DOCUMENT RESUME

ED 312 993 IR 014 031

AUTHOR	Cumming, Geoff
TITLE	Exploiting Ar' 'ficial Intelligence To Enhance Training: A Short- and Medium-Term Perspective.
PUB DATE	88
NOTE	11p.; In Proceedings of the Annual Conference of the Australian Society for Computers in Learning in Tertiary Education (6th, Canberra, Australia, December 1988).
PUB TYPE	Reports - Descriptive (141) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Artificial Intelligence; *Computer Assisted Instruction; Foreign Countries; Higher Education; *Industrial Training; *National Programs
IDENTIFIERS	United Kingdom

ABSTRACT

This paper is an introductory discussion of industrial training, artificial intelligence (AI), and AI applications in training, prepared in the context of the United Kingdom Training Commission (TC) program. Following an outline of the activities and aims of the program, individual sections describe perspectives on: (1) training needs, including examples in steelmaking and the health and safety field; (2) AI; and (3) AI applications for learning, including discussions of expert systems, simulations, Anderson's LISP tutor, learning environments, intelligent help, direct manipulation, adding a coach, and domain independence. Possible AI applications to training are then considered. Conclusions relevant to the TC program are drawn in several areas--demonstrators, overseas experience, promoting awareness, dangers of over-selling, and TC support for AI applications. Eleven annotated references are listed. (MES)

Exploiting artificial intelligence to enhance training: A short- and medium-term perspective

Geoff Cumming
Department of Psychology, La Trobe University,
Bundoora, Victoria, Australia 3083

The United Kingdom Training Commission (TC) has sponsored a £3.2M program to increase the use of AI in training and higher education in Britain. Demonstrator projects are being funded and dissemination activities undertaken. This paper is an introductory review of the prospects for AI applications in training, prepared in the context of the TC program. It emphasises the diversity of possibilities, the need to avoid over-selling, and the attractive prospect of intelligent educational systems that draw on learner intiative to enhance learning.

The United Kingdom Training Commission (TC; formerly the Manpower Services Commission) is investigating how AI could be exploited to enhance higher and further education in Britain and, especially, how it might be used to enhance training within British industry. As part of its Programme, the TC sponsored a seminar in June 1988 at which industrial trainers, computer people and academics discussed AI in training in general, and the TC Programme in particular.

This paper is an introductory discussion of industrial training, AI, and AI applications in training. It is partly based on discussions at the seminar. Following an outline of the Programme, there are sections describing in turn perspectives on training needs, on AI, and on AI applications for learning. Then more specific possibilities for AI applications in training are suggested, and conclusions drawn in relation to the TC Programme.

The context

The TC's Programme on AI Applications to Learning represents a commitment of some £3.2M over 1987-1990. Activities sponsored by the Programme to date include:

- 3 completed demonstrators;
- a survey of needs and resources;
- a further 5 demonstrators in progress;
- a further 3 demonstrators to be commenced soon; and
- initiatives in training people to work in AI applications in training.

The broad aims of the TC's programme are:

1. To explore the use of AI techniques in developing more effective training methods;
2. To accelerate the appropriate applications of AI techniques in learning; and
3. To encourage UK industry to become more competent and competitive by providing evidence and demonstrations of more cost-effective means of training.

TRAINING AND TRAINING NEEDS: A PERSPECTIVE

New technologies should be able to enhance training, whether by increasing effectiveness or reducing costs. There is, however, some disillusionment, and uncertainty as to what promises will actually be fulfilled.

Training needs are changing. Specific influences include:
• the shrinking population of young people;
• the prospect of Europe 1992;
• increasing need for retraining, and the concept of lifelong education;
• the needs of special groups e.g. women returning to work, the unemployed;
• the need in some cases that training be designed, prepared and delivered very rapidly;
• the need for workers to be more flexible, so training should not be narrow;
• severe and apparently chronic shortages of skilled people in some areas, especially in the new technologies themselves; and
• the need to train and retrain sufficient trainers, especially in new technologies where there are shortages anyway.

