

# Learning: From Interactivity to Cooperation

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**Abstract.** In Intelligent Tutoring Systems (ITS) the student model is one of the most difficult parts of the program. The student model represents the student's current state of knowledge. Instead of a student model, we build a partner model. In this article, we will discuss the cooperation paradigm for computer-assisted learning. In Intelligent Cooperative Systems (ICS), student and system work together as partners on problem solving tasks. The requirements for ICS are: complementary abilities or information, mixed control, mixed initiative and common goal between student and system. The advantages of the cooperative approach as a learning principle will be discussed. Some implications for the representation and implementation of the interaction component in ICS are examined. Examples are given from a research project which is concerned with the development of a framework to interpret the communicative actions that occur in cooperative problem solving.

**Keywords.** Cooperation, interactivity, problem solving, intelligent tutoring systems, intelligent cooperative systems

## 1 Introduction

In a chapter on cognitive principles in the design of computer tutors, Anderson et al. (1987, p93, p105) state: "The intelligent tutoring paradigm states that the most promising way for bringing intelligence to bear in delivering instruction is to emulate a private human tutor". "Students appear to learn information more effectively if they are presented with that information during problem-solving rather than during instruction apart from the problem-solving context".

The concurrence and coordination of information exchange during the process of problem solving seems to be a crucial aspect. One could expect the effectiveness of intelligent tutoring to increase if both student and tutor are allowed to communicate about each other's knowledge about the problem and their respective problem-solving procedures. In Intelligent Tutoring Systems, the student model and the diagnostic component try to fulfil this role. In

cooperative settings, however, this kind of tuning is a natural requirement.

In this article, we will discuss the cooperation paradigm for computer-assisted learning. In this paradigm the attention shifts from the problem of domain knowledge and teaching methods to the problem of communication between partners. Some issues are being discussed on the advantages of such an approach and on the directions that future research on intelligent cooperative systems could take. First, the cooperative approach is defined within the field of intelligent tutoring. Its characteristics and advantages will be described. Second, we will raise some issues that deserve attention from researchers in this field. Third, we will present some relevant examples from our own research. Finally, some implications for the construction of cooperative systems will be put forward.

## 2 Approaches in Intelligent Computer-Assisted Learning

In research on intelligent computer-assisted learning, two main approaches can be distinguished. One approach is the development of *tutoring systems* acting as a teacher, who guides the student and controls the learning path of the student. The system determines which problems the student has to solve, when a correct solution has been reached and when it is necessary to provide guidance. The control lies mainly with the system. Emphasis lies on the development of domain expert- and diagnosis-modules. The effectiveness of such tutoring ultimately depends on instructional and curriculum expertise in specific knowledge domains.

The other approach is the development of *open learning environments* in which the student is able to take over control and to determine his/her own learning path. These systems can take the shape of a simulation environment, a laboratory, a microworld etc. Control lies mainly with the student. The goal of many of these computer-based learning environments is typical for encouraging learning without specifying it directly (Levin and Waugh 1988). The effectiveness of this approach depends on the validity of a specific learning principle, that of (eventually guided) discovery learning.

In general, one could say that in both approaches the question "Who is in command?" is not a matter of negotiation but of predetermination. Control over the learning path lies either with the student or with the system. "Who has control" does neither depend on the ongoing problem solving process nor on the ongoing interaction process.

## 3 Intelligent Cooperative Systems

Presently, however, a third approach seems to emerge: systems that are meant to cooperate with the student. We propose to call these systems *Intelligent*

*Cooperative Systems (ICS)*. In this approach, neither the student nor the system has complete control over the learning path. They both work together as "equal partners" on a problem-solving task.

At this moment we do not know of any systems that are fully cooperative. Yet more and more research within the field of ITS aims at a more cooperative approach (Self 1990). Examples are: mixed initiative systems, systems in which the student acts as a teacher to the system and help-systems (Anzai 1987, Law and Ki 1987, Scheftic and Wood 1987, Breuker, Winkels and Sandberg 1987).

