# Artificial Intelligence and Education

Proceedings of the 4th
International Conference on
AI and Education,
24-26 May 1989,
Amsterdam, Netherlands

D. Bierman, J. Breuker and J. Sandberg, Editors

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# Preface

In many respects the fourth International Conference on Artificial Intelligence and Education (in short: AI & ED '89) is in line with its predecessors. It is a meeting place for researchers and the emphasis is on new ideas and reflection on experiments with new AI tools for education. The systems developed are 'proofs' or demonstrations of existence or tools for experimenting rather than practical applications. Although interest in applied AI -or knowledge engineering- has seen an explosive development over the last 6 years, the scientific development is rather linear and modest, as we will argue below.

An obvious difference with the other AI & ED Conferences is the availability of the full Proceedings at the conference. The second AI & ED Conference (Exeter, 1985) resulted in a collection of articles which appeared 2 years later. The editors (Lawler and Yazdani, 1987) signal a number of developments which can be summarised as:

- A tendency towards standard architectures for Intelligent Teaching Systems (ITS), in particular 'shellification', as opposed to handcrafted individual ITS.
- A need for synthetic views on the paradigms for instruction that enable a large degree of flexibility.
- The emergence of educational modelling tools which allow students to construct and/or explore worlds which may or may not map onto the real world.

The same need and tendencies are reflected in the papers for this Conference. Despite its theme "Synthesis & Reflection" it accomodates only a few papers that present views on developments and problems in major areas in ITS and AI-based learning enviroments. (Reimann, Murray) Instead of large scale new perspectives, the reader will find a very large variety of well exposed and often well polished gems, and it is up to him to assemble these in existing or new frameworks. For example: automatic counterexample generation (Evertsz), beautiful user interfaces (Towne, Böcker, Reiser, Kurland), and planning of tutorial discourse (Cawsey, Winkels, Woltz, Baker). This may indicate that AI in education is a maturing research enterprise, but the availability of a number of well tested and practiced techniques does not resolve the problem of the wide range of flexibility that is required in interacting with heterogeneous populations of students, who are irregularly moving targets for modelling.

This flexibility is in principle available in the learning environments, but in a very passive way, i.e. it does not require any adaptive capabilities of the computer system. Grown from the powerful but very general enviroments like LOGO into more domain specific worlds of arithmetic, physics, language, etc. building blocks, there has always been the question of the degree of guidance that is required in exploring these worlds. On one hand self constructed worlds have the advantage that they are well understood by the student, on the other hand it is often difficult or even impossible to induce generalisations from these constructions and their effects. In the papers on this subject (e.g. Reiman, Lees, Bocker, Kurland, Towne) some form of guidance and coaching is always implied, which was still an issue at the 1985 Conference. The tendency towards shellification for ITS and the use of standard architectures is certainly more pronounced in this Conference than in the previous ones (e.g. Valley, Spensley, Boulet). The construction of shells mark the transition between pure research and development, and show that after two decades of mostly pioneering research (in particular at Bolt, Beranek & Newman) a more or less stable and domain independent view on functions and components in coaching has been realized. This stabilisation can also be inferred from the fact that in almost all contributions prototypes and sometimes operational systems are presented. We are convinced that at this Conference the proportion of 'vapourware' presented is far less than at previous conferences.

The organisers of this Conference may have been somewhat disappointed by the number of theoretical and visionary contributions -which has been more than compensated for by the talks of the invited speakers (Schank, Anderson, O'Shea, Eisenstadt, Self, Yazdani). In another respect the contributions did meet our expectations: many papers contain full or partial evaluations of systems. In the long run these evaluations provide the required feedback information which may lead to new reflections and syntheses.

Dick Bierman
Joost Breuker
Jacobijn Sandberg

# Sponsors

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# Contents

# Psychology and Intelligent Tutoring

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Work on intelligent tutoring should take its direction from research and theory in psychology, especially cognitive psychology. There is in fact a considerable body of knowledge that can be used to guide the construction of tutoring systems although the process of extracting the implications is non-trivial. I will discuss some psychological implications and present work from our tutors that supports the application of these implications.

