programs to agricultural clients. Of particular concern are extension programs aimed at improving the understanding of managers and providing them with advice on important management decisions. The evaluation process presented here involves application of a teaching program model. The educational impact model developed by Joyce and Showers is used first to guide the design of a sample ES and then as a basis for qualitative evaluation of the contents and expected effectiveness of that ES compared to other extension tools. A summary analysis of costs for the sample system provides a quantitative assessment of the approach's effectiveness.

This paper is organized into five major sections. First, a description of expert systems and a sample application are presented. Next is a brief outline of the educational impact model. Third, training components of the samples ES are evaluated using the educational impact model. This is followed by an analysis of the cost effectiveness of the sample ES compared to other methods used in extension. Finally, conclusions and implications of the study are outlined.

Expert Systems

Many definitions of expert systems can be found in the computer science and artificial intelligence literature. Discussion of two concepts, "function" and "process," are almost always included in those definitions. The standard definitions state that the function of an ES is to "du-

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plicate as nearly as possible the problem solving techniques and rules of the expert" (Hayes, p. 52). The processes used by an ES are usually defined in terms of knowledge representation, inference engines based on symbolic reasoning, and use of heuristics. Waterman (pp. 22, 31) provides the following definitions:

Knowledge representation is "the process of structuring knowledge about a problem in a way that makes a problem easier to solve."

An *inference engine* is "that part of a knowledge-based system that contains the general problem solving knowledge."

Symbolic reasoning is "problem solving based on the application of strategies and heuristics to manipulate symbols standing for problem concepts."

Heuristic is "a rule of thumb or simplification that limits the search for solutions in domains that are difficult and poorly understood."

The most common type of ES is a rule-based system (see Harmon, Maus, and Morrissey for detailed information on building rule-based systems and Rauch-Hinden for a description of commercial applications of such systems). In a rule-based ES, knowledge is represented in terms of rules. For example, a cattle-marketing ES might include a rule stated as "only full truckload lots of cattle can be sold on satellite video auctions." Given a set of rules about cattle marketing and a ranking of marketing alternatives, the inference engine determines the order in which the rules are to be tested. For instance, a strategy termed "backward chaining" could be used to test all rules that are relevant to establish video auctions as the preferred alternative method of selling cattle for a particular rancher. In this example, heuristic knowledge is used to define rules as well as to define the ranking of alternatives. The rules would be tested using a series of questions for the client, and the results would take the form of a recommendation to the client concerning the problem at hand. This ES result is intended to duplicate the recommendation an expert would give clients in that particular situation.

Rule-based systems are extremely useful for certain types of well-defined problems, like diagnosing diseases or trouble-shooting problems with complicated machinery. In general, rule-based expert systems are appropriate under the following conditions: (*a*) The problem is well defined. For example: "My tractor won't start. What is wrong with it?" (*b*) The ES user has confidence in the system's ability to provide correct answers. Such confidence can be acquired if the client is knowledgeable about the subject matter dealt with by the ES and uses the system frequently. Doctors using disease diagnostic programs or mechanics using mechanical trouble-shooting programs are examples of clients who could develop confidence in an ES after frequent use if the knowledge programmed into the system produces correct results.

Unfortunately, many of the questions asked of extension's experts would not satisfy either of the conditions above. Also, the role of extension experts is not simply to solve diagnostic types of problems. Extension experts must spend much of their effort in correctly defining problems for clients. Once problems are defined, extension experts must also spend time educating clients about the problems. Extension programming aimed at problem definition and education would find a rule-based ES of only limited use. Finally, extension experts do spend time solving problems. However, because a large portion 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 these experts or ES must come from interaction. A computerized ES 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 its answers. Therefore, traditional rule-based expert systems which simply ask questions and give advice are not well suited for many types of problems in which extension agents and specialists are involved.