### 3.1 Which Should Be the Characteristics of ICS?

We can define a cooperative learning situation as one in which two or more students work together to fulfill an assigned task within a particular domain of learning, in order to achieve a joint product. From this definition we can infer the following criteria for ICS:

#### *a. Complementary abilities or information*

Cooperation is not very useful when one is able to complete the task by oneself. Only when the participants have abilities or information that are complementary, can cooperation be fruitful. ICS requires tasks that call for cooperation to be successfully completed. This also could imply that an ICS does not have complete knowledge about a domain and is not able to solve all the problems encountered.

#### *b. Mixed control*

In cooperative learning situations none of the participants is able to determine the process one-sided. The participants are dependent on each other's cooperation. System and student in ICS should interact with each other, give and ask for information, discuss inferences being made and strive for mutual agreement. Both participants have the opportunity to take control of the exchange and processing of information in the interaction.

#### *c. Mixed initiative*

Both system and student have to be able to take the initiative in interaction. They must be able to take initiative in asking questions, in making remarks, in transferring information, in suggesting solutions etc.

#### *d. Common interest and common goal*

In cooperation, system and student must have a common interest in solving the problem at hand. They have to reach common goals and common sub-goals that determine the flow of the problem-solving process.

## **3.2 Why Could This Approach Be Useful?**

### **3.2.1 Cooperative Learning**

In recent educational research there is very much interest in cooperative learning. Under certain conditions, learning in problem-solving domains appears to be more productive in peer-cooperative settings than in individual or teacher-student interactional settings (Webb 1982). The causes for favourable outcomes of cooperative learning experiments are not yet fully understood. Some explanations point at findings that students profit from the necessity to coordinate their actions and that students are more capable to understand each other's line of reasoning. Other researchers contribute the positive effects to situations in cooperative learning that evoke a so-called socio-cognitive conflict (Doise, Mugny and Perret-Clermont 1975). This conflict obliges the student to restructure his/her cognitive representation when confronted with contradictory information of the partner. However, most educational researchers agree that cooperative learning can, under the right conditions, be a valuable way of learning problem solving abilities.

Cooperation is not just working together pleasantly. Cooperation can be a hard struggle. One has to defend one's own standpoint, give arguments, challenge information transferred by the partner etc. Cooperation forces the partners to verbalize and defend their choices in the problem-solving process. These activities enhance reflection on one's own thinking process. Forcing a student to verbalize his/her thinking during problem solving can be a powerful instrument for the system to get a view on the internal cognitive processes of the student. A system should benefit from this "naturally" begotten data about the cognitive processes, at constructing its student model.

### **3.2.2 Open Domains**

For some learning domains it will remain impossible for an ITS to have a complete domain-representation. In open domains (for example, story writing) it is not feasible to determine the learning process completely. In these domains an approach, in which the system seeks for content information from the student and tries to give suggestions based on its own (limited) knowledge, can be fruitful.

Imagine an ICS for story writing. The system contains schematic and strategic knowledge about how to write a story. This system could have an extended knowledge of writing processes such as: planning, organizing content, formulating and revision. However, the system need not possess any content-knowledge at all. The student has knowledge of content matters. She/he knows what the story is about, but has to cooperate with the system in the process of writing the story down and evaluating the written product.

#### 4 Model of Cooperative Problem Solving

At the Utrecht University, research is being conducted within the field of cooperative learning and the development of intelligent educational computer systems. One project, the DSA-project ("Dialogue Structure Analysis of interactive problem solving") is concerned with research on the relation between information processing and information exchange during cooperative problem solving. In this project a simulation-program has been constructed that models two students cooperating on a problem-solving task. The model advanced in this project may serve as a prototype for further development of cooperative computer-programs.