The great strength of a human trainer is flexibility: if one approach does not work, the trainer will try an alternative approach. AI holds the hope that training could be made somewhat more adaptive to the needs of the individual learner, without the prohibitive cost of personal human tutors. But any awareness campaign, whether to senior managers or to training managers themselves, must be based on working systems and real applications. An industry will be persuaded best by an application that can be seen to apply to that industry. Without these it would be better to hold back for the present. The promise is there but the time may not yet be ripe; the demonstrators must come first.

No single view of the nature of training should be allowed to restrict our thinking. There is a great diversity of training needs, going well beyond e.g. the learning of specific procedures needed to operate a particular machine. Human expertise is complex and deep, and includes higher level skills of judgement, problem solving and being able to take initiative. Training for the various levels of management, for example, requires attention to a wide range of abilities. It is also worth noting that although the TC has 'training' in its title, the name of its programme on AI applications refers more broadly to 'learning'.

Two examples illustrate the diversity of problems that must be addressed by trainers:

Steel-making

British Steel is setting competency standards for every class of job, at all levels. This is a complex task, especially as the managers of the 40 plants have differing views as to what skills are needed for particular jobs. Traditions, equipment characteristics, and job organisation also differ from plant to plant. Setting competency standards may be regarded as an early step in the specification of training needs. Might AI be able to help?

Health & safety

The new Health & Safety legislation incorporates a vast mass of tedious, but precise and necessary detail. Mere statement of this information, or even retrieval of the parts of it relevant in a particular case, is not sufficient. There is, rather, a practical need for interpretation and conceptualisation, and judgement as to what information is applicable in some situation. These considerations apply both for the application of the legislation, and for training. Could some sort of expert system help?

The training perspective in outline

At present there is insufficient training, and the training that is offered is often poor. Demographic, social, political and technological change are all changing training requirements and increasing the need for training.

There is, therefore, need and scope for improved methods in the preparation and delivery of training. Training is, however, needs driven and output oriented: new methods will be adopted only if they are proved effective in practice.

The classical systems model of training is a specify-plan-prepare-deliver-evaluate-revise cycle. New methods could contribute at any point in the cycle.

Training is much more than acquisition of the skill to operate one machine. The great diversity of training needs, and of types of training activity must be recognised. There are, therefore, many opportunities for new techniques to be used to improve training.

ARTIFICIAL INTELLIGENCE: A PERSPECTIVE

The AI enterprise is an endeavour to build systems that show the flexibility, learning, and other characteristics of human intelligence. AI is an active, argumentative and changing field. Things that were regarded as AI a few years ago may now be taken for granted as routine and non-intelligent. Progress has been limited and slow, but powerful tools and techniques for knowledge representation, software development and interaction with users have been developed.

AI applications have been the subject of widely-known hype and disillusionment. Although spectacular advances are unlikely, useful applications will be made, and software engineering practice will increasingly rely on hardware, software and interfaces that have AI parentage. Systems will become easier to use, especially for untrained people, and some systems will be easier to develop. Progress will, however, be evolutionary; AI hype must not be allowed to over-rule our caution and critical attitude.

In expert systems (ESs), the best-known type of AI application, the knowledge base and the reasoning module are separated. ES shells have severe limitations, but give some scope for reasoning and interface modules to be reused with different knowledge bases. ESs can be practically useful in some applications, although their ability to explain their answers is very limited. It is vital to realise that an expert system can be used in a wide variety of ways: the value may come from building it, exploring its knowledge, or using it with imaginary problems. ESs should be seen as tools to assist humans, rather than as replacements for humans.

AI comprises much besides ESs. Natural language understanding, robotics, and cognitive modelling, among others, are areas with relevance for training.

Over-selling must be resisted, but there are now tools and techniques available that have many useful applications - in training and elsewhere - even if the resulting systems have only glimmerings of 'intelligence' or 'expertness'.