Hybrid Expert Systems

Systems falling under an expanded definition of ES offer potential for use in extension. The role of hybrid expert systems, which incorporate both artificial intelligence and more traditional computer techniques, has been recognized by practitioners in both operations research and artificial intelligence fields. These hybrid systems may be viewed as trying to duplicate the problem-solving techniques and rules of an expert who has access to computer tools such as data bases, statistical analysis, and simulation solftware. Such hybrids have been described as Intelligent Decision Support Systems (Hertz) and Knowledge-Based Management Support Systems (Hayes, p. 53) when their main purpose was to assist managers, and as Intelligent Tutoring Systems (Katz and Schultz or Psotka, Massey, and Mutter) when their main purpose was to provide expert training to students. It is simply a semantic problem to classify such systems because the real distinctions between these approaches are being challenged, as noted below.

> Operations research (OR) has developed both formal and heuristic solutions to a broad spectrum of real world issues. Artificial intelligence (AI) through its expert systems (ES) approches has recently begun to attack similar problems. I believe that AI/ES or OR applications have similar objectives to permit the executive or decision maker to improve his understanding of, and take desirable actions in a particular domain. Both must build computable models which have equivalent model structure. The surface differences are programming devices that may be stripped away. In the not too distant future, all significant programs intended to provide advice, diagnosis and analysis to aid decision makers will be hybrid. (Hertz, p. 9)

To minimize semantics, this paper uses the generic term "expert system" to describe the sample application presented in the next section. The ES is a hybrid in that it uses a wide mixture of computer techniques as appropriate to accomplish its dual goals of education and problem solving.

System Design

Using this general perspective, an ES was designed to provide extension programming to cattle ranchers. Problems concerning both marketing and production were included to make the test of the sample ES's value as broad as possible. The marketing problems included selecting the type of marketing institution to use in selling cattle and deciding whether to use commodity futures or options markets for hedging. Production problems included the nutritional management of a range cow herd and the associated management of breeding and weaning schedules. The goal of the system is to augment the abilities of ranchers to manage their businesses profitably by providing both the education programs and advice of extension experts in the form of computer software. From extension's viewpoint, the system is designed to provide county extension agents with a tool they can use to give ranchers the equivalent of both a workshop and one-on-one consultation by a team of specialists who are experts in the areas of marketing, range management, and animal science.

The first step was to develop traditional published materials and computer tools necessary for the team of extension experts to present effective workshops and provide useful one-on-one consultation to ranchers. In the marketing area, several extension publications and spreadsheet decision aids were used. To address range nutrition problems, a simulation model relating range conditions to cow performance was developed. A simulation model was chosen as the only practical approach, other than simple rules of thumb, to define the range production process in terms useful to analysis of alternative management decisions by ranchers. A graphics-based simulation modeling program, called Stella™, was used to facilitate development of the simulation by a multidisciplinary team. The basic structure of the model is (*a*) to calculate the nutritional intake of a cow based on the animal and the nutritional value of the forage species consumed; (*b*) to calculate the nutritional requirements of the cow as a function of her weight and stage of pregnancy; (*c*) to calculate the gain or loss in weight of the cow; (*d*) to determine the pregnancy probability of the cow based on her weight at breeding and on her rate of gain in the time period preceding breeding; (*e*) to determine calf weights; and, most important, (*f*) to determine expected economic returns for the lifetime of the cow for a specific management strategy. The model was calculated with daily time steps for a seven-year period in order to determine the present value of a cow under a specific management strategy.

The next step was to design the ES to accomplish the same results as a team of extension experts that present workshops and then work one-on-one with ranchers who had attended the workshops. The design approach had two major components. First, the ES was designed to include all of the learning components described by Joyce and Showers (explained in the next section). Second, HyperCard™ was chosen as a software platform. This allowed the ES to be developed without the necessity of programming in a complex artificial intelligence language such as Lisp or Prolog. It also allowed easy linkages of the ES to the simulation model through a HyperCard™ front end to Stella™, called StellaStack™. In addition, it gave access to a rule-based ES shell programmed as a HyperCard™ application, HyperX™, and the flexibility to link modules programmed in Fortran, Pascal, or C to the HyperCard™ application.

Educational Impact Model

The key to making this package of computer programs a single educational tool which could achieve the goals of the extension project was using a model of teaching to guide the system's design. The educational impact model of Joyce and Showers (hereafter JS) was used in this effort.

