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ANALYZING A NEW LEARNING STRATEGY ACCORDING TO DIFFERENT KNOWLEDGE LEVELS

ESMA AIMEUR and CLAUDE FRASSON

Université de Montréal, Département d'informatique et de recherche opérationnelle,
2920 Chemin de la Tour, Montréal, Québec, Canada H3C 3J7
[*e-mail*: {aimeur frasson} @iro.umontreal.ca; *Fax:* 1-514-343 5834]

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Abstract—Intelligent tutoring systems have recently evolved towards a co-operative approach between the learner and the system. Knowledge acquisition is facilitated by interaction with the system under the control of the learner. New tutoring strategies have been introduced to enhance motivation of the learner by involving a second learner or a companion who simulates the behaviour of a second learner in the learning process. An inverted model called "learning by teaching" in which the learner could teach the learning companion by giving explanations has also been presented. In this paper we discuss the advantage and the inconvenience of these strategies and present a new learning strategy which improves performance for good or intermediate learners. We describe an experiment with this strategy and compare results with those obtained with the companion. We analyze and discuss results obtained. Copyright © 1996 Published by Elsevier Science Ltd

INTRODUCTION

At the beginning of the 1980s, intelligent tutoring systems (ITS) aimed to reproduce the behaviour of an intelligent (competent) human tutor who can adapt his teaching to the learning rhythm of the learner. Individualized teaching can be provided to the learner taking into account his or her previous knowledge, reactions and progression throughout their interactions with the tutor. The control of the training is assumed by the tutor (prescriptive approach), not the learner. These systems were generally hard to control from a pedagogical point of view and not very efficient. They were also complex to build, taking into account the multiplicity of expertise to incorporate and particularly the handling of the learner model with its large amount of data and relationships [1]. An inconvenience of most of the ITS lies in their prescriptive approach, based on centralized decision-making and coaching.

More recent ITS developments consider a co-operative approach between the learner and the system [2] using a *co-learner*. The system participates with the learner in the learning process and facilitates knowledge acquisition through interactions under the control of the learner. An extension of this approach was presented by Chan [3] with the *learning companion* who stimulates the behaviour of a second learner (the companion) who would learn together with the human learner. Various alternatives to this co-operative approach were then conceived, leading more recently [4, 5] to an inverted model of ITS called "learning by teaching" in which the learner could teach the learning companion by giving explanations. This approach is worthwhile in the sense that it strengthens the knowledge acquisition process forcing the learner to structure the knowledge. An explanation of this principle derived from the self-explanation effect [6] was given in [7].

However, to obtain a valuable effect of this co-operative approach it is necessary to understand what the learner has effectively understood, what remains unclear, what he needs to examine again. A variety of information should be taken into consideration to emphasize mutual construction of knowledge. This information is included in the learner model. We distinguish two types of information in the learner model: information about the knowledge level of the learner, which is a cognitive part and information about his affective characteristics, the affective part.

We think that a good learning strategy should be selected according to these two facets of the learner. However, the participation of the learner can become more active if the system can challenge him. In this paper we propose a new learning strategy (called learning by disturbing) derived from the learning companion and in which the companion is a troublemaker who sometimes gives good advice to the learner but also wrong recommendations. The goal of this particular

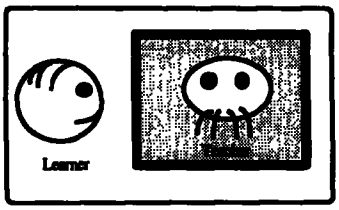

Fig. 1. ITS model of learning.

companion is to provoke the reaction of the learner. After reviewing the evolution of the different learning strategies we discuss their strength and weakness, and present our new learning strategy. We have implemented two strategies (learning companion and learning by disturbing) in order to set up an experiment in which we can compare this new strategy with the companion. We give the results of this experiment and show how this new strategy can strengthen learning.

EVOLUTION OF LEARNING STRATEGIES

The evolution of tutoring systems concerns several aspects such like structuration of knowledge to communicate to the learner, learning strategies and student modelling. If knowledge was initially considered as the most important part, at the end of the 1980s more emphasis was put on pedagogical aspects, allowing more participation of the learner in the learning process. In the following we review two co-operative strategies and compare them to the first approach used in ITS in which the tutor supervises directly the learner.

One-on-one

This approach [8, 9] preceded the co-operative systems and consisted in simulating an intelligent tutor by the computer who can understand the learner and provide adaptive tutoring. The learner receives knowledge directly from the tutor who communicates and acts accordingly to a prescriptive behaviour (Fig. 1). Most of traditional ITS adopt this approach with adaptive features more or less marked, according to the complexity of the learner model used to provide feedback. The teacher's knowledge is always higher then that of the learner.

