

Modelling Negotiation in Intelligent Teaching Dialogues¹

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Abstract

In this chapter we aim to establish a set of requirements for the design and implementation of models for sustaining dialogue in Intelligent Tutoring Systems, which incorporate mechanisms for negotiating cooperative teaching and learning goals. Our discussion is centred around a first prototype computational model called "KANT" (Kritical Argument Negotiated Tutoring system), which incorporates negotiation mechanisms within the framework of a more general model for dialogue. KANT bases its decisions on *what* to negotiate on a set of parametrised dialogue goals, in combination with a method for controlling dialogue focus based on spreading activation in working memory. Its decisions as to whether to cooperate or not in a negotiation are based on criteria of *relevance* with respect to a *dialogue state* consisting of speakers' justified beliefs in the domain and concerning the other speaker's beliefs, a model for focus of attention in dialogue, and a restricted memory of recent negotiations. After exploring the function of negotiation in tutorial dialogues, we discuss existing research and analyse negotiation extracts from a corpus of computer-mediated teaching dialogues. We attempt to identify what may be negotiated, the causes of negotiation and its success or failure, and the associated specific interaction structures. We then describe KANT, and critique it with respect to our previous analyses in order to define an agenda for future work.

1. Introduction : negotiation in tutorial dialogues

In this chapter describe how a computational model for generating intelligent tutoring dialogues may be developed, which incorporates mechanisms for *negotiation*. As a preliminary, we need to describe what we mean by negotiation, and why it is important that tutorial dialogue models should incorporate it. Beginning with the second question, the argument is essentially that negotiation fulfills some *function* which must be fulfilled in computational tutorial dialogue models. We also argue that tutorial dialogue models which have previously been developed within the framework of intelligent tutoring systems ("ITS") do not already fulfill this function. Consider first a larger question : what is the function of a tutorial dialogue ? If we could decide this, then the function of negotiation might be described relative to a specific view of the function of tutorial dialogues. An immediate and trivial response is : "that the student should learn". There is more to the story, however, since we are also concerned with *how* this learning takes place - teaching and learning styles - and with the related degree of learner autonomy. "Student autonomy" does not mean "complete student freedom", but rather the flexible possibility of sharing control throughout the learning process. The role of negotiation becomes apparent when we clearly state that the function of tutorial dialogues should be that the student learns within a *cooperative* interaction. Now, this is partly an educational philosophy, and partly a theoretical point of view in the educational psychology of learning. The educational philosophy is what Bennett (1976) termed "progressive teaching", elements of which are also present in the situated learning approach (Lave 1988). The psychology of learning is one of "learning by being told", or more generally, "by engaging in dialogue", and one where the autonomous engagement of an

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individual in his own learning is viewed as an important determinant of the extent to which he will be willing and able to integrate new knowledge. On this point, we pass also to an *epistemology of learning*, associated with our view of cooperation in tutorial dialogues - that the "knowledge" communicated in educational interactions is not a static thing to be transmitted, but is rather an emergent property of negotiation. In other words, that nature of what is mutually agreed to be 'knowledge' is not predetermined but is rather *negotiated* in interaction. Thus, as part of his "new epistemology of learning", Seely-Brown states that :

"Good learning situations and successful ITS are successful not because they enable a learner to ingest preformed knowledge in some optimal way, but because they provide initially underdetermined threadbare concepts to which, through conversation, negotiation and authentic activity, a learner adds texture."
(Seely-Brown 1989)

We have now described *one particular* point of view on the function of tutorial dialogues. Within this framework we therefore argue that the functions of negotiation in tutorial dialogues are essentially twofold : firstly, to maintain cooperation and a flexible degree of joint control over the interaction, and secondly, to permit *knowledge negotiation*. Since negotiation of knowledge depends on the freedom to do so, the first may be viewed as a precondition for the second. Knowledge negotiation in the context of tutorial interactions presupposes the willingness and freedom to arrive at *mutually agreed belief* on what counts as knowledge in a given domain.

We can now pass to the question of what we mean by "negotiation", the answer to which we propose clearly relates to our point of view on its function. As well as the function of negotiation, we need to consider the terms within which our definition is stated - linguistic, cognitivist, or other. Essentially, we claim that *negotiation is a sequence of dialogue exchanges whose function is that of securing cooperation with respect to some set of propositions*. The definition is stated in both dialogue and mentalistic terms :

Negotiation (definition)

"Negotiation" is the term for a sequence of dialogue exchanges between agents capable of generating and understanding them, during which the mental states of interlocutors are transformed from the propositional postures of indifference (absence of cooperation or conflict) or of conflict with respect to one or more propositions, to one of cooperation with respect to one or more propositions, and where one or more agent possesses the goal that this posture should be achieved.

Negotiation is therefore defined in terms of sequences of dialogue exchanges and changes in complex mental states of negotiating agents. Galliers (1989) has produced a number of definitions for the complex propositional postures of COOPERATION, CONFLICT and INDIFFERENCE, in terms of the logic of intention of Cohen & Levesque (1990). It is of course possible that negotiation takes place in which neither speaker has the goal that cooperation be achieved - such as "arguing for the sake of it". We therefore make a minimal assumption of cooperativity. As a first approximation, propositions include reference to states of affairs and the attitudes of speakers towards them - such as that they want or believe a given state of affairs. States of affairs may themselves be complex attitudes. In the domain which we consider, propositions concerning the domain (and concerning the attitudes of other agents), are modelled as *justified beliefs*. Our view of what beliefs are is intimately linked to the idea of negotiation : beliefs are dispositions towards generating dialogue actions whose content is negotiable in the sense that it is not assumed to communicate "certain" knowledge. In this chapter we restrict our discussion to negotiation of one specific kind of proposition : *negotiation of dialogue goals*. We need to say what is meant by "dialogue goals" rather than other kinds of goals. A dialogue goal is here defined in terms of three kinds of *parameters* : (1) an utterance type, (2) the conceptual content of the utterance , (3) dialogue roles. This corresponds loosely to an utterance analysed by speech act category with propositional content, and definition of speaker roles. Within speaker roles, the speaker who initiates the negotiation is distinguished from the speaker who will perform the cooperatively agreed goal. For example, in the situation

where "the teacher asks the student to give an answer to a question about PROLOG variables in a predicate PR1", this is represented as follows :

negotiator = teacher
speaker = student
concept = PROLOG(variables)
instance = PR1
utterance type = INFORM.

That is to say, "the teacher negotiates that the student should make an INFORM utterance about the concept 'variables', instance 'PR1'. This is not to say that negotiation of *beliefs* is not important - we have analysed this in the context of cooperative explanation generation in Baker (1991) - but rather that negotiation of this type of goal does occur in tutorial dialogues, and thus needs to be modelled. In a later section of the chapter the role of such a representation in a more general dialogue model is discussed in more detail. In the next section we compare this way of posing the problem of negotiation with other definitions derived from existing work, most of which associate negotiation exclusively with the incidence and resolution of *conflict*.

Finally, we claimed earlier that existing models for dialogue in intelligent tutoring systems have not included functionalities for negotiation. This is not surprising since, given that negotiation is a phenomenon which occurs in *dialogue*, little previous work has included a model of dialogue *per se*. "Dialogue" may be defined initially by comparison with "discourse" and "conversation". Discourse is written or spoken communication, with no interaction with the hearer(s). It may be more or less adapted to the discourse generator's knowledge of the hearer(s) knowledge, and more or less coherent. A conversation is a sequence of exchanges, each of which may be a discourse, between two or more agents, generally occurring in everyday life with no fixed topic or goals. A dialogue is a conversation in a specific setting, with specific goals or objectives. For example, consider the dialogues of Plato, or film dialogues, or again, a tutorial dialogue, occurring in an educational setting, with the objectives that the student learns something within a specific domain. Dialogues may be more or less 'rich' in dialogic characteristics. Consider the case where the student only responds "yes" or "no" to a teacher's utterances. If these are the only possibilities *available* to the student, then this is not a dialogue. If, however, the student *could* interact otherwise (but in fact did not) - proposing his own point of view, etc. - then this is simply an impoverished dialogue. We therefore need to introduce the idea of "symmetrical interactional possibilities" into the definition of dialogue. In terms of this discussion, the early work of Carbonell (1970), and Collins & Stevens (1983) concerned tutorial discourse - the student had the possibility to respond "yes" or "no", or to ask certain questions, but the system had greater interactional possibilities. In Elsom-Cook's earlier (1984) work, a model for extended discourse was developed which included many of the aspects (focus model, goal and topical elements, dialogue moves) to be included in a model for symmetrical dialogue, in later work (Elsom-Cook 1990). The work of Brown & Burton (1982) and of Clancey (1987) was conceived as providing "coaching rules" and "dialogue rules", respectively. This research resulted in the generation of non-continuous discourse, within the context of computer-based learning environments, and did not attempt to incorporate models for phenomena described in human dialogues (coherence, relevance, focussing, etc.). More recently, the work of Petrie-Brown (1989) and of Blandford (1990, and see this volume) has provided some of the theoretical and formal underpinnings of tutorial dialogue models, which could contribute to models for negotiation, but which do not explicitly address this issue.

In our own research (Baker 1989c) we have developed a computational model for sustaining tutorial dialogues, which aimed to incorporate some aspects of negotiation observed in human dialogues. The model is called "KANT" - "Kritical Argument Negotiated Tutoring system". After describing the model, we describe an agenda for future work by comparing its performance with the structure of negotiation phases analysed in a set of computer-mediated teaching dialogues.