The core claim is that design of tutoring should be guided by a production rule analysis of the skill to be tutored. Evidence will be presented to show that under an appropriate decomposition of a skill into production rules, the actual learning process is quite simple. This means one can use quite simple rules for monitoring student's knowledge states. On the other hand, this places a considerable emphasis on the process of analyzing a skill into productions rules (i.e., task analysis). The degree of success of a tutoring application can hinge on achieving an appropriate task decomposition. I will also discuss the issue of whether a production rule analysis is only appropriate for a restricted range of domains.

Another issue concerns the locus of control between the student and tutor and issues of design of tutor feedback. It will be argued that, ignoring issues of technical feasibility, tutoring is successful to the degree it achieves three objectives: minimizing waste of student time, maximizing student sense of control, and maximizing the degree to which student solutions are self-generated. As these three objectives are not always compatible, I will discuss what efforts we have taken to try to achieve an optimal combination. These principles lead to some non-obvious conclusions about the design of tutor feedback--there is little role for delivering cognitive diagnosis of errors in feedback and in many cases the tutor's feedback should be minimal even to the point of being non-existent.

Finally, I will discuss the implications of the Larkin & Simon analysis of diagrams for interface construction. The major goal of interface design should be to display in a perceptually salient form the information required to match the conditions of a production rule. One major consideration is the locality constraint--that information required to match a production rule be all available in a small region of the diagram. Another implication is that one needs to analyze which perceptual patterns are salient and which need special training. I will present successful and unsuccessful examples from our tutoring work which illustrate these considerations.

# A Model for Tutorial Dialogues based on Critical Argument

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**Abstract**

This paper reports work on development of a new model for computer generation of tutorial dialogues, which aims to teach skills in critical argument. A set of *dialogue moves* are used to generate sustained tutorial dialogues which share many common characteristics with argument, explanation, critiquing and Socratic tutoring, integrated within an ITS architecture. Significant new features are: (i) ability to conduct tutorial dialogues in incomplete and uncertain knowledge domains; (ii) integration of goal directed and topical structures, and use of spreading activation models of focus in tutorial dialogues; (iii) emphasis on symmetry of available dialogue moves for student and teacher, and use of explicit negotiation of dialogue goal pursuit, and (iv) integration of multiple teaching and learning styles. A first prototype of the model is currently being implemented on an Apollo Domain workstation, in Common Lisp, for the example domain of beliefs and justifications for existence of structures in tonal melodies.

**Introduction**

Two recent trends in ITS research which have been identified by Self (1988) are (i) a greater emphasis on cognitive and metacognitive skill acquisition, and (ii) a move towards providing a wider range of interaction styles. The model for tutorial dialogues presented here addresses these issues by aiming to teach the cognitive skill of critical argument via a naturalistic dialogue, and by providing a range of interaction styles which are symmetrically available for both system and user to pursue teaching and learning goals. By participating in the critical argument dialogue with the ITS the student is expected to acquire the cognitive skill of critical argument by means of that very participation *itself*, as well as learning the relevant knowledge sources to support claims. This represents a conception of the role of the dialogue model in an ITS, which complements and contrasts with the currently predominant view that an ITS is essentially concerned with "knowledge communication" (Wenger 1987). The educational value of engaging in critical argument is particularly clear in knowledge domains which (in cognitively realistic terms) can be represented as sets of uncertain and incomplete partially justified beliefs. An example of such a domain is our perception of musical structures (Baker 1989a), and ability to intuit and argue about this knowledge. The dialogue model described here takes this as its example domain, but is generalisable to other knowledge domains which are characterised by justified beliefs (archaeology, law and politics, for example). In a tutorial context, a dialogue participant may wish to support the ability of the respondent to present the most effective and complete argument which is possible for them. It is therefore necessary to develop a principled model which can integrate a variety of interaction styles, to include instruction and explanation concerning possible knowledge sources and critiquing arguments. We suggest that this can be achieved by defining interaction styles as specific combinations of a general set of *dialogue moves*, or *dialogue goals*. Recent work in dialogue research (Elsom-Cook 1984, 1989; Grosz & Sidner 1986) has realised the necessity to integrate intentional (goal-directed) and topical structures. Our model integrates intention-based structures using particular combinations of dialogue moves, with focus-based constraints on concept teaching goals, using a spreading activation model (Anderson 1984) in the semantic network which interrelates sources of justifying knowledge. Apart from issues concerning theoretical economy, this provision of alternative flexible interaction styles is required by the notion of *symmetry* in dialogue. In much earlier tutorial dialogue research (such as in Socratic teaching dialogues, Collins & Stevens 1983), very little autonomy was given to the learner in terms of the range of responses available, and the possibility of pursuing their own independent learning goals. We therefore argue that the student should be provided with the same set of dialogue moves available to the system, and that pursuit of interaction goals of teacher and learner should be *negotiated* to secure cooperativity. A mechanism is described for sustaining such cooperative dialogues, together with strategies for managing alternation between system and user goal choice, which is designed to be used within a Guided-Discovery framework for intelligent tutoring (Elsom-Cook 1984).