AI AND LEARNING: A PERSPECTIVE

'Intelligent Computer Assisted Instruction' and 'Intelligent Tutoring System' (ITS) are widely used terms, but ITS, in particular, is a misleading name because it suggests a one-way tutoring style in which the system teaches the student. It may also limit our conceptions of how AI applications can support learning. The broader term 'Intelligent Educational System' (IES) is preferable and will be used here.

Traditionally, an IES is described as comprising three components:
- domain knowledge, in the subject area for learning;

• teaching knowledge; and
• a student model, so that response can be adapted to the current needs of the individual learner.

It seems logically necessary that an IES should contain, at least implicitly, knowledge of these three types.

Several approaches that have been taken to IESs will be described briefly, to illustrate the variety that is possible, then a number of issues will be discussed.

Expert systems

The pioneering ES MYCIN was based on several hundred 'if-then' rules. Clancy started with MYCIN, then developed GUIDON, NEOMYCIN and other systems to explore the use of ESs to support learning. The major conclusion was that, although MYCIN performed creditably at medical diagnosis of infectious diseases, it was of only limited use in a tutoring system. Learning requires explanation, and an ES based on a simple set of if-then rules can only give explanation of limited scope. Richer knowledge representation, including broad conceptual knowledge and problem solving skills and strategies, is required for a good tutoring system.

ESs can, however, be used in a variety of ways. For example, a learner might use an ES not for its rather rudimentary explanations, but to give a comparison with his or her own growing expertise; a critical attitude to the advice given by the ES would be vital. Or the learner might use good AI-based tools to build or modify an ES, thus being forced to express and organise his or her own understanding in the topic area. Or CBT or other traditional means could be used to guide a learner who explores an ES in the domain of interest.

Simulations

Two large computer-based simulations intended for training use are STEAMER, and the RECOVERY BOILER TUTOR (RBT). In each case there are impressive facilities for displaying the state and behaviour of the system. The user can select from many schematic diagrams showing the workings of aspec. of subsystems or the whole system. Icons (small pictures) and displays are used to represent salient aspects (levels, voltages, pressures, etc) at many points. The user can intervene, and observe how the system reacts to the change made.

On top of the simulation is an advisor or coach (well-developed for the RBT; in development for STEAMER) which can guide, advise and tutor a user who wants to learn about the system. A very important feature is that a wide variety of interactions with the learner is supported, for example:

• the coach sets up a problem condition, the learner tries to manage and correct the problem, while receiving advice from the coach;
• the learner can take the iniative and try any change, observe what happens, and hear commentary from the coach;
• the coach can take the initiative and guide the learner through the sequence of actions that an expert might take to correct a problem;
• the coach can introduce a fault for the learner to diagnose, if necessary calling for help from the coach; or
• a pair of learners can collaborate in using the system.

Adding a coach to a simulation requires not only the representation of extra knowledge about the system and how it works, but also some knowledge about advising and teaching, and the ability to build and maintain a model of the individual learner.

These IESs are based on the cognitive science idea that the goal of learning should be conceptual change in the learner. We want to go beyond mere skills training to have the learner develop a good 'mental model' of the target system and how it works. Such an approach to training should give more flexible abilities, and lead to staff being more adaptable, and better able to cope with unforeseen situations.

A notable aspect of these systems is the interface. Powerful workstations with mouse, large graphics screens and windowing software were used. The graphical representation of system functioning was designed with great care. A learner can interact very closely with the simulation, and see immediate links between changes introduced and effects on system behaviour. The displays are designed not necessarily to give close physical fidelity with the target system, but to have good conceptual fidelity with the mental model we would like the learner to develop.

These systems are impressive, and reportedly have been used successfully to give training in realistic settings. They were large-scale development projects; an important question is the extent to which future systems can be built more quickly. Improved tools will help, but there seems no way of escaping the need to draw on the best human expertise in the area, and a great deal of technical knowledge about the target system being simulated.