As alternatives to one-on-one strategy, co-operative strategies comprise an additional element, namely peer interaction. Co-operative learning systems, called also social learning systems, adopt a constructive approach based on the use of the computer more as a partner then as a teacher in the process of knowledge transfer. Multiple agents, that are either computer simulated or real human beings, can work on the same computer or share a computer network.

Learning with a co-learner

The idea of introducing a *co-learner* in the learning process arose with the perception that knowledge should result more from a building process than from a transmission process [2, 10]. In this scope, the learner could co-operate with a co-learner having quite similar objectives and level of knowledge (Fig. 2). A learner is inclined to more easily understand explanations given by a co-learner, who has understood, knows what to do and to answer, than the teacher.

The co-learner is supposed to have recently passed through the same understanding problem and so is more aware of the level of explanation and detail to give to solve the problem. The knowledge

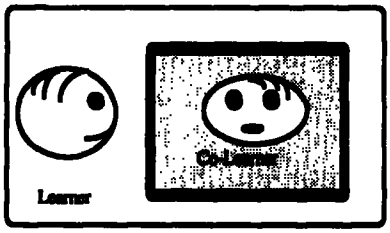

Fig. 2. Environment with a co-learner.

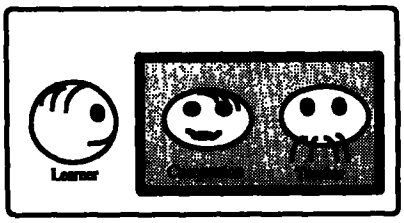

Fig. 3. Learning companion.

level of the co-learner is slightly higher than the learner. Chan and Baskin proposed a three-agents learning situation [3, 11] which consists in a co-operation between a human learner and a simulated learning companion who learn together under the guidance of the teacher (Fig. 3). The *companion* and the learner perform the same task and exchange ideas on the problem. The learner and the co-learner (the companion) work together and ask the teacher for help only if they cannot find a solution.

The role of the teacher is then to alternatively present problems and critiques of the learner's solution. The process is gradual in the sense that each learner produces a solution then checks the other's solution. Finally the teacher checks the solutions which are submitted to him in order to correct any remaining error. The companion and the learner have quite similar knowledge levels, while the tutor has a higher knowledge level.

Learning by teaching

An additional form derived from the learning companion was also proposed by Chan and Baskin [3]. The idea was to encourage the human learner to teach the companion, by providing examples, explaining why the solution given by the companion is not adequate. The approach is called learning by teaching (Fig. 4) and has been further elaborated by other studies [4, 5]. Explanation of this approach can be found in the learning theory of Gagné [12] who shows that a strong knowledge acquisition is achieved when a learner is able to fully explain the solution of a task using his own inference mechanism and this last exercise is in itself a knowledge acquisition method.

As we can see, each method requires a dialogue between the learner and the system, and explanations are fundamental. The learner can ask for an explanation to justify his opinion, propose an alternate solution, help another learner to formulate his questions, recognize the wrong interpretations and understand the motivation of another learner. In the next section we will discuss about the advantages and inconveniences of these learning strategies.

STRENGTH AND WEAKNESS

Each method presents benefits and weaknesses. To appreciate more precisely their differences we will consider some criteria in which innovative work has been done and that can improve the efficiency of an ITS. They concern either elements specific to the *behaviour* of the system toward the learner or *characteristics* of the learner. *Behaviour* of the system concerns the tutoring form, the form of dialogue, the quality of assistance. *Characteristics* of the learner concern the learner's level which is taken into consideration to orient the tutoring process, the self-confidence of the learner and the motivation in learning. In the following we briefly review the form of these criteria in the three strategies: one-on-one, the companion and learning by teaching.

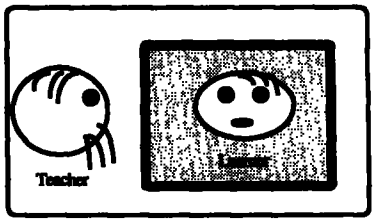

Fig. 4. Learning by teaching.

Tutoring form

Tutoring forms have evolved from directive supervision to co-operative learning as explained in [13]. One-on-one strategy is by definition oriented on a directive supervision of the learner. There is a no co-operation in the sense that knowledge is not built by interaction [14] with the tutor but progressively shown to the learner. There is no real discussion and exchange of point of view between the two participants.

Learning with a companion implies a co-operative dialogue between the learner and the companion through the tutor.

Learning by teaching implies a more advanced form of co-operation in the sense that the learner works with a tutor who simulates to have a lower level than that of the learner. He is forced to make retrospection, generalization, demonstration and gives self-explanation.

Form of dialogue

The dialogue represents an important component of human–machine interaction [15]. It can be restricted to one direction or established between several agents.