We focus our analysis on the following questions which may be asked in connection with negotiation :

- Q1: What is negotiated in tutorial dialogue ?
 Q2: When does negotiation occur, and why ?
 Q3: What interaction structures occur in negotiation ?
 Q4: When negotiation occurs, why does it occur explicitly or implicitly ?
 Q5: When and why is negotiation successful ?

KANT incorporated specific preliminary responses to some of these questions as follows :

- Q1: Speaker and negotiator roles, utterance types and associated conceptual content are negotiated, as described above.
 Q2: Negotiation occurs at the beginning of the dialogue when there are no cooperatively agreed goals, by speaker_2 when a goal negotiated by speaker_1 is rejected, or when speaker_1 has completed a negotiated dialogue action.
 Q3: Negotiation proceeds hierarchically, from general to specific utterance goals, and with increasing concreteness with respect to speaker and topic parameters.
 Q4: In KANT, all negotiation is explicit - no goals are assumed agreed, and hence subgoals are negotiated explicitly.
 Q5: Negotiation succeeds when the composite goal negotiated is viewed as *relevant* by a speaker, otherwise not. Determining relevance involves evaluating a complex set of *preconditions* with respect to a *dialogue state*.

As we describe later, not all of these hypotheses are borne out by dialogue analysis, and they are all a very partial view of what happens in negotiation.

2. Existing work on negotiation

Most existing work on modelling negotiation has been carried out within the framework of "Distributed Artificial Intelligence" ("DAI") research (Bond & Gasser 1988). Here the problem addressed is usually that of *resolving conflicts* in resource allocation and in bids for problem solving subtasks between distributed agents. For example, Adler, Alvah, Weihmayer & Worrest (1988) define negotiation as "... a process of exchange of conflict information and tentative commitments of resources to plans" which is done through the exchange of problem-solving plans (p. 141). Conflict which gives rise to negotiation is itself viewed as being caused by *resource limitations* : "Generally speaking, resources needed to solve a problem are the physical sources of conflict : there aren't enough or they are in the wrong place or they aren't the right kind" (*op. cit.* p. 146). If we count knowledge of how to solve a problem as a "resource", then this way of defining negotiation may be applicable to some tutorial dialogues, given the assumption that the teacher does not possess complete and infallible information or "knowledge". However, in the tutorial dialogues we consider here, conflicts may also occur concerning the problem to be solved - the learning goal - itself, rather than with respect to the information resources required to achieve it. Adler *et al* (*op cit*) also propose a useful classification of negotiation styles along three axes :

- (1) the degree to which goals are expanded before negotiation begins ;
- (2) the complexity of information exchanged and of models agents build of others ;
- (3) the degree of control the agent has over the negotiation process.

In terms of these axes, KANT begins with high-level dialogue goals which are successively expanded, the dialogue participants exchange information about their beliefs and justifications, including those about the other's stated beliefs, and each has the same degree of control over a fixed negotiation procedure.

The work of Sycara (1988, 1989) is also concerned with negotiation from conflict, in the specific case of *goals* of participants in labour disputes. Due to the relevance of this work for negotiation in tutorial dialogues, it merits discussion in some detail. Previous DAI work on negotiation had considered the case of single negotiations ; thus an important part of Sycara's work was on defining more extended negotiation sequences, leading to a *compromise* which

satisfies all (both) parties. Compromises are found by searching a database of previous cases and the associated compromises reached, in order to find a *successful* one which is most *similar* to the present case - Schank's (1982) method of "case-based reasoning". This involves using "... a set of salient features of the domain (e.g. industry, geographical location) as memory probes." (p. 247). An "evaluation function" is used to select the "best" case, which is then adjusted to fit the present conflict situation. A final check on the suitability of the case is then performed by selecting its features, and searching memory to check whether there are cases with these characteristics which previously *failed*, in accordance with Schank's (1982) "intentional reminding" theory. Once found by a "mediator" program, compromises are presented to each participating agent. If they agree, then the program reports success, otherwise the PERSUADER program attempts to *convince* agents by generating *arguments*. "Convincing someone can be modeled as increasing the payoff that the compromise gives him" (p. 248). An agent's payoff is represented as a linear combination of coefficients for the *importance* an agent attaches to an issue, and its *utility value*. The PERSUADER attempts to generate statements which would change these parameters for an agent towards those associated with the compromise solution. For example, an increase in wages represents an increase in company labour cost. The argument addressed to a union that has refused a proposed wage increase "IF the company is forced to grant higher wage increases, then it will decrease employment" is meant to decrease the importance the union attaches to wage increases by pointing out unpleasant consequences for the union of forcing a wage increase, not wanted by the company. The PERSUADER's strategy for repair is "explanation based" where the reason for rejection is supplied by the rejecting agent. The method used is again to search for cases where there was a similar "impasse", and use its associated *repair method*.

Some aspects of Sycara's work are clearly relevant to negotiation in tutorial dialogues, although there are many dialogue features which need to be modelled with which her work is not concerned. As will be described in the next section, there are some kinds of negotiation in tutorial dialogues which involve arguments where one speaker attempts to convince the other to accept a learning goal. This is done however, by appealing to their abilities rather than interests. It is not clear to what extent speakers have memories for success and failure of past cases of negotiation in a dialogue, although they may have a more general conception of what kinds of negotiated goals are likely to be acceptable to another or not. In terms of dialogue modelling, it is important to note that Sycara does not consider the structure of turn-taking in negotiation, nor its relationship with focus constraints, since negotiation is managed by a third party (the "mediator"). Finally, our analyses show that the incidence of negotiation in tutorial dialogues is not restricted to *conflict* situations, this being the case in Sycara's work.

There is presently relatively little work within Intelligent Tutoring Systems research which deals with negotiation in dialogue. One example is the work of McCalla & Brecht (this volume). Within the SCENT project, they presently consider the problem of negotiating the *domain content* of tutorial interactions rather than their delivery style. From analyses of Lisp teaching dialogues, they identify different kinds of goals which may be negotiated (content, delivery, cognitive, affective, deep and shallow). They also make the important point that "... negotiated tutoring does not imply that everything is always up for negotiation.", and stress the importance of the student understanding the motivation for negotiated instructional goals.

In summary, existing work on negotiation has almost exclusively been concerned with negotiation from goal conflicts in distributed problem-solving. A number of mechanisms for resolving conflicts and managing the ensuing negotiation have been described which may be applicable in some kinds of tutorial dialogues, notably those concerned with problem solving domains. However, the questions which we pose here are somewhat wider : we want to establish the range of things which are and which should be negotiable in tutorial dialogues, to describe attendant dialogue structures, and to relate these to fundamental aspects of protracted dialogues. We describe the role of a number of these features by analysing negotiation phases from human-human computer-mediated teaching dialogues in the next section.

3. Negotiation examples and analyses

For purposes of illustration, here are two examples of negotiation taken from computer-mediated tutorial dialogues in the domain of teaching PROLOG. These dialogues will be used as examples throughout this chapter. We use the following notation :

T = teacher

L = learner

<<...{comment}>> = omitted section from dialogue

The following are communication clichés developed by T and S themselves :

? = asynchronous interrupt

!...! = I am thinking

The dialogues were collected over a period of two years, and were conducted via electronic mail at a distance of over 200 miles. The teacher was a university lecturer in artificial intelligence, and the learner a masters student in the same subject. We shall discuss short extracts from a single dialogue, in terms of our research questions stated above. In the first, the two speakers attempt to achieve cooperation from a position where there were no explicitly agreed goals. In the second, conflict occurs, and is resolved (or 'removed') essentially by *persuasion*.

Negotiation Example 1

T1: I would greatly enjoy doing some prolog. Did you have something in mind?

L2: No, not really. Like I said I haven't really looked at your program with the idea of extending it yet. Could we do something simplish, just to make me feel good?!

T3: Certainly. You have a choice of something simple and interactive now, or something fairly simple with an interactive session later on today.

L4: Um. I'd like to do something now, cos I really should do the vp stuff later on ... is that ok?

T5: Fine. Ummm... How about writing a predicate called second_word, which takes as its argument a string, and instantiates its second argument to be the ATOM corresponding to the second word of that string eg

second_word("fish and chips",M).

M=and

yes. How does that seem?

L6: Ok I think. um can you do something else in another window while I think about it?

T7: Certainly ...

<<continues>>

To clarify our discussion, we use the following predicates to analyse negotiation structure and content, which relate to primitives of our model :

negotiates(n s p) - "n negotiates proposition p to be pursued or stated by speaker s"

responds(s r p) - "speaker s responds r <n=negative,a=affirmative> to proposition p".

_ - variable

<> - proposition value

U1 Un - utterance names

&,OR - logical connectives

Aspects of the dialogues which are not negotiations - 'dialogue actions' - will be left in the analysis.

A general analysis of example 1 is therefore :

T1: U1(negotiates(T _ prolog)).

U2(negotiates(T L negotiates(L _ prolog))

L2: U3(responds(L n U2)).

U4(negotiates(L _ <something simple>))

T3: U5(responds(T a U4))

U6(negotiates(T L <<simple & interactive & now> OR <fairly simple & interactive & later>>))

L4: U7(responds(L a U6))

U8(negotiates(L L <<U6<simple & interactive & now>> & <vp & later>>))

T5: U9(responds(T a U8))

U10(negotiates(T L <problem to solve - predicate,argument,string,atom>))

L6: U11(responds(L a U10))

U12(negotiates(L T <do something else to allow L to think>))

T7: U13(responds(T a U12).

We now attempt to respond to our five general questions with respect to this extract.

Q1: What is negotiated in tutorial dialogue ?