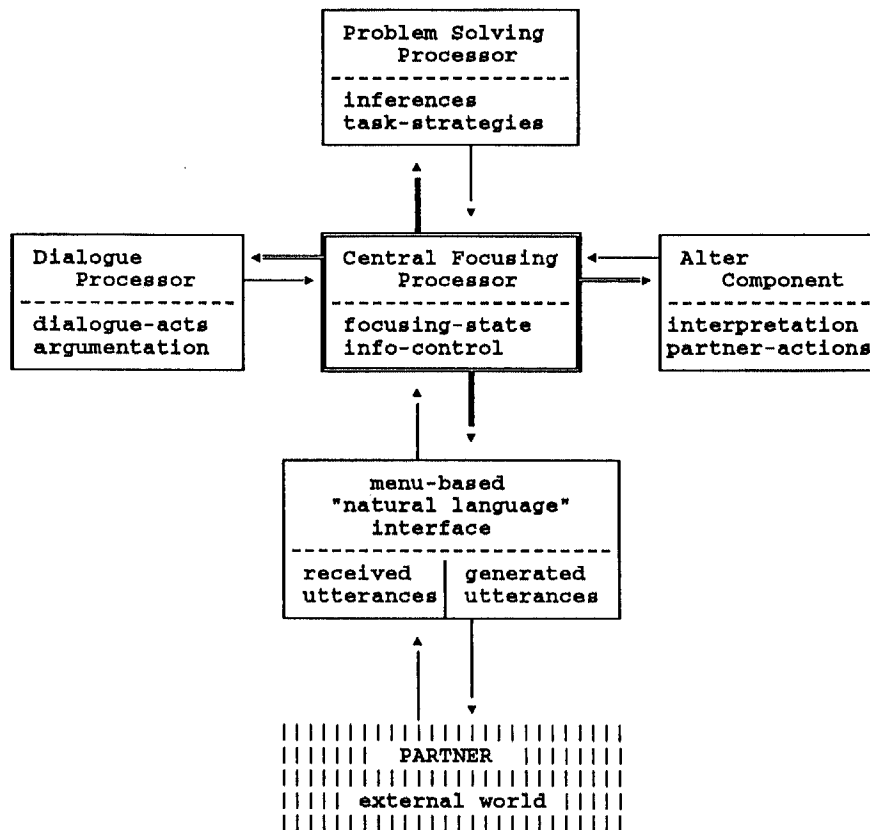


Fig. 1. Model of Problem Solving and Dialogue Processing

In the DSA-model, as shown in Figure 1, the following components can be distinguished:

- *Problem Solving Processor*: contains knowledge about the domain and problem solving strategies
- *Dialogue Processor*: contains knowledge about interaction processes, strategies for analyzing and generating communicative actions
- *Alter Component/Partner model*: contains a belief-system about the communicative and problem solving activities of the partner
- *Central Focusing Processor*: this component controls the flow of information between the different components and combines the results from the processes that go on in the other components. This component contains the cooperation strategies.
- *Interface*: translates the input from the partner in an internal representation and vice versa. In ICS it is crucial that the possibilities of interaction with the student are extensive and flexible. Therefore we will focus on the aspect of interaction.

## 5 Student-System Interaction

To reach a solution, student and system are engaged in a two-way process of communication. The crucial notion in the analysis of communication is Grice's principle of cooperation: in order for communication to be efficient and effective, participants serve the common goal of making each utterance relevant, informative, true and clear (Grice 1975). One consequence of this principle is that in natural conversation, without evidence to the contrary, every utterance is interpreted as coherent within the context of earlier utterances.

Ideally, student and ICS are partners in a conversation. Both possess certain knowledge and both need information of the other in order to solve a problem. What is essential here is that both have the common goal of solving a problem and for this it is necessary that both have a common understanding of the nature of this problem. The path to a solution is a matter of debate. In trying to understand the student's method, the system needs to interpret the student's actions. The system must be able to communicate with the student, in order to comprehend the student's actions more clearly, or to correct the student's actions.

In ICS, therefore, we need a framework for the interpretation and elicitation of different types of task-directed communicative actions. This requires results from empirical research on cooperation in problem solving contexts. We need to study the process of information exchange during cooperative problem solving to know what communicative actions are performed for what purposes during task execution. In the next paragraphs we will discuss these two central aspects: the characteristics of communicative actions and their interpretation during cooperative problem solving.

## 5.1 Communicative Actions

We will base our considerations mainly on the results of the already mentioned DSA-project. The project involves cooperative problem-solving tasks with 10 to 12 year old students.

The DSA-project aims at gaining insight into the relationship between the cognitive aspects of information processing and the communicative process of information exchange during cooperative problem solving. These processes are modelled by using the method of protocol-analysis and computer-simulation. Dialogues between students cooperating on a problem-solving task, are being analyzed and simulated. The simulation-program is the core of a prototype ICS that interacts with a student in cooperative problem solving.