JS 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. Because this is exactly what extension programs need to do, train managers to solve problems, their framework for judging educational impact is appropriate in the context of extension program design and evaluation. JS concluded that the level of impact a teaching program will have is affected by the following training components: (*a*) presentation of theory or description of skill or strategy, (*b*) model or demonstration of skills or models of teaching, (*c*) practice in simulated and classroom settings, (*d*) structured and open-ended feedback, and (*e*) coaching for application.

Further, JS indicate that components (*a*) through (*e*) 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% of students are able to apply what has been learned. The research by JS 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 are used as a guide to the following description and analysis of the sample ES as an effective extension programming method.

System Design Using the Educational Model

The first training component, presentation of theory is included in the sample ES through an introductory module 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 technique used in this module, commonly called hypertext in the computer literature (see Brent or Blank and Gum for more detail on hypertext applications for expert systems), involves presenting text on the screen with bold-faced text being linked to further explanatory sections. For example, in the section introducing video auctions as an alternative livestock-marketing method, 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 a 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 topics. If a user selects the option calculator, for example, a working spreadsheet appears which allows the client to calculate the expected results of a hedge using option contracts.

The series of computer screens is displayed in figure 1–3. If a user chooses to obtain the detailed information on hedging and to use the spreadsheets, he or she has at that point been exposed to the theory of hedging (component one of the JS model) and has seen a working example of how to calculate the results of a hedge (component two of JS). Further, the hypertext approach makes effective use of the user's time because the client chooses which material is displayed on the computer screen. If a rancher is not interested in using the futures market to hedge, the computer does not require him or her to page through screens full of that material to get to the information of interest. By using such a free choice system of displaying material, theory can be effectively presented.

The second training component, model or demonstration of skills, is implemented with a walk through of a typical range cow annual production process. This involves a hypertext presentation which includes (*a*) animated computer graphics illustrating the nutritional links to the range cow production processes using the simulation model as a basis, (*b*) a schedule of operations, (*c*) an illustration of hedging using the futures market, and (*d*) a budget for the ranch showing costs and returns.

The third component, practice in a simulated setting, is included as the ES guides ranchers through the process of modifying the computer simulation model to reflect their own ranching situation, and then guides them through the simulation process to evaluate different management alternatives. This is facilitated through the use of an intelligent user friendly front end for the simulation model, called StellaStack, which runs as a HyperCard™ application.

The fourth training component, structured and open-ended feedback, involves a series of evaluation questions the computer system asks the rancher which allows the rancher to comment, discuss, or question the system and/or the re-