A wide range of phenomena are negotiated, all of which are negotiated *goals* for one or both speakers, rather than *beliefs*. These include :

- ° proposed topics for future problems to work on (prolog, strings, arguments)
- ° specific problems to work on ("write a predicate called second_word")
- ° interaction style of problem-solving (interactive)
- ° future planning of joint problem-solving goals (now, later)
- ° level of difficulty of problems (simple, fairly simple)
- ° that the other speaker should negotiate a goal for a given topic (U2)
- ° 'time to think' (U12)

Q2: When does negotiation occur, and why ?

It is clear that negotiation occurs here because it is the beginning of the dialogue, and no joint goals have been decided, rather than because of *conflict*. In Gallier's (1989) terms, this is negotiation from a posture of INDIFFERENCE to one of COOPERATION, where "indifference" here is understood as lack of a common goal. What is important to note, is that the negotiation moves from non-specificity to specificity in terms of the values of negotiator, speaker and topic parameters.

Q3: What interaction structures occur in negotiation ?

Interaction structures are of the socially expected form, according to the Schegloff and Sacks (1973) turn-taking rules :

speaker1:	negotiation
speaker2: response,	negotiation
speaker1: response

The fact that this exists shows a high level of social cooperation. In terms of topic and speaker role parameters, the negotiation begins with the general topic of "prolog", and ends with a specific problem to work on. The general topic is discussed before that of the speaker role - that the student should solve the problem for the teacher to criticise.

Q4: When negotiation occurs, why does it occur explicitly or implicitly ?

Negotiation is all more or less explicit here - presumably because in a situation where the general goal is clearly understood to be achievement of cooperativity in defining a problem-solving goal, neither speaker needs indirect speech in order to interrupt that process, or negotiate a goal which may be not accepted by the other. These matters may be more clear in examining cases where goals were negotiated implicitly.

Q5: What makes negotiation succeed or fail ?

In this extract all negotiated goals succeed except for U3, where the learner says that she does not have a specific problem to suggest to be worked on. This is understandable given that it is the very beginning of the dialogue, and the teacher will not yet have been able to model the learner's goals and beliefs adequately in order to propose only goals which have a likelihood of receiving an affirmative response. In all other cases, negotiated goals are approached by successive levels of generality to specificity, which minimises the chances of conflict. Since no goals have yet been pursued, the learner is not yet sufficiently aware of her own problem-solving abilities in order to be able to definitely refuse a proposed goal (U10).

This relatively crude analysis does not capture all that we would want to say about this extract. For example :

- in L2, L's negative response is 'softened' by the words "not really", and she then goes on to explain or justify why this response was given - all strategies for maximising a generally cooperative posture.
- the phatic word "umm" is used even in these typewritten dialogues, to signal that the speaker is still attentive, but needs to think
- a number of responses to negotiations are not simply of the affirmative/negative kind, but communicate a *degree of confidence* on the part of the respondent (eg L6 " Ok I think, Umm...").

Negotiation Example 2

T31: ? Can I say something?

L32: yes

T33: That's quite a lot wrong, I'm afraid.

D'you want to tell me about it in English?

L34: Not really

T35: Ah. What do you want to do then?

L36: Stop?

T37: Oh. Really? I'd quite like to talk through this one, and it isn't exactly all that ego-boosting for your prolog morale so far is it?

L38: What prolog morale?

T39: Oh, come on. You can do it. <<continues>>

The general turn-taking structure is as follows.

T31: ? U1(negotiates(T T _)).

L32: U2(responds(L U1 a)

T33: U3<<That's quite a lot wrong, I'm afraid.>>

U4(negotiates(T L

<that L explains their problems and problem solving for previous utterance>))

L34: U5(responds(L n U4)

T35: U6(negotiates(T L negotiates(L _ _)))

L36: U7(negotiates(L _ <"Stop?" - terminate dialogue>))

T37: U8(negotiates(T _ <continue, U4))

U9<<It isn't exactly boosting for your prolog morale so far is it?>>

L38: U10<<What prolog morale?>>

T39: U11(negotiates(T L U4)

U12<<You can do it.>>

Q1: What is negotiated in tutorial dialogues ?

The principal propositions negotiated here are :

- ° that L explains and discusses her problem
- ° that L negotiates another goal (there are other cases where negotiations can be nested i.e. x negotiates that y negotiates that As with beliefs, there must be some psychological limit to nesting).
- ° that they stop the dialogue
- ° that they continue the dialogue (and that the original negotiation of T be accepted)

Q2: When does negotiation occur, and why ?

Negotiation occurs here because T believes that L is not achieving their goal that she solve the problem. This *conflict* of belief (about the correct problem solution) and goal (that the problem be solved by L), leads to *demotivation* on the part of the student, which T then attempts to redress by *persuasion*. The initial conflict thus leads to further conflict concerning whether the dialogue should be pursued or not.

Q3: What interaction structures occur in negotiation ?

The propositional posture of CONFLICT is marked by an interruption of the socially preferred turn-taking structure : L responds negatively, and exchanges of negotiation and opposed counter-negotiation follow one after the other. This illustrates the important point that turn-taking structures may provide analytical evidence for cooperation or conflict attitudes, as described earlier (see Roschelle & Behrend 1991, in press).

T31: interrupts
negotiates
L32: responds
T33: utterance
U4: negotiates
L34: responds
T35: negotiates
L36: negotiates
T37: negotiates

Q4: When negotiation occurs, why does it occur explicitly or implicitly ?

All negotiation is explicit here, but nevertheless the first interruption/negotiation is 'softened' - i.e. has an increased likelihood of being accepted - by being non-specific - "Can I say *something*". The situation of conflict is heightened by the exchange structure and the explicitness of the opposed negotiations.

Q5: What makes negotiation succeed or fail ?

The teacher's initial negotiation succeeds in virtue of its non-specificity - less likely to directly conflict goals or beliefs - and its placement in the dialogue almost at the end of the student's (erroneous) problem-solving. We can imagine that an interruption in the middle of this process, and with greater specificity, would be less likely to be successful. The subsequent negotiations fail because the student is not *motivated* to pursue the proposed goals (see the analysis in Elsom-Cook 1990). Subsequently in the dialogue, the CONFLICT situation is removed by the teacher, who succeeds in motivating the student sufficiently that she is *persuaded* to choose a simpler subproblem to work on.

We have analysed a number of other negotiations in this corpus of dialogues. The general conclusions we would make, relevant to criticising the model to be described later, are summarised as follows.

Q1 What is negotiated in tutorial dialogues ?

1 problem solving goals and subgoals

- negotiated from generality towards specificity and with increasing concreteness, thus minimising possibility of direct conflict.
- acceptance of a goal implies a presumption of acceptance of subgoals unless there are contrary indications
- conflict on a subgoal leads to negotiation of alternative subgoals before new goals.

2 dialogue goals

- stopping/continuing the dialogue, bringing the dialogue to an agreed *closing*.

3 timing/planning of joint interaction goals

4 interaction style

5 level of difficulty of problems

6 speaker and negotiator roles

7 motivation

- negotiating the speaker's perception of their own ability in problem-solving, i.e. their *metacognitive awareness* of their problem-solving ability.

It is clear that there are no *a priori* limits to what can be negotiated, and that this may greatly depend on the domain and other variables. We would hope that future research could identify general *empirical* limits. The kinds of features which may be negotiated may well include most aspects of control and metacognitive control of problem-solving, planning at the cognitive level, and interaction style, speakers, negotiators, topics, etc. at the dialogue level.

Q2 When and why does negotiation occur ?

From the dialogues which we have analysed, negotiation occurs under the following circumstances :

INDIFFERENCE - no goals are currently agreed, because

- it is the start of the dialogue,
- a previously agreed subgoal has been achieved

CONFLICT

goals or beliefs are communicated which are understood to be in conflict

because

- a previously agreed subgoal is perceived to have failed or be in the likely process of failing (by either speaker)
- a speaker no longer desires to pursue a previously agreed goal (often because of lack of motivation)

PERCEPTION AND UNDERSTANDING

actions or stated beliefs are not *understood* by either participant to be in accordance with the previously agreed goal

3 What interaction structures occur in negotiation ?

The propositional postures of COOPERATION and INDIFFERENCE are marked by socially preferred and expected turn-taking structures (Schegloff & Sacks 1973) - generally, speakers respond to previous negotiations, then re-negotiate and are responded to, with few interruptions. CONFLICT is almost always marked by a suspension of these expected structures - negotiations may follow unrelated previous negotiations, which are sometimes but not always responded to. In our analysis we have not been concerned to identify specific utterance types. This was because we prefer to analyse the general exchange structure together with higher-level goal and belief structures. Nevertheless, the types of adjacency pairs (Schegloff & Sacks 1973) which occur are reasonably small in number :

question/answer

offer/acceptance/rejection

utterance/acknowledgement

elicitation/response

request/response

statement(belief,goal)

explanation

justification

4 When and why does negotiation occur explicitly or implicitly ?

Negotiation occurs implicitly, or 'indirectly' when *speakers believe that the goal or belief they are negotiating may lead to conflict*. Speakers may communicate their own metacognitive beliefs as a means of implicit negotiation, thus inviting help or comment from the other speaker (usually the teacher in this case). A provisional answer as to when this may be the case is therefore as follows :

goals may be negotiated implicitly when

either

the execution of an action to achieve a jointly agreed goal is interrupted by either speaker

or

the interrupting speaker believes that their utterance may conflict with a jointly agreed specific goal (eg "solve problem p1") or general goal (eg "that the student be motivated", "that the student learn")

or

the interrupted goal was previously agreed 'with difficulty' from a marked conflict, and may hence be highly probable to lead to further conflict

or ...