## The Tutorial Dialogue Model

### Overview

The supporting ITS architecture fundamentally consists of a set of dialogue moves, a representation of the current dialogue state, and a set of interface mechanisms. Dialogue moves are represented as *parameterised goal operators*, each of which includes a complex set of *dialogue-state-preconditions*, which must be satisfied with respect to the current dialogue state for the goal to be a possible dialogue goal to be pursued by a speaker, given negotiated mutual acceptance of that goal. The current *dialogue state* (Power 1979) comprises representations of the long term memory traces of both conversants (the system's belief set and the student's belief set, or 'student model'), and an abstract short term memory representation of recent dialogue moves (the 'dialogue history'). Changes in this overall state are effected by procedures attached to *action-effects*. Interface mechanisms are required to present choices of dialogue goals to be pursued to the student, to read in choices of concepts and instances to be discussed, and to generate the system's dialogue 'actions'. At present these mechanisms are implemented via typed input to and from a Lisp environment, but future versions will append a menu driven interface and a graphical representation of instances of musical structures to be discussed. Generation of the dialogue proceeds in an essentially data-driven manner, given input of an initial concept to be taught: a sequence of dialogue moves is chosen from the hierarchical set of shared dialogue goal operators whose preconditions can be satisfied with respect to the current dialogue state, under specific bindings for goal parameters which record current values for *negotiator* and *speaker* roles. A further set of preconditions are evaluated to negotiate desired values for certain goal parameters. Conceptually, this takes place in an identical manner when either the system or the student attempts to pursue dialogue goals. Each cooperatively agreed move which has an action component is *conversed* using a fundamental dialogue action whereby a dialogue initiator *INFORMs* a respondent about a some belief stored in their long term memory. When negotiation fails, control of the dialogue passes to the previous respondent.

**System and student beliefs**

The system's belief set is derived from a musical parser (Baker 1989a), the output of which is represented as a set of frame hypotheses, concerning positions and justifications of musical structures for a given input melody. This represents the output of a perceptual process, and a higher level representation is required and provided for a listener's conscious memory recall and expression in dialogue. Beliefs are represented as sets of positions for possible instantiation of *belief types* (eg 'phrase_boundary') and attendant *justification types*, stored as the values of an 'instances' attribute attached to the appropriate concept node in a semantic network which interrelates a type hierarchy of justification types with interlinking subconcepts. This gives the system the representation required for explaining the nature of sources of justifying knowledge. Each node has connectors for justifications, subconcepts, subtypes and instances, with associated strengths of connection. Nodes also have attributes for 'activation level', 'explanatory text', and 'instrinsic strength' of the node, calculated as a function of its 'importance' or connectivity to other nodes. The network provides a simple overlay student model for nodes and links (with numerical node and link strengths), defines possible tutorial concept teaching goals, and provides a dialogue focus constraint mechanism via activation-level attributes attached to nodes (the next focussed dialogue topic is the node with highest activation level).