In the one-on-one strategy the dialogue is very poor in the sense that the tutor communicates advice, recommendations or explanations and the learner can only try to understand through the flow of messages. With a companion the dialogue is multi-lateral; it can be between the learner and the companion, the companion and the tutor or between the learner and the tutor. The form and the nature of the dialogue are different according to the case. The companion and the learner have a quite similar level of knowledge, the companion being there to help the learner to reach short term goals. With a learning by teaching approach the tutor needs (or simulates to need) to receive explanations from the learner and his level of knowledge is lower than the learner.

Quality of assistance

The quality of assistance is strongly related to various factors that can be combined together. They include the knowledge level of explanation, the time of interaction in the problem solving states, the form and accuracy of assistance that is provided (advice, example, question). To support all these aspects a good understanding of learner's knowledge is necessary.

With the one-on-one strategy the quality of assistance is dependent on the competence of the teacher but as generally a teacher has not a precise model of all of his learners (but rather a model of the group) he cannot provide an individually adapted assistance. The learner *receives directives* from the tutor [14].

With a companion the tutor is present and can correct the companion if necessary. The learner *discusses* with the companion and the assistance results from an evaluation by the tutor of the interaction between the learner and the companion.

With a learning by teaching approach the tutor feigns to ignore some aspects of the knowledge (concepts, procedures) and invites the learner to provide him some assistance. The learner *explains* to the tutor. There is no real assistance of the tutor or the assistance is induced by the explanations provided by the learner.

Learner's level

We will consider the knowledge level of the learner according to the level of Gagné. According to Gagné [12], instruction is a set of events external to the learner which are designed to support the internal processes of learning. We consider that these events can place the student in different learning levels corresponding to the main steps of the cognitive process [7]. The seven different levels are successively *acceptance*—no information given to the learner about the knowledge to acquire; *motivation*—student motivated and aware of objectives; *attention*—recall of previously learned capabilities done; *presentation*—introduction of learning tools and stimuli (text, video, demonstration); *initiation*—learner mastery of knowledge in particular simple situations; *intergration*—learner aware of some solutions for more complex situations than those associated with the previous level; *generalization*—learner can transfer the knowledge in various situations. Levels 1–4 represent the conditioning steps (the student is prepared to learn), while levels 5–7 correspond to the steps of effective knowledge acquisition. Notice that during the first steps (level 1–4) the student is not really active in the learning process—he is guided. His active participation increases from levels 5–7 where

he is finally capable of generalizing the solution. According to Gagné the external events which can occur to transfer the knowledge from short term memory to long term memory, lead successively, for the levels indicated above, to phases of semantic encoding, recall of previously learned material and reinforcement of the acquired knowledge.

With the one-on-one the learner can be within the first 4 levels.

With the companion the learner is at level 5 or 6 while in the learning by teaching approach the learner is at level 7.

Learner's self-confidence

The notion of self-confidence has not a common definition in psychology, psychoanalysis and human sciences. Thus, in the common sense expressions relating the notion of self-confidence are numerous [16] and can deal with confidence in the future, confidence in others, confidence in the group or the team, confidence in the test or the difficulty, confidence in justice and laws, climate of confidence, person in whom we can trust, mutual confidence and self-confidence.

We will consider only the self-confidence that we can define as follows: self-confidence in his knowledge, in acquired knowledge, capacity to link the knowledge with the different sources of knowledge, feeling of responsibility, feeling of implication in a goal and generally the learner's self-assurance.

With the one-on-one the self-confidence is not evaluated as the learner is entirely guided by the tutor. As there is a co-operation with the companion the learner needs to prove self-confidence to argument the discussion with him. With learning by teaching, the learner needs to strongly defend his point of view. By explaining he should acquire more self-confidence.

Motivation in learning

A learner can be motivated for several reasons [17]. We can say that there is a motivation [18] if the learner is inclined to reach a goal with personal interest, enthusiasm or pressure. It can be based on the pleasure of competition, discovery or reference to a model.

With the one-on-one the motivation depends on the quality of the tutor and the attraction of the subject matter for the learner. With the companion the motivation is based on a feeling of emulation, taking into consideration that an evaluation has to be done by the tutor. We guess that in a learning by teaching approach the feeling of responsibility is predominant.

The evolution of learning strategies is going to a greater participation of the learner in knowledge acquisition. However, there is a need to test the self-confidence of the learner, to introduce a new form of motivation, to increase the degree of stimulation and to anchor the knowledge in the learner. For these reasons we think that it would be useful to provoke the learner with a companion who would play the role of a troublemaker. We call this new strategy learning by disturbing.

A NEW LEARNING STRATEGY: LEARNING BY DISTURBING

This learning form suggests (Fig. 5) that the computer can be simulated as two agents: a teacher and a troublemaker. The competence level of the troublemaker is superior to the learner in order to provide a reasonable competition with the learner. A problem is submitted both to the learner and the troublemaker. The troublemaker can have different behaviors: give a wrong answer to the problem in order to force the learner to react and propose the right solution, or wait for the solution of the learner and give a wrong suggestion or solution or counter-example. The learner explains the

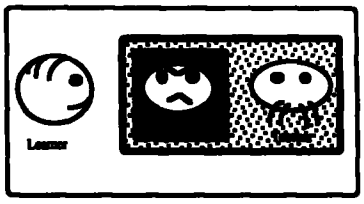

Fig. 5. Learning by disturbing.

troublemaker under the control of the teacher. If the learner is unable to give a correct solution the teacher gives him the right solution.