Anderson's tutors

Anderson's LISP tutor is based on a large set of production rules; a production rule has the form 'if (condition) then (action)'. The rules model correct LISP programming skill, and also many errors made by students learning LISP. A learner works through a series of programming exercises. The system monitors the learner's performance and intervenes when an error is made. It also answers questions and gives advice if asked. The LISP tutor is reportedly successful in tutoring beginners, and is now available commercially. It can be criticised for the very tight rein it keeps on a student, which gives an oppressive tutoring style. It generally recognises only one correct way to solve a programming exercise, so a student has no scope to explore alternatives, or to make a sequence of errors then try to recover. Anderson is also developing similar tutors for high school geometry and algebra.

Learning environments

Papert advocated an approach entirely different from that of CAI and intelligent tutors. Recalling very early notions of liberal education, he insisted that the learner should have a set of tools, or a domain for computational play, and be encouraged to explore, experiment, discover things, and, most fundamentally, construct his or her own understanding.

Attempts to put Papert's ideas into practice have had mixed success, but the notion that learners should be given a 'microworld' - a small simulation environment - and the tools and the scope to take initiative and build things themselves has been influential.

Intelligent help

An intelligent help system contained in a software package would monitor the user's actions, build up a picture of what the user did and did not know, and also what goal the user was trying to achieve. The help system could thus give more appropriate answers to a user's question, and could intervene to point out errors or suggest a more efficient way of achieving the goal. The user could thus work more effectively, and at the same time become more expert at using the computer application.

A full intelligent help system remains a big challenge, but even modest systems should be worthwhile. It is an attractive notion that software packages and computer-based machines should incorporate their own intelligent advice and training for users.

Direct manipulation
An extension to Papert's learning environment approach is to provide objects on the screen that have properties similar to objects in the domain of interest. The user can manipulate the objects, build simulations, and 'learn by doing' in a computer-based representation of the domain. An example is ARK, the Alternative Reality Kit, which was developed in the Smalltalk language by Randall Smith. In ARK an object created on the screen has many of the properties of physical objects, such as motion and momentum. ARK has been described as the best visual programming system yet; it will support simulation work in a variety of domains.

Adding a coach
STEAMER and the RBT, the two large simulation systems described earlier, show that a simulation plus a flexible advising, helping and coaching function can be a valuable tool for learning. This approach can be extended: we could add a coaching function to a computer-based simulation, or to a machine itself - with an interface allowing the computer-based coach to communicate with the machine - or even to a direct manipulation or learning environment in which the learner is building and using his or her own small simulations.

Domain independence
Many have dreamed of an IES shell into which we would merely need to put a domain knowledge base to have an IES in the domain. Clancy linked GUIDON to three different knowledge bases and found that it could carry on discussions with a learner in each case. But the differing nature of the domain knowledge in the three cases meant that the discussions were of limited usefulness for learning. More recently Clancy has described the Training Express system, which is a less ambitious attempt to achieve some domain independence by giving the developer good tools to add some tutorial functions to any knowledge base expressed in a particular format. Training Express is now available commercially: see the appended list of References.

The Instructional Design Environment (IDE), described in several papers given in the References, is a promising system or collection of tools in which a variety of approaches to instruction can be expressed and used for trials.

Summary
The structured, directive instruction of CAI and early ITSs can be effective. The flexibility, richness and encouragement for learner exploration and thinking offered by simulation environments is extremely attractive, and accords well with cognitive science conceptions of learning. The vital realisation is that advising does not require taking control: the learner can have great scope for initiative, yet still be offered support and encouragement. Such a coming together of the ITS and microworld traditions offers great promise for IESs.

AI APPLICATIONS IN TRAINING

Three approaches will be taken to discussing possible AI applications to training:
- how may the use of AI change the need for training?
- where in the traditional training process can AI contribute?
- what suggestions arise from IES research?

CAN AI CHANGE THE NEED FOR TRAINING?

Use of AI tools is changing software engineering, and giving us more powerful and friendly applications, even on cheap microcomputers. These advances naturally influence the need for training. For example, it may require some serious training effort for a novice to learn to make good use of the early word processing program Wordstar. By contrast, for a novice to learn MacWrite is scarcely a training issue at all, because the interface used is so much better. From a training point of view, perhaps the best applications of AI are those that reduce the need for having training at all!