**Dialogue goal operators**

Dialogue goals are represented in a hierarchy of subgoals, which are disjunctive in either the exclusive or non-exclusive sense. If subgoals are exclusive-OR - for example, in choosing whether to pursue a CLAIM or a CHALLENGE goal - we use a decision mechanism based on the educational principle of attempting to elicit some response from the student as much as possible (Bellack et al, 1966). The highest level goal is to DISCUSS some concept (initially, this is the concept 'phrase'), which is always satisfied provided that the discussion is not over (the student quits, or the system has exhausted its topics). Subgoals divide fundamentally into either a CHALLENGE to some previous utterance, or the making of some CLAIM. A dialogue initiator may choose to challenge their own previous claims, as well as challenging those made by the respondent. This has the extra property of obviating the necessity for a 'goal stack', once a planned sequence of moves has failed to secure cooperativity, and corresponds to a "return move", in Reichman's (1985) sense. Challenging involves such possible subgoals as disagreeing or agreeing with claims and their supports (similar to Collins & Stevens' 1983 rules for Socratic tutoring), and pointing out competing or complementary claims, where all or any of these subgoals could be pursued with the respondent as speaker (for example, the system attempts to elicit these utterances from the student). CLAIMs divide into CONCRETE_CLAIMs and ABSTRACT_CLAIMs, and the statement of supporting evidence. In our initial conceptually simple implementation, a concrete claim can be made when the concept node possesses unmentioned instances, and an abstract claim corresponds to something like a general 'explanation', using the attached text attribute value. We conclude our description of dialogue goals with a discussion of a simplified and abbreviated example, in quasi-Lisp code:

```
((GOAL-NAME= claim)
    (GOAL-PARAMETERS= (c ) (inst ) (s ) (n ))
    (PRECONDITIONS=
      (DIALOGUE-STATE-PRECONDS=
        (OR
          (AND
            (bind s (dialogue_participant n)) #|let next speaker be non-negotiator|#
            (IF <c is in focus>
            THEN <succeed, retaining original concept bound to c>
            ELSE (bind c <c with highest activation level in s's ltm model>))
            (<s has sufficient knowledge to be able to make a claim about c>))
        (AND
            (bind s n) #|let the speaker be the current negotiator|#
            (IF <c is in focus>
            THEN <succeed, retaining original concept bound to c>
               ELSE (bind c <c with highest activation level in s ltm model>))
            (or (and (<c not known according to respondent's ltm model>)
                  (<s has ltm trace for c>)
                     (<claim goal not used too often with this s binding in dialogue
                     history>)
                  (<previous goal was CHALLENGE>))
               (<it is start of dialogue>))
      (NEGOTIATION-PRECONDITIONS=
        ((negotiate n goal-name=) (negotiate n s) (negotiate n c))))
    (SUBGOALS= (OR (concrete_claim (c inst s n))
                  (abstract_claim (c inst s n))))
 (EFFECTS=
    ((NEGOTIATION-EFFECTS= ((update_dialogue_model (goal-name= s c))))
     (ACTION-EFFECTS= nil)))
 (ACTIONS= nil))
```

Goal parameters used are similar to those used by Levin & Moore (1977) and Power (1979), with the exception that we distinguish separate negotiator and speaker roles: the role of putative negotiator (initial binding of *n*) simply alternates between participants upon negotiation failure; but since a negotiator may be able to satisfy dialogue state preconditions with the other participant as speaker, there is no necessary speaker role alternation. Other parameters concern the current concept and instance to be discussed. Dialogue state preconditions are represented as logical expressions which are evaluated with respect to the current dialogue state. The evaluation returns new binding values (for *s*, *n*, and so on) which are negotiated if the binding is non-nil. In this example, if *s* is bound to the non-negotiator, and *c* is in focus, and the next speaker has sufficient knowledge to be able to make a claim, then this branch of the disjunction succeeds, and the new bindings for *s* are negotiated by the current negotiator. If these bindings are agreed between participants, then subgoals are pursued with the new agreed bindings. *Negotiation-effects* record a trace of variable bindings and goals pursued in the dialogue history. There are no actions to this goal, and hence no action effects. With conceptual parsimony, we use only *one* kind of action, where some speaker *s* INFORMs the respondent of the bindings of *c* and *inst*. Since we are considering higher level dialogue structures, not extending to generation at the sentence level, the dialogue action procedure is based on the speech-act formulation of belief communication ("INFORM") described by Cohen & Perrault (1979), and involves uttering text attached to a concept node attribute, or using text templates to describe instances. As will be discussed in the final section, the INFORM procedure is reinvoked by the dialogue generation mechanism for unknown subconcept trees (precursory knowledge) attached to a concept to be discussed. Belief communication actions have the *action-effects* of either creating a new long-term memory trace (concept node) in the respondent model, or increasing the strength of an existing trace, and of inputting a new *activation source* into the system's and student's long-term memory representations, corresponding to the explicitly mentioned concept. In accordance with Anderson's (1984) model of spreading activation in memory, this will have different effects on the *separate* conceptions of dialogue focus (activation level) of each dialogue participant, since activation propagation depends on the specific relative node and link strengths in a network.