Tutoring form

This type of learning forces the learner to react to the provocation of the troublemaker by solving problems or questions proposed by the troublemaker. The same process applies when the learner gives a solution to the teached (after a question from the teacher).

Form of the dialogue

The dialogue is deceitful. The teacher asks questions to the learner and the troublemaker interrupts the dialogue to give his own solution. This solution is sometimes right and sometimes wrong.

Quality of assistance

The assistance is erratic. Sometimes, the troublemaker helps the learner and sometimes he misleads. The learner tries to avoid overriding his knowledge by wrong conceptions and thus, has to justify his opinion. This learning method develops a critical behaviour of the learner [19] and also a need to show his competence.

Learner's level

With this approach the learner needs to defend his/her point of view. He knows how to retrieve information previously stored and well organized (level 5 or 6) and the external events that result from the troublemaker lead to recall of previously learned material, link with related knowledge and finally reinforcement.

Learner's self-confidence

This method forces the learner to take self-confidence in his/her actions or conclusions and distinguish between wrong and correct solutions. In addition, it strengthens the knowledge acquisition process. The learner confronts the troublemaker and is faced to his own knowledge and needs to prove that he has assimilated a right knowledge. Ultimately, he would feel a certain pleasure to give proof of his capacity in front of the troublemaker.

Motivation in learning

Here, motivation can be of two kinds: *internal* or *external*. Internal motivation consists in trying to confirm knowledge already acquired facing the assumptions of the troublemaker. Confirmation concerns not only the type of knowledge but also the link with all the other elements of knowledge. The main goal is to avoid a unstabilization of learner's ego. External motivation is guided by the need to show that he/she is right regarding other people. The main goal is to eliminate a feeling of inferiority and stimulate a competition.

Learning has evolved from a passive attitude of the learner to a more active form. The different degree of learner's implication can be illustrated by Fig. 6.

Having reviewed the most important learning strategies and presented our new learning strategy we will experiment this last one and will compare it to the companion strategy.

EVALUATION

In order to verify the validity of this approach we have realized the following experiment. The

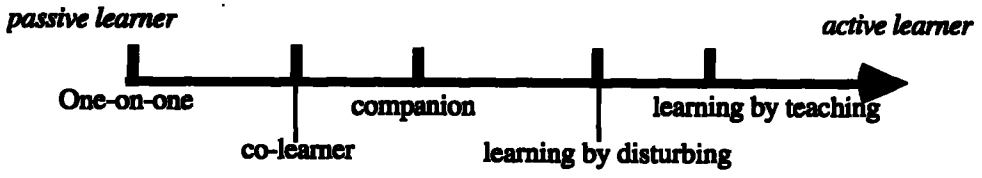

Fig. 6. Evolution of learning strategies.

conditions of experimentation are defined according to: the participants, the material and the evaluation procedure.

Participants

The subject matter that we decided to choose for the experiment was the highway code on which the experiment was conducted. The participants for this evaluation were 40 learners of the computer science department (students or professors) at Université de Montréal. We wanted to compare the results of the learning by disturbing strategy with the learning companion according to different initial knowledge levels.

Materials

The data on which questions were asked dealt with highway code. A total of 42 questions were asked on the traffic signs. Questions were presented to the learner using texts or icons and were visualized on HTML documents. The advantage to use HTML documents is their accessibility on the WEB and their portability on various platforms. However, in this experiment they have no real pedagogical contribution and they consist in giving multiple choices questions. Examples of such questions are given in Figs 7 and 8.

Procedure

We have separated the set of learners into two groups using a random criteria: a *reference group* which was put through the learning companion strategy and a *test group* which experimented the