We would need to look extensively at other examples in order to verify and complete this analysis. A different but important phenomenon concerns the *level of specificity* of an explicit negotiation, which may be made deliberately tentative and general so as to minimise the possibility of conflict, where this is thought to be likely.

5 What makes negotiation succeed or fail ?

Speakers attempt (unconsciously) to ensure that their negotiations succeed by a variety of strategies designed to promote acceptance and minimise the chances of conflict, as follows :

avoidance of conflict, relating to the timing and level of specificity of the negotiated goal, *a gradual general-specific negotiation* from a position of INDIFFERENCE,

or by

resolution of conflict, by proposing some other (sub)goal, or *persuasion* on the part of one speaker, often using *motivational means*.

The reason why negotiations fail depends on the nature of what is being negotiated. In the case of problem-solving goals, failure relates to the negotiation respondent's *metacognitive* assessment of their abilities to achieve the goal. In the case of failure to achieve a goal, the student may become strongly *demotivated*, and hence future similar negotiations may fail. This in turn may have effects on the success of negotiated dialogue goals, such as wanting to terminate the dialogue.

There are a number of features of negotiation phases observed in the dialogues which we are analysing which have not been discussed earlier. We summarise them as follows :

Justification/explanation

Speakers often justify or explain why they are negotiating a particular proposition at a given point in a dialogue. For example "Could we do something simplish, just to make me feel good?", or "Can you do something else in another window while I think about it?". They also often justify or explain in the case of negative responses: "No, not really. Like I said, I haven't looked at your program with the idea of extending it yet". Similarly, they sometimes ask for an explanation of the goal negotiated :

"T41: <...>

... why don't we take the case in which first_word instantiates its second arg to be a list of the ascii codes of the first word, then you don't need to much k about with "name".

o

L42: You mean I use "name" in defining first_word?

I don't seeeeee what you mean...."

Motivating moves

An important number of utterances in these dialogues are concerned with motivation - "Don't panic", "Oh come on, you can do it", "Super stuff", "It's VERY EASY". Formalising the recognition of motivational states is a difficult but important problem which needs to be addressed. The importance of motivation in these dialogues has been analysed by Elsom-Cook (1990).

We now describe the current state of our model for dialogue generation. In the final section of the chapter we describe some directions of further work towards incorporating some of these features into our model.

4. KANT: a model for high-level processes in tutorial interaction

The KANT (Kritical Argument Negotiated Tutoring) system (Baker 1989c) is a computational model for generation of structures associated with high-level tutorial interactions. A model of 'high-level' interaction (Kiss 1986 ; Elsom-Cook 1990) consists of the specification of a set of representations for mental states of interlocutors and the processes which operate upon them to generate a set of dialogue structures. These representations include beliefs (concerning a domain of discourse, the beliefs of some other interlocutor, the previous dialogue which has occurred), their goals, intentions, preferences, ... and representations of other mental states. By the 'structure' of dialogue, we mean the structure of "turn taking" (Schegloff & Sacks 1973), the content of each utterance unit, as defined in terms of a set of *dialogue goals*, parametrised for the speaker, negotiator and topic and a set of constraints on *sequences* of utterance units. We have adopted the research approach of attempting to specify such a model at a 'high' level, which does not extend to the level of sentences in natural language (the system uses "canned" text). There are two reasons for adopting this approach. The first is that since there are currently few existing models of dialogue *per se*, in comparison with discourse and text generation, a reasonable approach is to develop hypothetical models, which may then be adapted with respect to results of dialogue analyses and in combination with models for generation and understanding of natural language. The second is that in the context of computer-mediated dialogues in Intelligent Tutoring systems, we seek models which are sufficiently general to serve as the basis for *multimodal* dialogues, where 'utterances' may be performed in graphical as well as linguistic form (see Reichman 1986). Once high-level dialogue research has produced more complete models, it is clear that such an approach which assumes a clear separation between deciding what to say, and how it is said will have to be abandoned. The scope of our research is of course limited : it emphasises the definition of a framework which situates negotiation phases within a model which incorporates mechanisms for deciding which parametrised dialogue goal to negotiate, and how to negotiate it, in relation with a mechanism for controlling dialogue focus (Grosz & Sidner 1986). In terms of ITS research, we aimed to define a model where each interlocutor (computer and human student) was given as great a degree of symmetrical freedom to pursue their goals as possible, in accordance with the views expressed in the ITS literature by Elsom-Cook (1984) and by Petrie-Brown (1989).

4.1 Representing the 'dialogue state

The fundamental representations of mental states of a dialogue interlocutor used in KANT were based on the notion of a "dialogue state". This was first defined by Power (1979) as

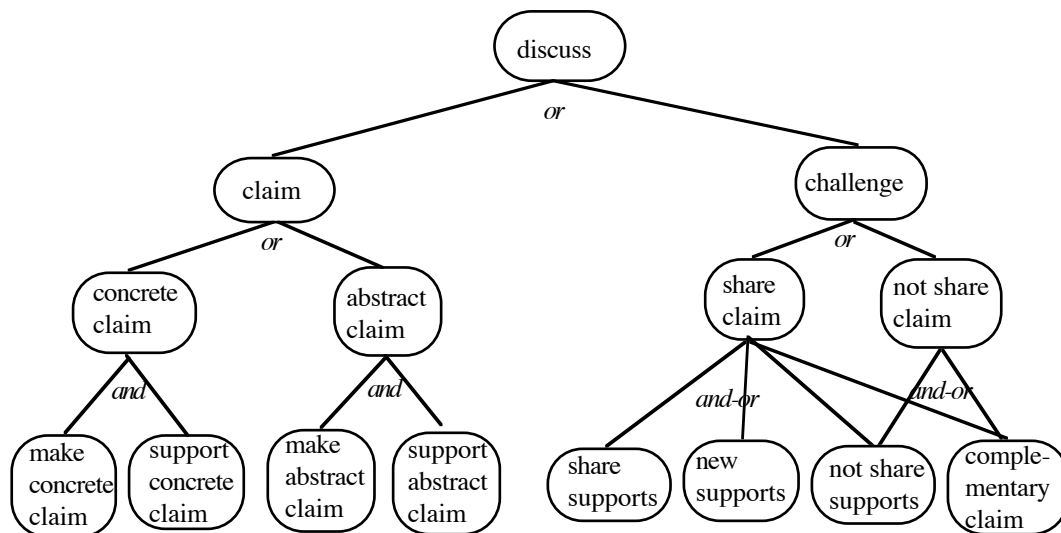
"... the situation which has arisen between two speakers as a result of their previous dialogue." (p. 131).

In human dialogues this 'pragmatic context' should include elements of the social situation, such as social roles and affective goals. In KANT we restrict this context to a memory of dialogue goals and parameters negotiated so far, and beliefs explicitly communicated in dialogue. A third component is the specific activation pattern resulting from dialogue in the interlocutors' working memory (to be discussed later), which controls focus of attention.

Dialogue goals

The dialogue goals represented in the system were specifically adapted to the knowledge domain which the dialogue model discussed, which were assumed to consist of *justified beliefs* rather than 'knowledge'. The original domain on which KANT was based was that of *analysis of musical phrase structures*, as will be seen in the example trace later in the chapter. Our previous research on developing cognitive models for understanding musical structures (Baker 1989a, 1989b) had shown that in this domain, human experts have incomplete and largely implicit justified beliefs concerning multiple possible structural analyses. In the system which we developed as a domain model for KANT, a frame-based parser derived multiple solutions for phrase boundary positions in tonal melodies, with associated musical features used in the recognition process. These were represented in the form of a set of justified beliefs concerning phrase boundaries, for use in KANT. Dialogue goals were therefore incorporated in KANT for stating and illustrating beliefs and their justifications, and for critiquing the beliefs and justifications which had already been stated in the dialogue (by either dialogue participant). These goals corresponded to those which had been described (Toulmin et al 1979 ; Reichman 1985) for *critical arguments* (see figure 1). Their representation formalism was based on existing research (Cohen & Perrault 1979; Levin & Moore 1977) in representing dialogue goals as planning operators, based on the general theory of language as rational action - "speech acts" - in the pursuit of goals (Searle 1969). The major differences in our representation are that extra kinds of preconditions were included for constraints on dialogue focus, the operators were parametrised (for speaker and negotiator roles) in order to be adapted to interactive dialogue, and they included preconditions relating to negotiation of those goals. More importantly, the major difference between our model and previous ones lies in the procedural role which the goal operators play in dialogue generation. Goals are represented *hierarchically*, which enables us to model the general-to-specific negotiation of dialogue goals, described in our previous analyses. This hierarchy is accompanied by successive *concretisation* in defining speaker and topic parameter values, on descending the goal tree. For example, the system may begin by negotiating that a particular concept be discussed, then that a claim be made about it, then that the student should make the claim, and so on.

Figure 1 : Hierarchy of dialogue goals in the KANT system



The and/or tree of goals is a fundamental representation in decision-making in KANT. It is searched top-down during the process of trying to find a relevant goal to be discussed. When the student has a 'negotiated turn', the same set of goals is available, with the exception of making an 'abstract claim', or general explanation. This goal is excluded in view of our concentration on high-level decision making mechanisms : since the system does not generate utterances down to the sentence level, neither can it analyse the meaning of sentences input by

the student. At the highest level of the goal tree, a fundamental distinction is made between disjunctive 'claim' and 'challenge' goals. This corresponds generally to a distinction between stating something 'new' in the dialogue, related to the previous dialogue by local focus constraints, and a direct reference to a previously stated goal in the dialogue (eg critiquing a previous directly referred to claim).