**Dialogue move negotiation**

Negotiation preconditions serve the purpose of attempting to secure mutual cooperation concerning dialogue goals to pursue, and values for speaker and topic (concept) parameters. Announcing the goal which a negotiator wishes to pursue involves *describing* the goal (for example, a COMPLEMENTARY_CLAIM involves making some claim concerning some other instance which possesses the same justification set as the previous claim challenged), to ensure perceived dialogue coherence between dialogue moves (as well as in topic-based dialogue state transitions). For each such precondition, there is an associated *adjacency pair* (Schegloff & Sacks 1973), generated by a PREANNOUNCE dialogue game (Levin & Moore 1977), which has an associated text format, arguments which relate to the specific precondition, speaker roles, and a set of associated possible responses. Upon acceptance, a dialogue action may be uttered, otherwise the goal fails. We have thus adopted Power's (1979) approach of *explicit* negotiation in the form of *preannouncements*, given our present inability to model non-verbal communication and real-time elements of negotiation in human-human dialogues.

**Tutorial dialogue generation**

Dialogue generation proceeds essentially by interpreting the procedures attached to the data structures so far described, which perform all the features 'traditionally' required in an intelligent tutoring system - updating the student and dialogue models, generating utterances, and choosing the most pedagogically relevant teaching strategy at any point in the educational interaction. Given an initial set of parameter bindings for the negotiator (initially the system) and concept to be taught (initially the highest level concept for which the system possesses some belief instances and justifications), the largest scale dialogue structure is generated by an *iteration*, where the system and student take alternate *negotiated turns*. Within a negotiated turn, the generation mechanism attempts to find and converse a path, top-down, through the dialogue goal tree, by evaluating dialogue state preconditions with respect to the current dialogue state, updating parameter bindings, negotiating those bindings, and uttering attached dialogue actions (the INFORM procedure) if present. As successive goals are cooperatively agreed, subgoals are pursued, satisfied, negotiated and conversed in the same manner, until all which can currently be satisfied are conversed. The negotiated turn is over and control passes to the other dialogue participant, if (i) the turn is interrupted, when a negotiator fails to achieve cooperation (assent to a negotiation precondition); (ii) a negotiator cannot satisfy any goal with respect to the dialogue state (iii) a participant quits (a dialogue state precondition of the highest level goal, DISCUSS); (iv) neither participant can satisfy any goal. We assume that a dialogue respondent (whether student or system) will base their decision whether to cooperate (respond with acceptance to negotiation) on checking whether they can satisfy dialogue state preconditions for the goals proposed by the current negotiator. Unless interrupted, the system will continue to pursue a negotiated turn until no further utterances can be satisfied with respect to the dialogue state, thus effectively attempting to retain control of the interaction. It does this by reinvoking the top-down dialogue-goal-path mechanism described using the INFORM dialogue action: if INFORM receives a concept as an argument which has sufficient known subconcepts, then it will communicate that belief; otherwise it will re-apply the dialogue goal selection mechanism for each concept in the associated subconcept tree, in order of highest activation level (focus-based relevance).

**Conclusions, implementation and further work**

The overall dialogue generated integrates a number of levels of structure, in terms of who controls the interaction (the current negotiator), meta-level presequences designed to negotiate cooperative goals, topics and speaker roles, and the generation of belief communication utterances. The generation mechanism is *not* a 'planner', in the traditional AI sense, although it does utilise goal-based dialogue structures. Once we allow the student the freedom to interrupt the system, to take control of the interaction, and to negotiate the pursuit of their own learning goals, the creation of a complete 'plan' to teach the entire set of system's beliefs may well be wasted computational effort, since it presumes that system always has control over the interaction. A more naturalistic and coherent educational critical argument may be generated by allowing the system and student to influence the course of the discussion, constrained by a topic-based model of dialogue focus, and the pursuit of sequences of dialogue goals which are relevant to the current dialogue state. The model is in fact closer to Suchman's (1985) notion of intelligent "situated action".