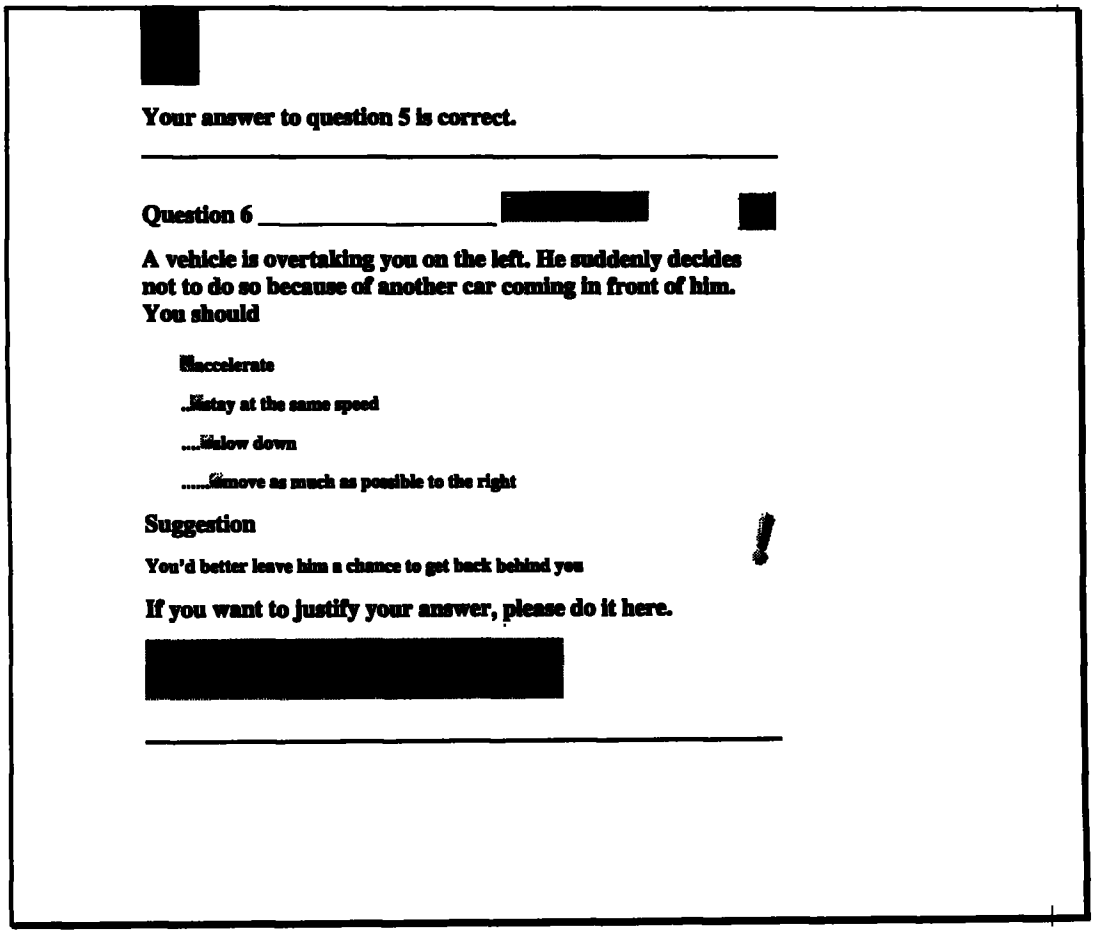

Fig. 7. Question for Learning Companion strategy. The answer of the learner (indicated by the inverted diamond) shows that the learner accepted the suggestion of the companion.

learning by disturbing strategy. After a questionnaire in order to know the *sex*, *age*, *self-confidence* and *experience* of the learner (information that is not directly used in this experiment but that will be considered in further analysis), each group was successively submitted to a *pretest*, *a training phase* and a *posttest*.

The *pretest* was used to (1) eliminate subjects having no prerequisites or with a complete positive evaluation, (2) ensure that we have two groups with the same level of knowledge, and (3) know the initial knowledge of each learner and be able to measure the progress in learning. Candidates to the pretest were evaluated using a set of 12 questions.

For the *training phase* subjects of the two groups were submitted to a same set of 18 questions according to the two strategies, one group receiving suggestions (for the answers) from the companion and the other one from the troublemaker.

The *posttest* allows to evaluate the knowledge of the learners in order to compare them with the results of the pretest and so appreciate the progress (or regress). Posttest contains 12 questions and 15% of them have been proposed in the training phase.

Learners were not aware that they could be exposed to wrong suggestions and they did not communicate in order not to introduce a bias during the test. During the training phase suggestions were given to the learner in each group by the companion or the troublemaker and they were inhibited during the evaluation phase in order to appreciate the effect of the two strategies.