Each dialogue goal has parameters for the current negotiator, speaker, concept and instance discussed (n,s,c,i), which are successively bound to specific values as the negotiation proceeds. The dialogue state preconditions consist of a logical expression into which current parameter values are substituted, and are evaluated with respect to the dialogue state. Negotiation preconditions state what needs to be negotiated and accepted for the dialogue actions associated to be performed. In this case there are no actions, since these are only attached to terminal nodes (see figure 2). The operator lists its subgoals, and the effects of successful negotiation and performance of the dialogue action are propagated on the dialogue state by the "negotiation_effects". These update the dialogue history with the instantiated negotiated goal, encode a representation of the beliefs expressed in the action for each interlocutor and propagate activation through the belief network (according to the equations described in Anderson 1983).

Dialogue state preconditions refer to the dialogue history and the mental states of interlocutors. For example, a claim move is relevant if it is the beginning of the dialogue, the speaker has a memory representation for the concept to be communicated, and believes that the other interlocutor does not "know" that concept. We have not addressed the philosophical and psychological problems associated with the distinction between knowledge and belief, nor concerning their acquisition. We simply assume that memory traces will be encoded in dialogue for concepts which are mentioned, which correspond to 'belief' in the way in which they are used in dialogue : beliefs are intensional objects which when communicated in dialogue, have to be justified, whose justifications can be critiqued, and which can not serve as the basis of straightforward contradiction of a previously stated belief.

Figure 2 : Example dialogue move "CLAIM"

```

dialogue move: CLAIM
parameters: (c inst n s)
dialogue_state_preconditions:
  ( (not (null c)) &
    ((null *dialogue_history*)
     OR
     ((in_focus? c (ltm_model s)) &
      (not (known? c (ltm_model (dialogue_participant s)))) &
      (exists_ltm_trace? c (ltm_model s))))))
negotiation_preconditions:
  ((negotiate s (goal= 'CLAIM)) & (negotiate s c)))
subgoals:
  (OR ((concrete_claim (c inst s))
       (abstract_claim (c inst s))))
negotiation_effects:
  ((update_dialogue_history
    '(((goal_name= 'CLAIM) (s= s) (c= c) (inst= inst))))))
action_effects: nil
actions: nil

```

Speakers' beliefs

The beliefs of each participant are represented as instances of concepts in a semantic network (Quillian 1969). Our model for memory encoding and retrieval during the course of dialogue is

based on the ACT* model of Anderson (1983). We assume that if a concept is mentioned then both interlocutors encode a working memory trace for it, which has a probability of forming a long-term memory representation with repetition. Retrieval from long-term memory is based on the phenomenon of *spreading activation* in semantic memory, from an input source. We have applied this feature of Anderson's theory to the definition of focus in dialogue (shown by the "in_focus?" predicate in the example above). From the point of view of the system, when it attempts to satisfy *relevance* (Sperber & Wilson 1986) dialogue state preconditions for a dialogue move, it checks the current concept value with respect to its own working memory, being the traces with the highest activation level : if the concept is in working memory, then it is viewed as sufficiently in focus to satisfy this precondition, otherwise not. If no concept is proposed, then it selects the concept with the highest activation level, in order to find a parameter value which enables this precondition to be satisfied. When it is the student's turn to negotiate a dialogue goal, the system bases part of its decision as to whether to cooperate or not on checking its own representation of the activation level of that concept, thus judging its relative focus.

We have now discussed the basic data representations which need to be understood in order to describe the fundamental dialogue generation mechanisms of KANT.

4.2 Managing turn-taking in negotiation

At the highest level, a 'dialogue controller' program controls the alternation of negotiated turns between system and student. These do not necessarily correspond to speaker turns, since an interlocutor may negotiate that a dialogue goal be pursued by the other. Our model can accommodate this by specifying dialogue moves and their associated parameterised preconditions in a sufficiently general way so that a dialogue goal may be used with any combination of speaker and other parameter values (for example, $n = \text{system/s} = \text{system}$, $n = \text{student/s} = \text{system}$, for a claim goal). The dialogue controller incorporates a simplified version of the turn-taking mechanism described by Schegloff & Sacks (1973) :

- "1. at least and no more than one party speaks at a time in a single conversation; and
 - 2. speaker change recurs."
- (Schegloff & Sacks 1973, p.293).

The turn-taking mechanisms in KANT are simpler than those which have been described for natural human conversations. They may be summarised as follows:

- 1 speaker1 negotiates a goal ;
- 2 speaker2 responds with agreement or disagreement ;
- 3 if speaker2 agrees, then speaker1 performs dialogue actions associated with the agreed goal ;
- 4 when a dialogue action associated with a goal is performed by speaker1, speaker1 may self-select, and attempt to negotiate subgoals of the first goal (step 1). These may succeed, in which case associated dialogue actions are performed, or they may fail, in which case the negotiator role changes.
- 5 depending on the degree to which speaker1 believes that speaker2 understands the subgoal to be negotiated, speaker1 may pursue a subgoal, generate a preannouncement, or negotiate it as in step 1.
- Upon assent to a preannouncement, dialogue actions of subgoals are performed.
- 6 if the speaker disagrees, then the negotiator role changes, and the disagreeing speaker takes a negotiated turn (goto step 1).

In step 4 above, we can see that the mechanism is in fact recursive - step 4 invokes step 1. We shall see this mechanism in operation when we present an example dialogue generation trace produced by KANT, in section 4.7 of this chapter. The simple turn-taking and negotiation mechanism described is one of the assumptions of our model which we shall consider with respect to negotiation phases which are analysed in section 5.

4.3 Factors determining which dialogue move to negotiate

We now turn to the mechanisms which speakers use to decide which goal to attempt to negotiate, and how they decide whether to cooperate or not with a negotiated goal. The following are factors which are used in determining which goal to negotiate :

- 1 the structure of the and/or decision tree of dialogue moves, which defines mutually exclusive alternatives, and conjunctive possibilities ;
- 2 satisfaction of dialogue state preconditions for the relevance of a dialogue move, with respect to the dialogue state ;
- 3 choice of alternative mutually relevant dialogue moves according to a set of educational preferences.

When either speaker converses, the dialogue move tree is searched in order to find a set of goals in the tree whose dialogue state preconditions are satisfied, and the negotiation of which is accepted. For each goal encountered, existing parameter values are substituted into the dialogue state preconditions expression, which is evaluated with respect to the dialogue state (factor 2). If it returns "true", the goal is satisfied and can be negotiated, otherwise not. If alternative goals are both satisfied, then the set of educational preferences is applied in order to choose one (factor 3). Upon success, any attached dialogue actions are performed, and search continues below that goal. If none are satisfied, then the speaker 'can think of nothing [relevant, preferred] to say', and the other speaker is now the negotiator. The number of educational preferences required is related to the number of points where a choice may be made , i.e. the number of disjunctive branches. In the present goal tree, there are only two : discriminating between claim and challenge goals, and between abstract and concrete claims (other preferences are required for preferred parameter instantiations of these goals, as discussed later).

It is often the case that in evaluating a particular dialogue state precondition expression, parameter values are not already assigned. For this reason, the system may attempt to satisfy preconditions by *actively searching* for some appropriate value. Thus the evaluation process involves procedures which search for certain parameter values as well as interpreting the expression. For example, in the following precondition expression, the system may have to choose a value for s (speaker) and c (concept) :

```
((in_focus? c (ltm_model s)) &  
  ;; is the concept c in focus with respect to memory model for speaker s ?  
  (not (known? c (ltm_model (dialogue_participant s)))))  
  ;; is the concept c known with respect to memory model of other speaker ?
```

This is done using a complex set of functions which choose the concept most in focus (activation level in working memory), and which prefer to select a concept which is "not known" to the hearer (discussed later).

4.4 Educational preferences for discriminating dialogue goals

The preferences used are as follows :

Pref 1: "Prefer to challenge an existing claim if relevant to do so, rather than making a new claim" (claim and challenge goals).

Pref 2: "Prefer to make a concrete claim, if relevant to do so, rather than making an abstract claim" (concrete_claim and abstract_claim goals).

Pref 1 relates to the stable 'initiate-response-feedback' pattern observed by Sinclair & Coulthard (1975) in classroom educational dialogues: in effect it prefers to give feedback to a response rather than stating something new, thus making more connected dialogue. Pref 2 corresponds to concretisation of a discussion, before discussing a concept in the abstract.

For determining a preferred speaker parameter value for a dialogue goal, a second kind of educational preference is used :

Pref 3: "Prefer the student to be the speaker when the system is the negotiator"
(choosing preferred s parameter value).

This is derived from the empirical analyses of classroom dialogues of Bellack et al (1966), who found that the majority of teachers' 'moves' were elicitation, i.e. the teacher negotiating that the student should respond. If the precondition expression cannot be satisfied with the (preferred) student as speaker, then the system attempts to satisfy it with the system as speaker. In summary, for each predicate referred to in the dialogue state preconditions, there are both :

- 1 procedures which test its truth value under a given substitution with respect to the dialogue state;
- 2 a set of procedures which search the dialogue state for parameter values (for goal, concept, speaker, instance) under which the expression would evaluate to be true.

4.5 Performing dialogue actions

Once a dialogue goal has been satisfied as relevant, discriminated according to preferences, and negotiated as accepted, dialogue actions (if any) may be performed, and effects propagated on the dialogue state. Since we concentrated on describing a model for high-level decision processes in dialogue, the performance of dialogue actions in KANT involves generating a text template corresponding to communicating the concept and instance parameter values which have been satisfied as relevant and communicated for a goal, for a given speaker. In the case where the student is speaker, the system generates a summary of this, and asks the student to agree that this represents their negotiated goal. For each dialogue goal, the function 'INFORM' has the appropriate parameters which were negotiated. In addition, each concept node in the semantic network may have some explanatory text associated with it. For example, in performing the dialogue goal ((INFORM s c)) as part of an abstract claim, the system says

"The following is an explanation of concept <<c>>: <<explanatory text generated>>".