A number of fundamental problems remain to be addressed concerning issues of planning and replanning, planning to achieve multiple simultaneous goals, partial plans and situated action, developing psychologically plausible methods of belief revision in argument, algorithms for selecting alternative interaction styles, methods for dealing with goal conflict and developing non-explicit methods of goal negotiation. A number of possible future research directions for addressing these issues have already been indicated (Baker 1989b). The principal theoretical contribution to tutorial dialogue research concerns the mechanism for providing symmetrical multiple interaction styles within a cooperative tutorial dialogue.

At present the dialogue model is partially implemented in Common Lisp on an Apollo Domain AI workstation. All belief structures and dialogue goals are represented fully, an initial simplified generation algorithm has been implemented, and interface mechanisms for student interaction and system utterance generation are not implemented (at March 1989). The implementation of the first prototype will be completed by June 1989.

**References**

Anderson, J.R. (1984). Spreading Activation. In J.A. Anderson & S.M. Kosslyn (Eds.), *Tutorials in Learning and Memory*. New York: W.H. Freeman.

Baker, M.J. (1989a, in press). An Artificial Intelligence Approach to Musical Grouping Analysis. *Contemporary Music Review*.

Baker, M.J. (1989b). Arguing with the Tutor: a model for tutorial dialogue in uncertain knowledge domains. Open University, Centre for Information Technology in Education (C.I.T.E.) (Technical Report No. 51), September 1988. The Open

University, Milton Keynes MK7 6AA, Great Britain [to appear in M. Elsom-Cook (Ed.), *Guided-Discovery Tutoring*. Great Britain: Paul Chapman Publishing.

Bellack, A.A., Kleibard, H.M., Hyman, R.T., & Smith, F.L. (1966). *The Language of The Classroom* .Teachers College Press.

Cohen, P.R., & Perrault, C.R. (1979). *Elements of a Plan-Based Theory of Speech Acts.* (Technical Report No. 141). Washington D.C.: Center for the Study of Reading, National Institute of Education.

Collins, A., & Stevens, A.L. (1983). A Cognitive Theory of Inquiry Teaching. In C.M Reigeluth (Ed.), *Instructional-design theories and models: an overview of their current status.* Hillsdale, N.J. : Lawrence Erlbaum Associates.

Elsom-Cook, M.T. (1984). *Design Considerations of an Intelligent Tutoring System for Programming Languages.* PhD thesis. Warwick: Department of Psychology, University of Warwick.

Elsom-Cook, M.T. (1989). Dialogue and Teaching Styles. C.I.T.E. (Technical Report No. 62). Great Britain: The Open University, . [To appear in P. Goodyear (Ed.), *Teaching Knowledge and Intelligent Tutoring.* Norwood: Ablex Publishing.].

Grosz, B.J., & Sidner, C. L. (1986). Attentions, Intentions, and the Structure of Discourse. *Computational Linguistics, 12,* (3), 175-204.

Levin, J.A., & Moore, J.A. (1977). Dialogue-games: metacommunication structures for natural language interaction. *Cognitive Science ,1,* (4), 395-420.

Power, R. (1979). The Organisation of Purposeful Dialogues. *Linguistics ,17,* 107-152.

Reichman, R. (1985). *Getting Computers to Talk like You and Me.* Cambridge , Mass.: MIT Press.

Schegloff, E., & Sacks, H. (1973). Opening up closings. *Semiotica 8.*

Self, J. (1988). The Use of Belief Systems for Student Modelling. *Proceedings of the 1st European Congress on AI and T raining.* Lille, France.

Spensley, F., & Elsom-Cook, M. (1988). *Dominie: Teaching and assessment strategies.* (Technical Report No. 74). Milton Keynes: Open University, CAL Research Group.

Suchman, L. A. (1985). *Plans and Situated Actions: the problem of human-machine communication* (Technical report No. P85-00005). Palo Alto: XEROX PARC.

Wenger, E. (1987). *Artificial Intelligence and Tutoring Systems: Computational and Cognitive Approaches to the Communication of Knowledge.* Los Altos: Morgan Kaufmann.