### 5.1.1 Example from a Dialogue Protocol

First we would like to present an example; a few lines from a protocol. The cooperation-task the students work on is the solving of a logical problem. They have to deduce several characteristics of some children described in the task-material. Each of the two students receives a letter which contains different information about the children mentioned in the task.

In the example given in Figure 2, the students try to find out which child does gymnastics and who sleeps in which tent in a summer camp. Student A has information in a letter from a boy named Peter. Both students know that the red tent stands between the blue and the yellow tent.

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1  A: And Chris does gymnastics
2  B: Oh,..yes
3  A: (reads from the letter) "John is the boy who sleeps in
    the red tent next to me"
4  B: Who,..eh, who says so? Chris?
5  A: Eh, yes, Chris does gymnastics
6  B: Then Chris sleeps in blue or yellow,
7     ...if he sleeps next to John.
8     He sleeps in blue or yellow
9  A: I don't know if he sleeps next to John

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Fig. 2. Example of a dialogue protocol

When we look at the fragment in Figure 2, we see the first coordination problem in line 4. Student B does not understand who is "me" mentioned in line 3. He confuses Peter, the writer of the letter, with the already mentioned Chris. Because student A misunderstands the question and repeats that Chris does gymnastics, student B concludes in line 6 that Chris sleeps next to John. In line 8 we see that student B repeats his conclusion, this kind of re-conclud-

ing has an important function for the coordination between partners. In line 9 we see that student A also actively engages in the process of coordination, he does not accept the solution gratuitous, but checks it.

### 5.1.2 Coordination

In the example from a protocol we already noticed the role of coordination. One of the main findings of our analyses of the protocols, is that students spend a great deal of their time in these task-oriented dialogues on controlling and coordinating activities such as checking of plausibility and giving information about the status of information transferred (Erkens and Barnard 1988).

Checking procedures were found to play an important role in the coordination of actions in the analyzed task-dialogues. In the dialogues checking can be found in the form of: check questions, (for example: are you sure?); confirmations; denials; acceptations and counter-arguments.

Students often give an explicit indication of the status of information transferred. Examples are: "I think", "I know for sure", "I don't know". On the average, 25% of all utterances in the protocols give such indications.

In the protocols, checking takes a substantial part of all the utterances, made during task-performance. We think that before information can be incorporated in a cognitive representation, this checking procedures on relevance and coherence with earlier knowledge is necessary. People can only relate external information to their own knowledge if it is perceived as relevant, plausible and consistent (Ausubel and Robinson 1969).

## 5.2 Facilitating Cognitive Representation

Students, cooperating, give redundant information, context-indications, recapitulations etc. These serve an important function for the receiver to distinguish the kernel of the information transferred. They also facilitate the integration of this information into the cognitive representation of the problem at hand.

When we look at sequences of communicative actions that occur frequently in the protocols we can distinguish some prevailing dialogue-patterns. One of the most basic patterns is shown in Figure 3.

1. Asking for attention	A: "Eh, look"
2. Transferring new information	A: "Peter sleeps in white"
3. Accepting or confirming	B: "Yes"
4. Re-concluding	A: "So, white"
5. Writing down the solution	A & B: writing

Fig. 3. Example of a basic dialogue pattern



Coordination occurs by means of signalling, asking for attention before new information is transferred, and by means of explicitly accepting and re-concluding before writing down the solution. By these means, both partners make sure that they share the same understanding of the problem.

As was indicated, this kind of coordination and adaptation processes were frequently found in interactions between students. ICS should profit from these natural phenomena and stimulate these checking processes in order to control or to prevent the occurrence of different representations.

## **6 Implications for Construction of the Interaction Component**

The empirical results of our projects inform us about communicative actions that occur during cooperatively solving complex problems. They also inform us about how to evaluate the appropriateness of these actions. If we want an ICS to offer the student the possibility to interact with the system in the same manner, then what are the consequences for implementation and representation? In our opinion the most interesting consequences concern the bandwidth of the interaction component and the design of the partner model in the system.