In the case of a concrete claim, there will also be an instance parameter value, leading to :

"I am claiming that <<i>> is an instance of concept <<c>>".

In the case of challenge subgoals, a repetition of the name of the goal which has been negotiated plays an important part in communication. For example, in the 'new_supports' subgoal, this corresponds to stating one or more justifications which the speaker also believes to apply to a previously stated instance. Therefore, the system generates a summary of what the goal is. For example :

"goal: new_supports = state a new justification for a previous claim about a concept",

communicates the sense of the 'standard' statement generated as for a concrete claim,

"I am claiming that <<i>> is an justification of concept <<c>>".

and the fact that this claim is viewed as a new *support* to the previous one. Restating the goal definition thus corresponds to explicitly stating the dialogic or argumentative *relation* between dialogue goals (Ferrara 1985). In describing the negotiated turn-taking mechanism earlier, we stated that after a dialogue goal has been uttered, the speaker may self-select, and, under certain conditions, either state or negotiate subgoals of that goal. In accordance with the model of dialogue focus based on spreading activation incorporated in KANT, subgoals are explored in order of highest activation level. This also involves a recursive invocation of the turn-taking mechanism ("dialogue controller"), an algorithm for choosing the order of pursuit of subgoals, the generation of special metadialogue sequences called *preannouncements*, and tests for their

applicability. Preannouncements (Levinson 1983) are sequences where speakers announce the general topic of what they are going to say before doing so, in circumstances where they are not sure of its 'newsworthiness'. For example, before someone says "England won against Mozambique at football last night", they may try to ensure that what they are going to say is not already known by saying "... about the match on TV last night ...", or "Did you see the match last night?", thus allowing the hearer to say "No, go on ...", or alternatively "Yes, England won didn't they??" . Since these sequences relate to the beliefs of one speaker about those of the other, we incorporate this feature using a the predicate "known?", which is defined in terms of (theoretically uninteresting) values of the strength of a memory trace (*re* concept node in the semantic network), as follows :

- if a concept is "known" then the system does not pursue it as a subgoal and mentions this
- if a concept is "possibly known" then the system generates a preannouncement of the form "I now want to go on and discuss the subconcept <<c1>>; is that ok?"
- if a concept is "not known", then the system negotiates it as a subgoal.

When the student is the speaker, exactly the same dialogue generation mechanisms are used. The principal difference lies in the input and output to the program. In the case of the student as speaker, the system generates summaries of the responses (yes and no) to negotiation, of the beliefs and instances chosen, and presents the set of dialogue moves available at a given point in the goal tree for the student to choose.

4.6 Acceptance and refusal in negotiation

We finally need to say how a negotiator decides whether to accept a negotiated goal or not. The mechanism which we have adopted in the present version of KANT bases this decision on the same relevance preconditions which an interlocutor uses to decide which dialogue goal to pursue, i.e.

an interlocutor *i1* agrees to accept a negotiated dialogue goal if and only if the dialogue state precondition expression for that goal evaluates as satisfied with respect to the interlocutor's representation of the dialogue state when substituted with the negotiated parameter values and *i1* as speaker.

In this sense, the speaker asks himself if, from his own point of view, the dialogue goal negotiated by the other is *minimally* relevant. Note that the restriction is not so strong as to demand that the goal be also *preferred*. Clearly, this is a considerable simplification, resulting from the fact that the dialogue system does not incorporate a notion of longer-term and higher-level goals. Our negotiation mechanism is also considerably simplified in that it could easily be modified to include further exchanges where the respondent does not accept a goal with some parameters, but then attempts to find values under which it would accept, which are then proposed in turn as a 'compromise' (see Sycara 1988, 1989). We did not incorporate such further sophistications into KANT at this stage, preferring to reserve them for a phase of evaluating the model with respect to dialogue transcripts.

4.7 Example dialogue trace generated by KANT

Finally, we discuss an example a dialogue trace generated by KANT, describing how it is generated. We restrict ourselves to a single example which illustrates most features. In the examples, typed input by the user is in *italics*, plain text is an output trace generated by KANT. The lines have been numbered (eg "9/") for reference in the commentary.

This is an example taken from the middle of a 'dialogue' with KANT, i.e. an interactive trace. There are two negotiated turns, each of which consists of a negotiation phase, followed by a dialogue action, which is recursively continued in the second negotiated turn. In the first turn, the student is the negotiator and the speaker, in the second the system is the negotiator and speaker, and challenges the claim made by the student in the first. The domain discussed is that of a set

of justifications for the existence of musical phrase boundaries in an example melody, integrated into a semantic network representation.

1/My turn over ... your move
2/Are you sure you want to continue the discussion? (y or n)
3/y
4/Please type who you want the SPEAKER to be ...(student or system)
5/student
6/Please type in the concept you want to talk about (if you want a full list of possibilities, type 'show')
7/phrase_boundary
8/Please type in the instance position you want to talk about
9/p10
10/I will tell you if I agree to cooperate ... Ok, I will cooperate
11/Please choose one but not both of the goals to pursue:
12/ CHALLENGE = make a challenge to a previous claim
13/ CLAIM = make a claim concerning a concept
14/claim
15/I will tell you if I agree to cooperate ... Ok, I will cooperate
16/Please choose one but not both of the goals to pursue:
17/ CONCRETE_CLAIM = make a specific claim about a concept instance
18/ ABSTRACT_CLAIM = make a general explanatory claim about a concept
19/concrete_claim
20/I will tell you if I agree to cooperate ... Ok, I will cooperate
21/Please choose a goal to pursue:
22/MAKE_INSTANCE_CLAIM = state a claim about an instance
23/SUPPORT_INSTANCE_CLAIM = state justifications for an instance claim
24/make_instance_claim
25/I will tell you if I agree to cooperate ... Ok, I will cooperate
26/You are pursuing the dialogue goal MAKE_INSTANCE_CLAIM, with
27/PHRASE_BOUNDARY as a concept, and P10 as its instance. Please confirm or disconfirm your intentions (y/n)
28/y
29/Ok, I'll remember that.
30/Please choose a goal to pursue:
31/SUPPORT_INSTANCE_CLAIM = state justifications for an instance claim
32/support_instance_claim
33/Please type in the justification(s) for the instance P10
34/(CONTRAST PARALLELISM)
35/I will tell you if I agree to cooperate ... Ok, I will cooperate
36/You are pursuing the dialogue goal SUPPORT_INSTANCE_CLAIM, with
37/PHRASE_BOUNDARY as a concept, P10 as its instance, and (CONTRAST PARALLELISM)
38/as the justifications. Please confirm or disconfirm your intentions (y/n)
39/y
40/Are you sure you want to continue the discussion? (y or n)
41/y
42/My move ...
43/Do you accept that we pursue the dialogue goal CHALLENGE (== make a challenge to a previous claim) (y/n?)
44/y
45/ Do you accept that we discuss the concept PHRASE_BOUNDARY (y/n?)
46/y
47/ Do you accept that we discuss the concept instance P10 (y/n?)
48/y
49/ Do you accept that we pursue the dialogue goal CLAIM_SHARED (== agree with a previous claim) (y or n?)
50/y
51/I agree that P10 is an instance of the concept PHRASE_BOUNDARY
52/Do you accept that we pursue the dialogue goal AGREE_SUPPORTS (== agree with some previously stated justification types) (y or n?)
53/y
54/AGREE_SUPPORTS is the dialogue goal currently being pursued with the justification type(s) PARALLELISM.

55/I want to try to explain what I mean by the justification(s) PARALLELISM. Is that ok? (y/n)
56/n
57/Ok, maybe we'll talk about PARALLELISM next time around...
58/Do you accept that we pursue the dialogue goal NEW_SUPPORTS (== state some justifications which we not mentioned for previous instance claim) (y or n?)
59/y
60/NEW_SUPPORTS is the dialogue goal currently being pursued with CHORD_PROGRESSION as the new support(s).
61/I want to try to explain what I mean by the justification(s) CHORD_PROGRESSION. Is that ok? (y/n)
62/n
63/Ok, maybe we'll talk about CHORD_PROGRESSION next time around...
64/Do you accept that we pursue the dialogue goal DISAGREE_SUPPORTS (== disagree with some previously stated justification types) (y/n?)
65/y
66/DISAGREE_SUPPORTS is the dialogue goal currently being pursued with CONTRAST as the disagreed support(s).
67/I want to try to explain what I mean by the justification(s) CONTRAST. Is that ok? (y/n)
68/n
69/Ok, maybe we'll talk about CONTRAST next time around...
70/My turn over ... your move

Lines 1-35: Negotiation phase

n= student
s= student
c= phrase_boundary
i= p10

At 1/ the dialogue controller gives the negotiated turn to the student, the previous negotiator having been the system. At 2/ we have a 'transition relevance point' (Schegloff & Sacks 1973), where speaker roles may shift and either participant may choose to terminate the dialogue. From 4/ to 35 the dialogue goal tree is searched top-down, and at each point parameters which are unbound are presented to the student with the choices available, as well as the choices of dialogue move at that point. At the beginning, the 'DISCUSS' move is satisfied provided that the memory representations of both participants are not equal. For the student, the s, c and i parameters are presented for choice. The system now substitutes the chosen parameter values into the preconditions of 'DISCUSS', which evaluate to 'true' and so the system agrees to cooperate. The student now chooses the 'CLAIM' move, for which a summary explanation is given (lines 11-14). Again the system substitutes the parameter values into preconditions, this time to give :

```
( (not (null 'PHRASE_BOUNDARY)) ;; there is a current concept value
  &
  ((null *dialogue_history*) ;; it is not the start of the dialogue
    OR
    ((in_focus? 'PHRASE_BOUNDARY (ltm_model 'SYSTEM)) ;; the concept is sufficiently in focus
      &
      (not (known? 'PHRASE_BOUNDARY (ltm_model (dialogue_participant 'STUDENT))))
      ;; the student does not know the concept to be claimed
      &
      (exists_ltm_trace? 'PHRASE_BOUNDARY (ltm_model 'STUDENT))))))
  ;; the student possesses a memory trace for the concept
```

The system evaluates this expression with respect to the dialogue state : the concept 'PHRASE_BOUNDARY' is found to have a high enough focus level in the system's representation of the student's memory, naturally, the student is found to possess a memory trace for the concept regarding which (s)he wants to make a claim, the node strength for this concept in the system's memory is found to have a strength sufficiently low so that it should decide to want to hear something about this concept, so it agrees to cooperate (line 15). A similar

procedure takes place with respect to the proposed CONCRETE_CLAIM goal and its subgoals (conjunctive).