The detailed task analysis and knowledge elicitation that is needed at an early stage in the design of training often suggests how redesign of the task, or provision of better job aids or interfaces may reduce the need for training, perhaps drastically. This has always been true, but becomes more likely now with the extra possibilities for task redesign and job aids offered by AI. An IES with the ability to demonstrate some operation to a learner, and to evaluate the learner's attempt at the operation, may itself be able to carry out the operation, at least in some circumstances, thus reducing the need for human training. In addition, more machines and processes now have a computer component, thus giving scope for intelligent help and advice to be incorporated.

Trainers should, therefore, have familiarity with AI tools, techniques and possibilities. Ideas of knowledge elicitation and representation should also help in the development of conventional training.

AI AND THE SYSTEMS APPROACH TO TRAINING

Where in the classic systems approach to training might an ES be used to help? The problem is one of identifying an area of expertise that is suitable for the building of such a system: it must not be too complex or amorphous - too hard for an ES - and not too trivial to warrant the ES development effort; it must also be an area in which human expertise is scarce or expensive, or again an ES would not be justified.

Considering a typical systems model suggests that 'identify the training need', and 'analyse the training need' are too broad and vague for ES treatment. Some aspects of 'design the training' and 'prepare the materials' have been proposed as candidates for ESs, but may be too limited or trivial e.g. selection of media, choice of screen layout, choice of question format. Some aspects of training design may, however, be appropriate: indeed the TC has already sponsored development of a Course lanner's Assistant, which reached early prototype stage. There has also been some work on Training Needs Analysis, although this seems a very difficult area for an ES. (See the Reference list for pointers to further discussion of these possibilities.)

An especially promising approach is to use an expert system not as a teaching device but as a resource, to be called on by the learner, perhaps partly under the guidance of CBT. An ES could provide the domain knowledge, to be explored with some CBT guidance, or an ES could advise a learner trying to make the most of CBT. A variety of ways of using ESs to enhance CBT deserve to be investigated.

Another attractive possibility is to consider how elements of IES functioning might be incorporated into CBT. Enhancement of CBT authoring tools is one promising approach. Even a modest ability to model and adapt to the individual user would represent useful progress.

LESSONS FROM IES RESEARCH

From a training point of view, the most promising approaches include:

• Simulation, with or without coach. Tools will help development.
• Modelling, or direct manipulation environments, possibly with advice or coaching.
• Expert systems, used in a variety of ways.
• Integration of advice and training functions, including intelligent help, into software and computer-based equipment. Training is thus to some extent integrated with use, and takes place at the workplace.
• Tutors for defined procedural skills that need to be learned and practised; Anderson's tutors provide a model.
• Hypertext and browsing: there are many possibilities worth investigation. A promising one is the rapid prototyping of CBT.
• Enhancement of CBT design and preparation by incorporation of an expert system into the classic model for training.
• Use of AI tools and interfaces to assist the preparation and delivery of CBT.

CONCLUSIONS RELEVANT TO THE TC PROGRAMME

Demonstrators

Good demonstrators are the key to a successful programme. Industrial collaboration is needed, and careful selection and planning so that a successful demonstrator can be seen to make a clear and valuable enhancement to learning. The challenge is to find projects that are feasible within, at most, 1 - 2 years, that address a practical learning or training issue, and that draw on IES research expertise. Goals must be realistic: only limited systems are likely to be achieved within 1 - 2 years.

Exploiting the lessons of IES research is a vital aspect: there are only a few research teams in the U.K. at the forefront of this research, and they, quite properly, put their primary effort into research projects with a longer time-scale than the TC can support. Some form of consultancy with leading research workers may be the best way to ensure that demonstrator projects are informed by the best possible advice.

Overseas experience

Several books and papers noted in the Reference list describe AI-based systems developed in the U.S. specifically to enhance training. It would be worthwhile to investigate such systems, looking especially for tools.