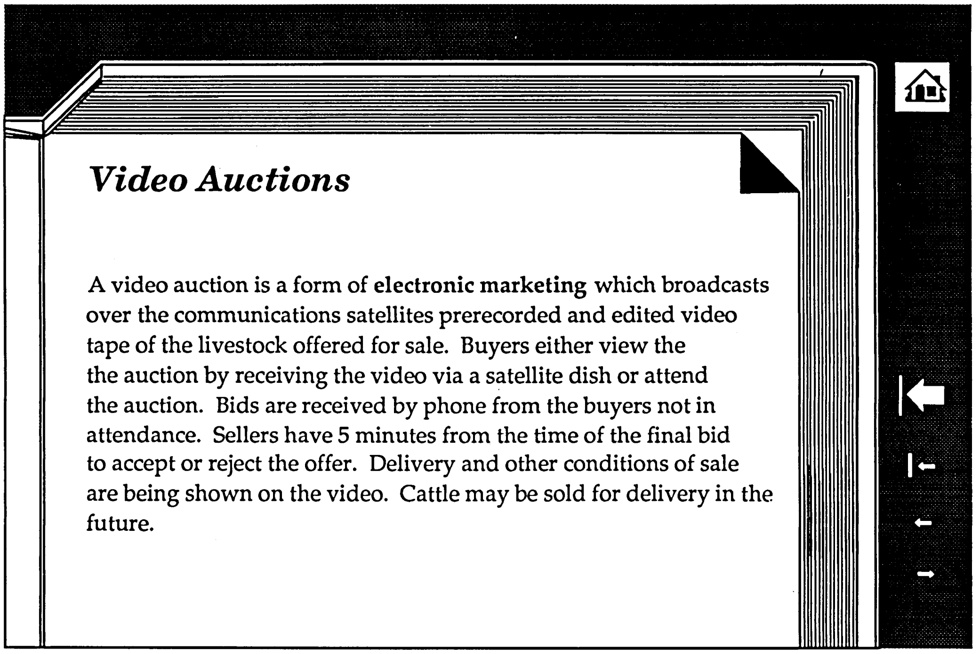

Figure 1. Video auctions

sults generated. This can involve electronic communication with the specialists who designed the system. In addition to setting up a mechanism to provide additional feedback to ranchers, this approach allows the developers of the ES to monitor its use and collect data on its effectiveness. Such information can provide a valuble basis for continuing modification and improvement of the heuristics included in the system.