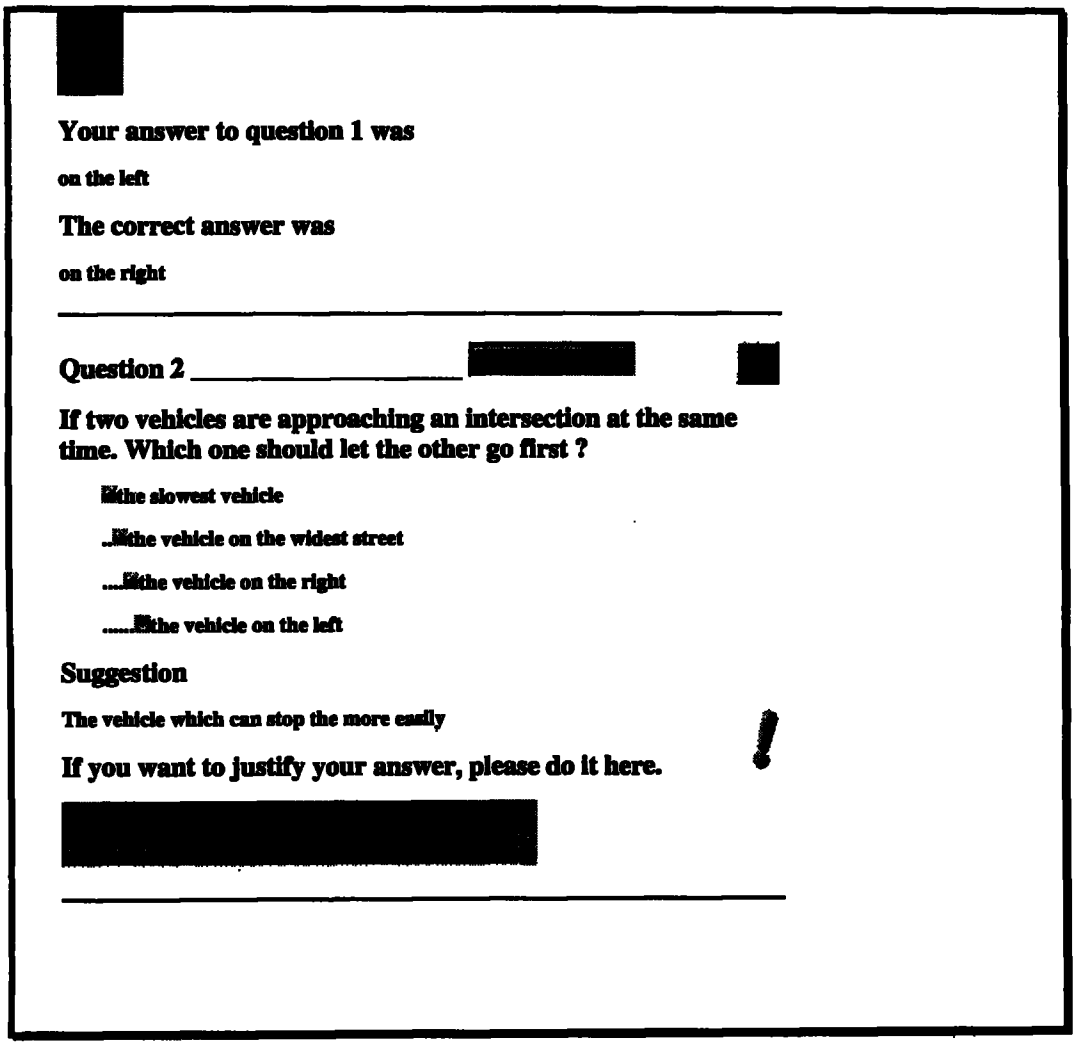

Fig. 8. Question for learning by disturbing. The answer of the learner (indicated by the inverted diamond) shows that the learner did not accept the suggestion of the troublemaker.

Table 1. Pretest results

Strategy	No. of learners	Mean	SD	SEM
Troublemaker	18	71.76	10.36	2.44
Companion	22	72.35	13.21	2.82
t-Value 0.27				
P-Value 0.79				

Table 2. Pretest vs posttests results

Strategy category	Troublemaker		Companion	
	high	weak	high	weak
No. of learners	11	7	12	10
Pretest	78.8	60.7	81.9	60.8
Posttest	83.3	56.0	79.9	74.2
Paired differences				
Mean	4.55	−4.76	−2.08	13.33
SD	13.10	23.99	8.04	10.54
SEM	3.95	9.07	2.32	3.33
t-Value	1.15	−0.53	−0.90	4.00
d.f.	10	6	11	9
P-Value	0.277	0.618	0.389	0.003

Hypothesis

The success of learning by disturbing strategy should depend on the initial knowledge level of the learner and should be efficient for people with a high knowledge level and inefficient for people with unconfirmed knowledge.

RESULTS AND DISCUSSION

The two groups have been separated randomly and were submitted to the pretest in order to verify that they were of equivalent initial knowledge level. The pretest results are listed in Table 1. The high *P* value confirms that the learners in the two groups were not significantly different.