Promoting awareness

Awareness and promotional activities should be based mainly on demonstrators or other applications that can be seen to perform. Direct comparisons of AI-enhanced training alongside conventional CBT or other training would be useful. There is also scope for more general educational activities, to raise preparedness in advance of future AI applications, and to help trainers benefit from AI ideas, such as the importance of knowledge elicitation and representation.

Dangers of over-selling

Past over-selling and disillusionment about AI, and the occasional use of the AI label to add glamour to systems that embody no AI should lead to caution. It is important to find and support example applications that are likely to have a marked impact in some particular training setting.

TC support for AI applications

Experimental IESs have given concrete demonstrations of many ways that AI tools and techniques can contribute to learning. There is a great breadth of possibilities to consider.

Application of the advances made by IES research has been slow in coming, partly because there is a shortage of specialist expertise: consultancy should be used to draw on this expertise. The large development effort needed by IESs has also been a problem, although improved tools now give scope for more rapid building of usable systems. Practically useful improvements over what is possible with CBT and other traditional methods have been illustrated.

The aims of the Programme are worthwhile and practical, and amply justify TC support. Future support by the TC of applied research, demonstrators, dissemination and awareness activities about AI applications to learning is also justified, and, if carefully planned, would lead to worthwhile improvements in the efficiency and effectiveness of training and education.

SELECTED, ANNOTATED REFERENCES

Clancey, W. J. (1986) From GUIDON to NEOMYCIN and HERACLES in twenty short lessons. The AI magazine, August, 40-60;187. (A readable account of one of the longest-running and most important IES research projects.)

Clancey, W. J., & Joerger, K. (1988) **A practical authoring shell for apprenticeship learning.** Paper delivered at the ITS-88 Conference, Montreal, June. (Clancey describes the Training Express system, which is distributed by Teknowledge, Inc. Clancey's address is: Institute for Research on Learning, 3333 Coyote Hill Road, Palo Alto, CA, U.S.A. 94304)

Dear, B. L. (1987) AI and the authoring process. IEEE expert, Summer, 17-24. (A paper discussing how expert systems and AI tools can be used to enhance CBT.)

Kearsley, G. P. (Ed.) (1987) **Artificial intelligence and instruction**, Reading, Mass.: Addison-Wesley. (A collection of recent papers describing IES systems, from the viewpoint of training; several come from the American 'instructional system design' tradition familiar to CBT designers.)

Lawler, R. W., & Yazdani, M. (Eds) (1987) **Artificial intelligence and education, Vol. 1**, Norwood, N. J.: Ablex. (Papers from the ITS perspective, and the learning environment perspective, and links between the two.

Merrill, M. D. (1987) An expert system for instructional design. IEEE expert, Summer, 25-37. (A paper describing 'ISD Expert', an expert system that is intended to incorporate knowledge of instructional system design and thus be able to assist the CBT author.)

Naughton, J. (1987) **Artificial intelligence: Applications to training**, 2nd ed. A research study for the Manpower Services Commission, by the Systems Group, The Open University. Milton Keynes: The Open University. (An introductory and very readable report describing AI, training, CBT, and AI applications in training.)

Polson, M. C., & Richardson, J. J. (Eds) (1988) **Foundations of intelligent tutoring systems**, Hillsdale, N. J.: Erlbaum. (Recent review papers on basic issues in IES research.)

Psotka, J., Massey, L. D., & Mutter, S. A. (Eds) (1988) **Intelligent tutoring systems: Lessons learned**, Hillsdale, N. J.: Erlbaum. (Descriptions of many current simulation and tutoring projects in the U.S.; several papers refer to the Instructional Design Environment (IDE).)

Self, J. (Ed.) (1988) **Artificial intelligence and human learning**, London: Chapman and Hall. (A collection of recent research papers; technical, but illustrating the wide range of IES research.)

Wenger, E. (1987) **Artificial intelligence and tutoring systems**, Los Altos, Calif.: Morgan Kaufmann. (Tells the story of 20 years of IES research. Somewhat technical, but comprehensive.)