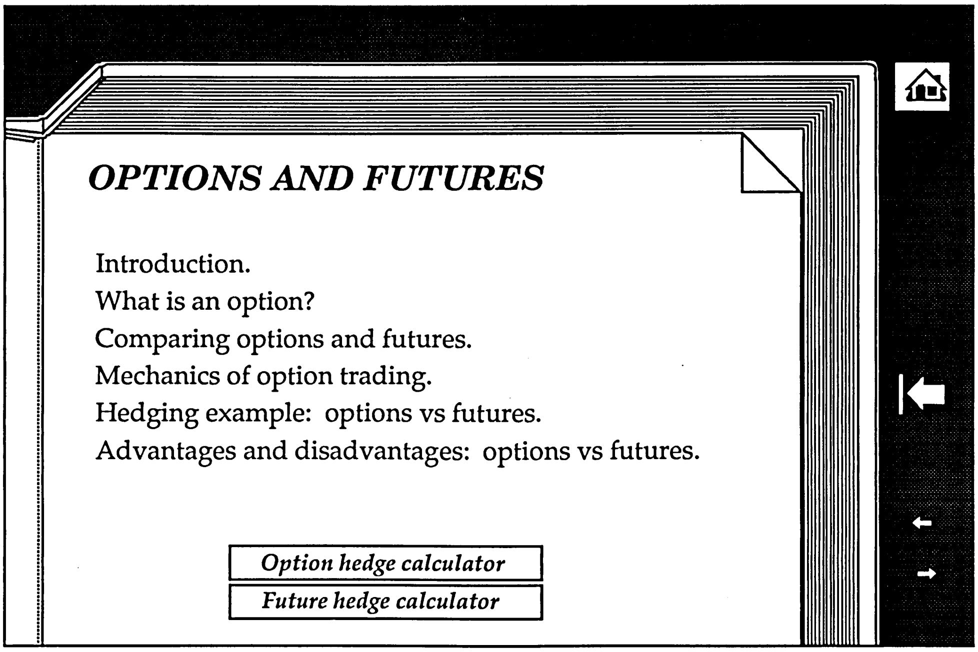

Figure 2. Options and futures

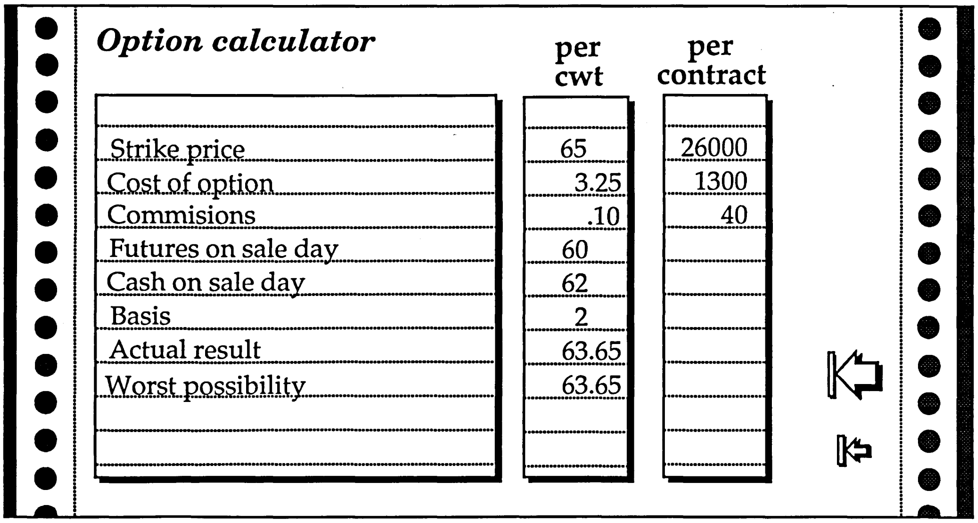

Figure 3. Option calculator

The fifth component, coaching for application, is accomplished by the computer using a rule-based analysis of the simulation results developed by the rancher for a specific management alternative and then suggesting economically reasonable alternatives. For example, if phosphorus is a limiting factor for cow gain under the management alternative being simulated, the coaching module would point this fact out and suggest a reasonable mineral supplementation strategy.

Comparison of Programming Approaches

To provide a base for comparison, the JS model was used to assess other extension programming approaches in terms of their learning components. The results of that qualitative assessment are presented in table 1. The information illustrates that traditional extension outreach techniques can be categorized as those designed for general audiences and which stress presentation of theories, concepts, and general models of the applicability of a potential practice, and those which involve direct contact with a client for the purpose of real-world problem solving. No traditional approach includes more than three training components and only agent/specialist "one-on-one" contact with clientele includes the desirable components of feedback and coaching.

The expanded ES designed as an example is expected to have great impact as a teaching tool because it includes all five learning components, as described earlier. Currently only extension programs designed using a mixture of techniques include all five components. Thus, based on the educational model, the expanded ES approach is expected to be a more effective means of information delivery than any other single programming approach.

Table 1. The Learning Components of Extension Programming Approaches

	Learning Components[a]				
Programming Approach	1	2	3	4	5
General audiences targeted:					
Extension bulletins	X	X			
Spreadsheets			X		
Video tape		X	X		
Interactive video disk	X	X			
Personal contact, small audiences:					
Agent/specialist "one-on-one"				X	X
Agent/specialist workshops	X	X	X		
Traditional expert systems				X	
Expanded expert system	X	X	X	X	X

[a] 1 is presentation of theory; 2, model or demonstration of skills; 3, practice in simulated settings; 4, feedback; 5, coaching for application.

Observations from users of the sample ES have supported this expectation. They have revealed:

(*a*) Cattle producers are significantly more interested in the nutrition module than in the marketing module. This is probably because there are no noncomputerized alternatives which are as effective as the computerized simulation model in analyzing nutrition management, while noncomputerized alternatives do exist for analysis of marketing decisions. This observation supports the hypothesis that ranchers' analytical abilities are augmented by the simulation model embedded in the ES.

(*b*) The computer is accepted as a valuble tool when a user-friendly interface is in place. Ranchers simply do not have the time or interest to learn how to run a computer. The application of HyperCard™ and the user-friendly animated graphical interface (with numerous on-screen prompts) allows ranchers to overcome their fear of computers and to begin using them as a tool.

(*c*) Ranchers accepted advice from the computer after the ES led them through the simulation and analysis of their nutrition management. This observation is consistent with the hypothesis that the tutorial components of the ES were effective in teaching the principles necessary for nutrition management and that the analytical components provided advice for alternative management strategies that the ranchers viewed as useful.

To provide a quantitative assessment of the sample ES's value relative to other extention programming approaches, a simple cost effectiveness analysis is presented. The costs presented below are derived from the sample system described earlier. The costs represent current estimates for systems configured as outlined. The benefits specified are also best estimates from clients using the sample ES. The costs of the ES are compared to those for an extension program composed of only traditional approaches, yet which is expected to produce similar benefits. That "straw man" program includes both agent/specialist one-on-one and workshop approaches. As shown in table 1, a combination of these two teaching approaches will include all five training components of the JS model, making such a program approximately equal to the ES in expected educational impact. Therefore, the most effective program is that with the lowest cost.