To distinguish the people with a high knowledge level and the people with unconfirmed knowledge we have separated the two groups mentioned above (troublemaker and companion)

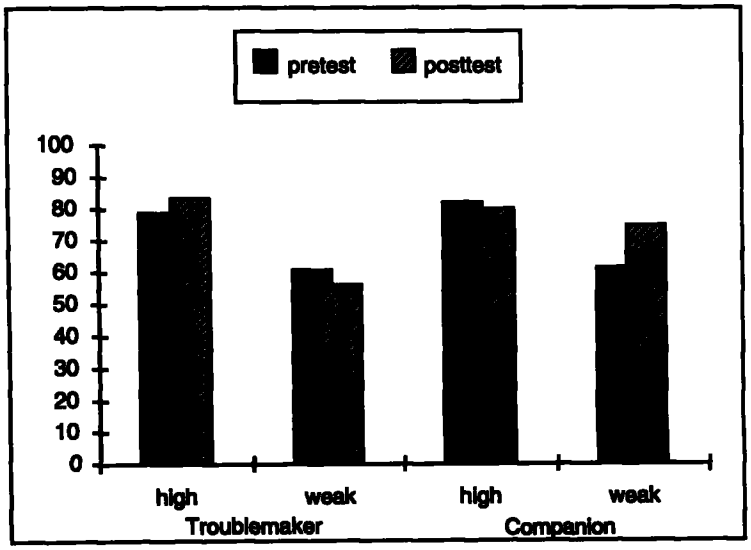

Fig. 9. Results of the two categories within the two strategies.

Table 3. Difference of posttests performance for high level learners

Strategy	No. of learners	Mean	SD	SEM
Troublemaker	11	83.33	12.91	3.91
Companion	12	79.83	8.33	2.41
t-Value −2.255				
P-Value 0.035				

Pretest difference 3.15.

Table 4. Difference of posttests performance for poor level learners

Strategy	No. of learners	Mean	SD	SEM
Troublemaker	7	55.91	26.25	9.91
Companion	10	74.16	13.33	4.16
t-Value 2.040				
P-Value 0.059				

Pretest difference 0.12.

into two categories according to their results at the pretest. Subjects with a score below the average were classified in a *weak* category while subjects with a score greater than the average were classified in a *high* category. These categories correspond respectively to level 5 and 6 of Gagné, as mentioned above. For each category we calculated the difference between the posttest and the pretest. A paired *t*-test was conducted to determine if there was a significant difference in the pretest and posttest scores for each category.

The results are listed in Table 2.

Results of pretest and posttest of each category are indicated in Fig. 9.

We have considered the difference of posttests within each category in order to compare it with the difference of pretests. We have made a bilateral test to check if the difference of posttests means

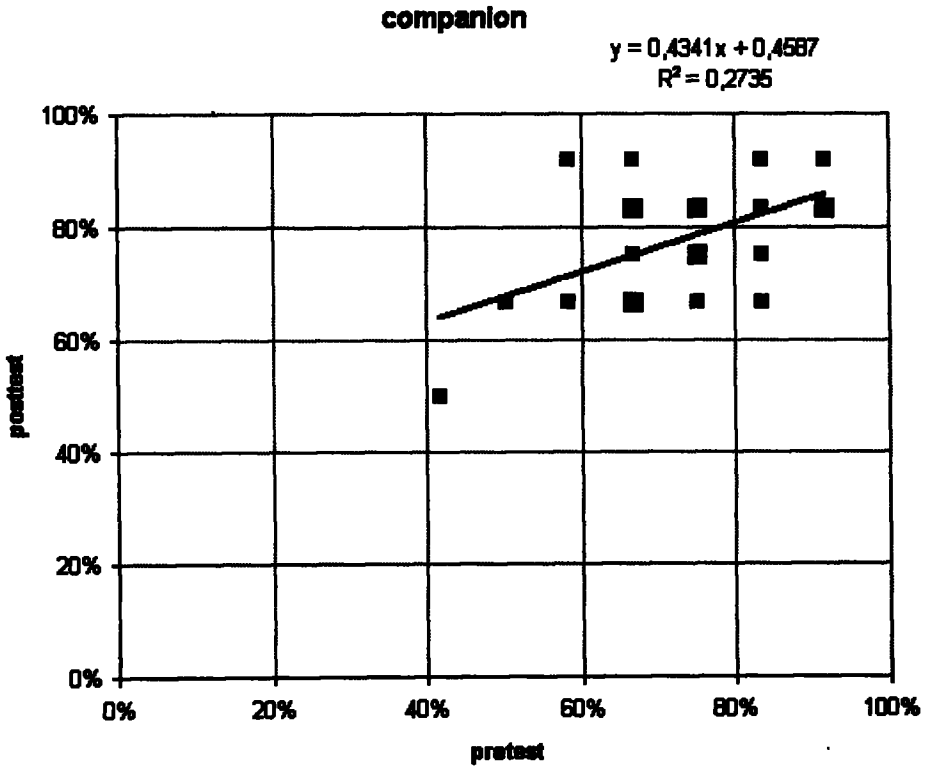

Fig. 10. Results of posttest according to pretest for the companion.