### **6.1 Broadening the Bandwidth**

The "intelligence" of computer-assisted educational systems is related to the degree by which the system is able to recognize the information processed by the student, and able to adapt itself to it. This depends on the "bandwidth" (VanLehn 1988) of the system. We define the bandwidth of the interaction component as the variety the system is able to receive and process in terms of propositional and communicative information transferred by a student. The bandwidth sets the limits to the adaptability of the computer-program to the individual student. The interaction channel between system and student is the bottleneck through which the system receives the information necessary to model the student (Douglas 1988). This applies not only to ICS but to all computer-assisted educational systems.

Broadening the bandwidth of the interaction component is not identical to the development of new interfacing-techniques such as menu-driven systems, natural language interfaces, speech recognition and synthesizing systems, auditory-video connections, graphical presentations etc. (Miller 1988). If we plead for broadening the interaction, we would rather refer to the variety of communicative functions than to all the different forms in which the functions may be put. We illustrate this by an example from natural discourse. In natural dialogues, the listener has direct control over the kind of information that will be transferred by the speaker by means of only two simple communicative actions: confirmatory head nodding and looking blank. In reaction to head

nodding or confirming, the speaker will continue the line of thought he or she is transferring. However, when the listener looks blank or frowns, the speaker will tend to elaborate on, explain or rephrase the information at focus. In most computer applications we do have the possibility to nod, for example by means of pressing the return-key. However, we strongly miss the possibility of looking blank or raising our brows as the text scrolls before our eyes.

## 6.2 Construction of the Partner Model

What differences in representation do we observe if we compare the construction of a partner model in ICS and student modelling in ITS? Without giving final answers, some preliminary remarks can be made:

- How to interpret the communicative actions of the other?  
The partner model in ICS also has to contain information about the procedures used at the communicative level. The ICS has to interpret the communicative actions of the other. This interpretation must be driven by the expectations and demands derived from the information the partner transfers by his or her communicative actions.
- How to restrict the partner model to information that is useful?  
We could answer this question in the same manner as Ohlsson (1986) does on student modelling in ITS. Ohlsson pleads for a direct relation between student model construction and the didactic action repertoire an ITS possesses. Likewise, we could relate the partner model to the cooperative goals and communicative action repertoire an ICS should possess.
- How deep should the partner model be?  
To put this question in another way, what has to happen if the ICS encounters a line of thinking of the student it cannot recognize or integrate with its own representation? To answer this question, let us take a look at what happens if two cooperating students do not understand each other? They will explain and rephrase their arguments. They try to find a common representation in which their common goal can be fulfilled. We hope that the strength of a cooperation-approach for computer-assisted learning will not only be in the issue of learner control, but also in the possibility for the system to oblige the learner, in a natural manner, to stay on grounds that the system can understand.

## 7 Concluding Remarks

We do not think that the cooperative approach will be the panacea for all learning situations in all educational domains. Nevertheless, cooperation in itself may be an effective educational method for computer-assisted learning. Particularly in those domains in which the learning of problem solving abilities is central.

If we view cooperation as an educational method in itself, we do not contend that in ICS there will be no room for a didactic component, which contains teaching strategies and didactic principles. In fact, a cooperative system could be expanded with a didactic component containing instructional knowledge. The essence of the cooperative approach lies within the criteria of complementary abilities or information, mixed control, mixed initiative and common goal. On account of the first criterion, complementary abilities, it is feasible that the ICS has more didactic expertise than the student. However, in ICS it is the common problem solving state that will determine when and where the didactic action will be offered on the basis of a goal mutually agreed upon.

The construction of a working ICS that really cooperates like a fellow-student still has a long way to go. Study of task-oriented human interaction and developmental research on ICS construction should take us further along this way. The most attention should be devoted to the interaction component. This research should be conducted within domains of cooperative interaction during problem solving.

Research on ICS development has as its final goal the application of such a system in the classroom. In the near future this will not be a realistic option. The first benefit of this type of research will not be the construction of a working application, but the gaining of more insight in the various aspects of cooperative problem solving and interaction processes. In this way ICS research could be an important contribution to the study of learning and education.

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