The costs for the range cattle module of the ES are approximately:

Computer hardware	$4,000 per unit
Computer software	$600 per unit
Development costs	$20,000 one time
Maintenance & training costs	$5,000 per year

Unfortunately, expert systems of the type described here require powerful microcomputers. A reasonable computing platform for the sample system is Macintosh SE 30 with a 40 megabite hard disk and two megabites of memory, a 2,400 baud modem, and a printer. The ES requires HyperCard™ (the all-purpose computer program construction set which is used as a shell to put together the necessary parts of the ES) and is bundled with all Macintoshes, StellaStack™ (the graphics-based simulation program), and Timbuctu Remote™ (the communication program to allow remote control of the ES). The one-time development cost must be divided between the effort necessary to develop information and to do applied research on the problems covered by the ES, and the additional effort required to package the results of the applied research into an ES format. These costs are estimated to be $20,000 for the cattle ranching ES and do not include the costs of developing the basic simulation model. Maintenance and training costs are incurred because any complicated system needs to be kept up to date and new personnel must be trained in its use. The present value of these cost streams at a 10% discount rate, assuming a five-year life of the ES and associated hardware, is approximately $44,000 for one unit and $52,500 for three units. (Each unit would be located in a different county extension office.)

The benefits to the client derived from the sample ES are significant. A rancher saves $10 per head per year resulting from changes in management suggested by the ES. For an average ranch with 200 mother cows, this would mean an increase in profits by $2,000 per year. This result (for Arizona) may be an underestimate; savings of over $70 per head have been reported for similar integrated management programs elsewhere (see Eftink and Walter).

Because of the complicated nature of providing advice about nutrition management, it was judged that quarterly visits by an extension specialist would be required for a similar level of benefits to be obtained by clients. Thus, the extension budget "savings" from using the ES would equal $250 per day of specialist time and travel or $1,000 per year per ranch. For problems which are less complicated, such as providing information on marketing alternatives, the savings would be less as specialist one-on-one input could be obtained over the phone.

The cost effectiveness breakeven point for extension can be roughly calculated in terms of the number of ranches which must use the ES to pay for the model by reducing expenses incurred in providing this training. With just one unit in operation, approximately ten ranches must participate to make the sample ES more effective (in present value terms) than the "straw man" program. However, with three systems in operation, only two additional participants are needed to cover the marginal cost of the two extra ES units. In the sample project, during the first meeting (at which the basics of the system were introduced) more than ten ranchers from one region indicated strong interest in utilizing the system. Thus, with units located in county offices around the state, the odds of the ES being a cost-effective educational tool for extension are extremely high.

Conclusions and Implications for Extension

The expanded ES approach offers a cost-effective means of extension program delivery. Specialists can make more 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 with multiple clients as the computer system has to be developed only once. In addition, once developed, the ES can serve as a focal point for the collection, organization, and dissemination 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, hybrid expert systems, Intelligent Decision Support Systems, Intelligent Tutoring Systems, computer driven multimedia programs, or the newly popular "hyper something or other," only sound design, based on proven learning techniques, will result in truly effective advances in the delivery of extension programming. The expanded ES described in this paper demonstrates the possibilities of developing educational programs which include the full range of training components, suggesting that this approach holds realistic promise for improving the effectiveness of extension's operations.

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 which require major changes for them to be used at all. Because 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. In some cases the lumpy nature of this innovation will not be recognized, and resources may be diverted into the development of expert systems with restraints attached, such as the requirement that any systems developed must work with the existing set of extension computers. Restraints such as this may reduce the likelihood of being able to develop truly effective expert systems. This leads to questions concerning the optimum path of adoption of expert systems. The answers to these questions are specific to each extension organization and, therefore, will be debated at length.

The analysis presented here, both in terms of learning efficiency and cost effectiveness, strongly suggests that the concept of enhanced expert systems should be an important new addition to the toolbox of extension personnel. If extension is to be an agent of change in the effort to make 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 ES approach cannot be justified at present, the results for the sample ES suggest that development and implementation of expert systems dealing with some types of problems should proceed and be closely monitored to test their long range effectiveness in delivering extension programming.

[Received June 1989; final revision received October 1989.]

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