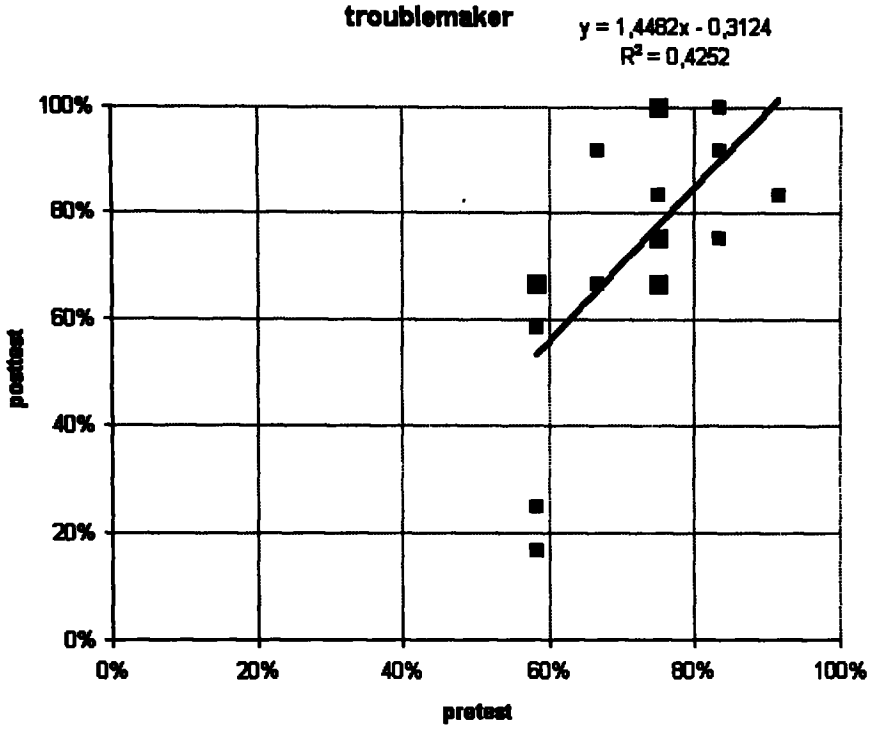

Fig. 11. Results of posttest according to the pretest for the troublemaker.

were equivalent to difference observed for pretests. We have made the same *hypothesis* for high and poor levels learners: "if the difference between pretest means is equal to the difference of posttest means then progress in learning would be equivalent within each strategy for both categories of learners".

Tables 3 and 4 indicate results obtained for high level learners and poor learners. The low *P* value shows that a significant difference effectively exists.

Analysis of Tables 3 and 4 shows that good learners learn better with a troublemaker than with a companion while poor learners learn better with a companion.

Now we aim to show the relationship between performance at the pretest and the posttest for each strategy. Figures 10 and 11 illustrate the results (pretest and posttest) for each learner in a given strategy. Each small square represents results of a learner while bigger square represents more than one learner's result with the same performance at the pretest and the posttest.

We have calculated the regression line for each strategy. It appears that the slope of the troublemaker is greater than one while the companion is less than one. The two lines intersect for a pretest of 76%. This determines the conditions of efficiency of each strategy. For a pretest lower than 76 the companion appears more suitable while the troublemaker should be more efficient with a pretest higher than 76.

CONCLUSIONS AND PERSPECTIVES

We have considered the evolution of learning strategies and found that participation of the learner can benefit from various modes of interaction between different agents. In this way we have progressively found that implication of the learner into the learning process can be increased according to several parameters. Among them the level of knowledge can be used to improve learning but also to prove that knowledge has been well acquired.

We have developed a new strategy called learning by disturbing involving a troublemaker. The pedagogical interest is that the troublemaker can sometimes give misleading advice and so points out some subtlety which would have been hidden. It can also provoke the learner in order to force him to deploy and demonstrate the linkage of his knowledge and his self-confidence in defending his opinion.

Results of the experiment clearly demonstrate that training can be enhanced using learning by disturbing, according to certain conditions:

- learning by disturbing gives better results for people having a good knowledge of the subject matter and seems to be dangerous for people with unconfirmed knowledge;
- the companion is more efficient for poor learners.

Why does learning by disturbing appear useful for good students and inefficient for poor learners? We can advance several interpretations:

- the memorization process is better activated with failure than with success cases [2], especially for good learners;
- learning by disturbing strengthens the attention of the learner, increases the perception of details and provides the means for argumenting and memorizing;
- good learners are more motivated by competitive situations while poor learners aspire to receive help rather than troubles. There is no competition in the companion strategy but rather a co-operation;
- the learning by disturbing has the advantage to highlight the subtleties of some questions which would have been hidden.

We are presently experimenting, into the SAFARI† project [21, 22], a system based on multiple strategies which can be dynamically selected according to the learner's knowledge level. It involves the tutor, the companion and the troublemaker. The present results are fundamental to know how to select the best strategy for a given learner. Previously, we were only able to consider some initial characteristics of the learner but with a dynamic analysis of the knowledge level it is particularly useful to detect the point for which the companion or the troublemaker should be efficiently activated. These two strategies are important as they can intervene when the learner is in the most active conditions of learning.

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†The SAFARI project aims to develop various ITS in industrial training.

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