Lines 36-39: Dialogue action

The student performs the dialogue action in the form of agreeing to a summary of a statement generated by the system.

```
... You are pursuing the dialogue goal SUPPORT_INSTANCE_CLAIM, with
37/PHRASE_BOUNDARY as a concept, P10 as its instance, and (CONTRAST PARALLELISM)
38/as the justifications. Please confirm or disconfirm your intentions (y/n)
39/y "
```

This is followed by a similar procedure for the conjunctive 'SUPPORT_INSTANCE_CLAIM' subgoal. After line 39/ is generated, the system performs negotiation and dialogue goal effects, which are to update the dialogue history and the memory models of each interlocutor. This involves 'PHRASE_BOUNDARY' becoming an input source of activation in both network representations, through which activation is spread, and increasing the appropriate node strength.

Lines 40-54: Negotiation phase

```
n= system
s= system
c= phrase_boundary
i= p10
```

At 40/ the argument controller passes a negotiated turn to the system. Both the claim and challenge goals are satisfied as relevant, but since a 'challengable' claim has been made, preference Pref1 operates to choose the challenge goal. The concept parameter is now bound to the concept referred to in the previous dialogue move (i.e. PHRASE_BOUNDARY of CLAIM move), from the dialogue history, together with the instance p10 to be challenged. Looking at its own memory representation and the supports claimed by the student in the previous turn, the system agrees with the previous support 'PARALLELISM', performing a dialogue action.

Lines 55-69: Dialogue action

At this point (line 55) the system decides that subconcepts of PARALLELISM are 'possibly known', and so generates a preannouncement in line 55. This is not accepted by the student, so the system continues to negotiate with other satisfiable subgoals of the CHALLENGE move. It states some NEW_SUPPORTS for the claim challenged which the student had not mentioned (line 60), then finally disagrees with the support CONTRAST for this claim (line 64). Again it attempts to pursue this dialogue action, which is refused by the student. After each of these actions, effects are propagated on the dialogue state as before. Finally, at line 69 the system has no further satisfiable subgoals to negotiate, all subactions of dialogue actions have been refused, and its negotiated turn ends. At 70 the argument controller passes the negotiated turn to the student.

There are a number of features which we have not been able to show in this example (see Baker 1989c for further details) such as the system refusing to cooperate with negotiation, the system negotiating that the student should speak, the student negotiating that the system should speak, and so on. Nevertheless, we have illustrated the major features of KANT, which also apply in these other cases.

4.8 Some preliminary criticisms of KANT

We must emphasise that we are not claiming that the example which we have described would be suitable for 'real' use with students, and no effort has presently been made to develop an educationally suitable and robust interface. The example is *an interactive trace of the execution*

of a model for generation of tutorial dialogue, incorporating a notion of dialogue focus and a negotiative style.

An immediate comment which may be made is that the negotiation phases are very lengthy : it would be possible to condense much of this into a single sentence, for example

"Do you accept to tell me where you think there is an instance of a phrase boundary?".

We did not adopt this approach initially because any such conjunction would require analysis into the 'finegrained' mechanism shown above in the case where this was not accepted - does the respondent disagree with who speaks, with the topic, ... ? Furthermore, it is not clear that goals need always be negotiated, nor that they are always negotiated explicitly. The range of moves which can be performed with the present version of KANT is limited by the fact that there is no understanding of the student's utterances - propositions are simply compared and 'contrasted' - which is one effect of our initial hypothesis that dialogue mechanisms can be initially specified at a 'high' level. In general, the negotiation mechanism itself is too simple, and does not admit of interactive renegotiation on a given negotiated turn.

We now summarise some of the assumptions which we made in developing KANT, and some initial simplifications which we made for methodological reasons, as a focus for comparing the model with dialogue analysis results.

Assumptions of KANT

- 1 In tutorial dialogues, the topic and goals of dialogue are negotiated.
- 2 Negotiation of goals proceeds from higher level to lower level goals, with increasing concreteness.
- 3 When a goal is successfully negotiated, it is pursued by the agreed speaker.
- 4 After a negotiation initiated by a given speaker fails, the other speaker initiates a negotiation.
- 5 After a negotiated turn, either speaker may decide to terminate the dialogue.
- 6 After speakers have successfully negotiated and pursued a goal, they may negotiate its subgoals.
- 7 When negotiating the pursuit of subgoals after the higher level goal has been pursued, speakers may generate preannouncements depending on their knowledge of the other speaker's mental states.
- 8 A speaker cooperates with a negotiated goal if (s)he believes it to be relevant, otherwise not.
- 9 The propositional content of dialogue utterances is encoded in working memory.

Simplifications of KANT

- 1 Goals are (always) negotiated, and always negotiated explicitly.
- 2 A determinate set of dialogue goals (such as those used in KANT) are used within any given dialogue.

5. Comparison with dialogue transcript analyses

Our previous analyses of computer-mediated teaching dialogues have given us some analytical data with which to test the assumptions and initial simplifications which were made in KANT.

1 Negotiating goals

Evidence that negotiation forms an important part of educational dialogues is clearly evident from our analyses. As a rough measure, of the 83 exchanges (turns) in the example dialogue analysed here, approximately 46 are concerned with explicit or implicit negotiation. This dialogue was the second in a total series of 8, and so we would expect a greater degree of negotiation to be initially required in order to define general goals.

2 Generality and specificity of goals negotiated

There are a number of cases in which goals are negotiated from general to specific :

T1: I would greatly enjoy doing some PROLOG ...
negotiates(T _ PROLOG)
T5: ... How about writing a predicate called second_word ...
negotiates(T L <PROLOG(predicate second_word)>)
L8 ... I am wondering about strings
negotiates(T L <PROLOG(predicate second_word(strings))>)

Here we can see a process similar to the successive definition of negotiator, speaker and topic parameters, used in KANT. However, this example occurs at the very beginning of the dialogue, in order to define the general goals of the interaction. Later in the dialogue, these more general goals are assumed to be still in operation, so speaker and subtopic parameters are negotiated directly in a truncated form :

T27 ... why not warm up by defining first_word, which can (nearly) be done in one clause?
negotiates(T L <PROLOG(predicate first_word)>)

This suggests that recognisable subgoals of an already agreed goal may be negotiated assuming the higher-level goal to still hold, even if they are not the current explicit focus. Our assumption of general-specific, and successive negotiation of parameters was therefore too strong - KANT needs to incorporate negotiation at this general level of successive negotiation of parameters, and to subsequently be able to switch to a smaller 'grain-size', to negotiate completely instantiated goals in a single utterance (as discussed in the previous section).

3 Negotiation and dialogue actions

The distinction between negotiation phases and performance of the agreed goal, is generally supported by analysis - it relates to a difference between metacognitive and cognitive activity. For example :

"T27 ... why not warm up by defining first_word, which can (nearly) be done in one clause?
[negotiation]
L28: ok [response]
first_word([], []).
.....
[dialogue action]

Given the problem-solving domain in these dialogues, actions here concern problem-solving in the domain, whereas in KANT actions concerned communication of beliefs and their justifications. We can, however, find dialogue actions which communicate belief :

L8: Well, yeah, I am just wondering about strings and things ...
T9: We discussed this last week.
A string is really a list of ascii codes, yeah?"

In this example, the learner's utterance is interpreted as an implicit request for information by the teacher.

4 Negotiation and turn-taking

This prediction is partially confirmed by the transcripts. For example,

T1: I would greatly enjoy doing some prolog. Did you have something in mind?
[negotiation]
L2: No, not really.
[negative response]

Like I said I haven't really looked at your program with the idea of extending it yet. Could we do something simplish, just to make me feel good?!

[negotiation]

This is equivalent in structure to the following extract from the KANT dialogue trace shown earlier:

(KANT OUTPUT TRACE)

67/I want to try to explain what I mean by the justification(s) CONTRAST. Is that ok? (y/n)

[NEGOTIATION - system]

68/n

[NEGATIVE RESPONSE - student]

69/Ok, maybe we'll talk about CONTRAST next time around...

70/My turn over ... your move

71/Are you sure you want to continue the discussion? (y or n)

72/y

73/Please type who you want the SPEAKER to be ...(student or system)

74/student

[NEGOTIATION - student]

However, as we mentioned earlier, this 'normative' turn-taking sequence only applies in cases of INDIFFERENCE or COOPERATION, and breaks down in cases of CONFLICT, the paradigmatic case where negotiation is required. KANT therefore needs to be extended to incorporate elements of both structures, together with the required mechanisms for recognising the appropriate propositional posture with which they are associated.

5 After a negotiated turn, either speaker may decide to terminate the dialogue.

Attempted negotiation of the termination of the dialogue does occur (example 2 in section 3 of this chapter), and therefore this needs to be provided as a possible choice to each speaker. However, we have also seen that *benevolence* can not necessarily always be assumed - in KANT, we adopted the initial simplification that if the student wishes to terminate the dialogue, the system automatically consents, and vice-versa. We therefore need to incorporate some elements of Galliers' (1989) analysis of conflict situations, in order to address the issue of when a speaker should agree to terminate, and when they would accept the negotiation of some alternative goal for which they have a preference. As Schegloff and Sacks (1973) argued, closings of conversations need to be *prepared* in order to be mutually acceptable, which includes the generation and careful timing of *preclosings*. Some aspects of conversation analysis applied to openings and closing of conversations have been incorporated as a 'grammar of adjacency pairs' in the advice system of Frohlich and Luff (1990). In the dialogues analysed, elements of preclosings can be seen in a shift from actual problem-solving and negotiation of its joint control, to a retrospective discussion for evaluating the student's performance :

L75: Jesus christ I don't know why it took me so long...

T76: Some days things like that are hard. Brains switch off ...

T78: You're warming up now...

T80: Good. I don't think we can do much more at the moment. Shall I leave you with a problem to ponder, and we can talk about it some other day?

6 Negotiating subgoals

Speakers naturally extend their dialogue actions to subgoals which are strictly beyond the initially agreed goal, for example, in giving further information than is requested :

L12: ... If I did name("fish and chips", N). would I get N = [no, no, no, no, 32 no,no,no,32, no,no, etc]?
((question))

T13: No, actually, you'd get an error.


```

((answer))
The first argument has to be atomic and the second list.
((explanation/clarification))
If you did
    name("fish and chips")
you'd get X=fish and chips
where the value of X is actually an ATOM, though it doesn't look like it.
What I suspect you want is .... [etc.]
((explanation))

```

Notice that the teacher remains the speaker, and that the extra information is still of a 'reasonable turn length'. We may therefore hypothesise that if the teacher wished to continue on an extended discussion of some concept - eg atoms, etc. - that this *would* be negotiated, or that if the continued extra information required the other to speak, then this would also be negotiated. The lessons which we draw for KANT are therefore :

- ° subgoals may be negotiated if longer than the "normal" length of a single turn, or if they require speaker change
- ° otherwise, a speaker may extend their negotiated and agreed dialogue action without explicit negotiation.

We would require further empirical work in order to establish the precise extent to which turns may be extended by a speaker. The initial simplification of allowing a speaker to continue to negotiate subgoals of an action in a straightforward depth-first search manner must therefore also be modified. The question of how long a 'reasonable' turn is can probably be simply resolved by giving the student the possibility of *interrupting*. From the point of view of the system, however, we need further research before we could specify exactly when the system should interrupt the student. Given a certain educational philosophy which prefers the maximum of initiative to be taken by the student (see the educational preferences included in KANT), it is possible that this aspect should *not* be symmetrical for the system and student : we would want the student to be allowed to continue a turn as much as possible, provided the system recognises that their actions are relevant to achieving the agreed goal. In fact we do find the teacher interrupting in this way, when he feels that the student is no longer performing actions to achieve the goal :

```

L28: ... first_word([],[]).
first_word(A,B) :- name(C,A);
    hang on
first_word([],[]).
first_word(A,B) :- name([C|D|E],A);
D=32
That C should be a B
T29: Is that it?
L30: um
T31? can I say something?
<<...>>

```

7 Negotiating subgoals and preannouncements

Although preannouncements occur in everyday conversations, we have not observed their use in these dialogues, in the way in which they are incorporated in KANT. The extent to which this poses a problem for the model depends on our research goals. If we want to generate human-computer dialogues in ITS which are perceived as coherent by a learner, it is possible that the inclusion of preannouncements for negotiation of subgoals could improve user acceptability. Their use in everyday conversations is well established (Levinson 1983), even though we have not observed them in these example dialogues. For the present, the changes which need to be made to KANT with respect to negotiation of subgoals indicate that we should suppress their inclusion in KANT until their use can be better defined by analysis.

8 Relevance and cooperation with negotiated goals

We have not analysed cases where a speaker refuses to cooperate with a negotiated goals because it is not relevant. Conversely, all goals negotiated which *were* relevant to the previous goal were accepted. In KANT the notion of relevance combines topic-based focus, with speaker roles and dialogue goals, in a complex set of preconditions with respect to the dialogue state. We observed cases where the speaker does not accept such a combination, presumably in terms of their *preferences* :

T1: I would greatly enjoy doing some prolog. Did you have something in mind?
(negotiates(T L negotiates(L _ prolog))
L2: No, not really.
(responds(L n U2)).

Since KANT includes the use of (educational) preferences in choice of goals to pursue, it therefore should be extended beyond its present (relevance-based) benevolence (Galliers 1989) to incorporate more strict criteria for accepting the student's negotiated goals, using these preferences. Given the greater likelihood of conflict which would result, we need to extend the current mechanisms to resolve these conflicts. One way to do this would be to attempt to find a 'compromise' satisfaction of the dialogue goal which was close to that proposed by the student - for example, with a different speaker role - or else to attempt to defer the goal to later in the dialogue (see negotiation example 2 in section 3 of this chapter). In order to achieve this, we need to incorporate a representation of *preferences* and *commitments* (as described by Cohen & Levesque 1990 and Galliers 1989) and a more explicit representation of temporal aspects of *deferred goals*. Conflicts arise mostly in the dialogues because the goals proposed concern the form of the dialogue itself - such as its termination - rather than its topic. The extent to which a speaker accepts such negotiated goals must relate to higher level persistent goals, or commitments (again, in Cohen & Levesque's terms) - such as "that the student should complete the problem" - and the extent to which they are in direct conflict in these negotiations.

Other more fundamental aspects which need to be developed in KANT include a more sophisticated model of relevance (Sperber & Wilson 1986), and means for managing *conversational repair* (Good 1990). The following is an example of a misunderstanding leading to a repair sequence :

T23: ? Can I suggest?
second_word(A,Bno
L24: yes
T25: yes what? I'm confused.
L26: Yes, suggest.
T27: Oh...

9 Encoding utterances in dialogue

The simple memory encoding hypotheses used in KANT were consistent with the general theory of memory adopted (Anderson 1983), but clearly fail to distinguish a memory that some other speaker stated a belief from a belief which is *genuinely adopted by the hearer as their own*. This difficult problem will need to be addressed in the future in terms of recent AI theories of *belief revision* (see the collection of papers in Halpern 1986).

6. Summary and conclusions

In this chapter we have explored the nature of negotiation, and attempted to establish the functions which it performs in teaching dialogues. We have analysed computer-mediated teaching dialogues in order to identify what may be negotiated, why negotiation occurs, and the interaction structures with which it is associated. This has provided us with an extensive research agenda of new features to incorporate in a first prototype computational model for intelligent teaching dialogues which includes negotiation mechanisms. With respect to existing work on

negotiation, the distinctive contributions of KANT include the integration of negotiation mechanisms within a more general model for extended dialogue, rather than in a single exchange, and the extension of the problem of modelling negotiation in tutorial dialogues beyond conflict resolution situations. Major features to be modified in KANT include :

- changes to turn-taking mechanisms in negotiations, with respect to the propositional attitudes of conflict, indifference and cooperation ;
- introduction of mechanisms for resolving conflict by the more principled representation of propositional postures, preferences and commitments ;
- changes to the procedures used for negotiating dialogue subgoals ;
- provision of mechanisms for interruption, including knowledge of when and how to interrupt whilst maintaining a cooperative posture.

We also described a number of other specific phenomena which the model needs to take into account, including the range of goals and beliefs which can be negotiated and explanation and justification of negotiated goals. Clearly, a number of difficult problems were not addressed previously, including belief revision (Harman 1986 ; Fagin & Halpern 1988), the formal representation of conflict and its resolution (Galliers 1989), and the representation of metacognitive awareness and reasoning. From our dialogue analyses, the negotiation of goals from more abstract and general to more concrete and specific, and the basic turn-taking mechanism were shown to be adequate at a first approximation.

As a phenomenon in interaction, negotiation is closely linked with *metacognitive awareness* of problem-solving abilities on the part of a speaker, as a prerequisite for negotiation of future cooperative control of joint dialogue goals. An important feature of metacognitive awareness is a speaker's affective attitude to towards the possibility of achieving goals, especially in conditions of apparent failure. When we consider the problem of how a teacher can successfully negotiate goals, therefore, the problems of understanding the affective and the motivational effects of utterances are particularly important. Progress for cognitive modelling in the area of affect (Donohew, Sypher & Higgins 1988), the emotions (Ortony, Clore & Collins 1988) and motivation (Weinhert & Kluwe 1987) is now at the stage where we may have reasonable hope of including such aspects in models for dialogue in Intelligent Tutoring Systems. Given the different *nature* of the goals and beliefs of teachers (and ITS) and learners, it is clear that negotiation in educational discourse fulfills the important functions of securing cooperativity and genuine *engagement* in the learning process on the part of the student, and the possibility of a joint construction of meaning.

In future research we plan to validate and refine KANT by a combination of approaches. In order to test the extent to which an extended version of KANT can successfully maintain a coherent and focussed dialogue, and use negotiation appropriately in interaction with a human student, we plan to develop a graphical interface to the system (which is implemented in LISP), for 'pragmatic validation' with students.

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