

# Some justifications about the learning by disturbing strategy

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**Abstract:** Intelligent Tutoring Systems (ITS) are evolving towards a more co-operative relationship between the system and the student. More and more, learning is considered as a constructive process rather than a simple transfer of knowledge. This trend has brought to light new co-operative tutoring strategies. One of these tutoring strategies, the learning companion, designed to overcome some of the limitations of the classical tutoring model, involves a student and two simulated participants: a tutor and another student. More recently a new strategy, learning by disturbing, has been proposed. In this strategy, the simulated student is a troublemaker whose role is to deliberately disturb the human student. This article describes the learning by disturbing strategy by contrasting it with the learning companion strategy. In addition, some links are drawn between this new strategy and the psychology of learning, in particular the cognitive dissonance theory.

**Key words:** Intelligent tutoring systems, tutoring strategies, co-operative learning, cognitive dissonance, learning by disturbing

## 1. INTRODUCTION

Intelligent Tutoring Systems (ITS) have long sought to reproduce the behaviour of intelligent human tutors in dispensing personalised education. In many of these systems, the tutor plays a central role : directing the content of the instruction and controlling the discourse with the student. This prescriptive approach has evolved and is being replaced by a more constructive approach.

It is therefore not surprising that in the late 80s ITS begin to model relationships other than the tutor-student team. The first such approach was the co-learner strategy [1] which allows the student to work with a co-learner simulated by the system. Since there is no tutor, this strategy is most useful for discovery learning. In a second approach, initially proposed by Chan and Baskin [2], a tutor supervises the human student and a simulated companion. Initially, this companion was to act as a student with strengths and weaknesses comparable to the learner. In this respect, the companion has no pedagogical expertise.

The next step in this approach is to replace the companion with a troublemaker [3] who is no longer a simple simulation of a student but who has the pedagogical expertise necessary to maximise the impact of its interventions. In particular, the troublemaker can propose erroneous solutions to the learner so as to systematically test the student's level of self-confidence. In a sense the troublemaker can zero-in on the learner's weaknesses and force the student to confront and overcome them.

According to Festinger [4], *cognitive dissonance* is an important factor in motivating a student. In perceiving a difference between his knowledge and that which the troublemaker suggests, the learner experiences cognitive dissonance. This psychological discomfort leads the student to either revise or defend his position and motivates him to learn.

The goal of this article is to, on one hand, compare the two tutoring strategies ( that of the learning companion and that of the troublemaker) and, on the other, to present some of the psychological justifications for the troublemaker strategy. To do this, we begin with a review of some tutoring strategies, paying particular attention to the co-operative strategies. We then present the comparison of the two tutoring strategies followed by the psychological foundations of the troublemaker. Finally, we will present an ITS prototype which successfully applies the troublemaker strategy to teaching diagnostic reasoning for mammography analysis.

## **2. TUTORING STRATEGIES**

It is necessary to have different tutoring strategies since :

- different domains require different approaches (some can be taught by a very directive approach while other simply can not),
- the variation of teaching strategies serves as a means to maintain the interest and motivation of the learner,
- different tutoring strategies fulfill different goals and develop different abilities in the learner.

### **2.1. Directive learning**

This approach (also called *one-on-one* strategy) [5] preceded the co-operative systems and consists in having the computer simulate an intelligent tutor who can understand the learner and provide adaptive tutoring. The learner receives knowledge directly from the tutor who communicates and acts according to a prescriptive behaviour.

## 2.2. Peer learning

An alternative to the 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 using the computer more as a partner than as a tutor. Multiple agents that are either computer simulated or real human beings can work on the same computer or share a computer network.

Chan and Baskin proposed a three-agent learning situation [2] which consists in a co-operation between a human learner and a simulated learning companion. They learn together under the guidance of the tutor. 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 tutor for help only if they cannot find a solution. The role of the tutor is to alternate between a presentation of problems and a critique of the learner's solution.

The learning by disturbing strategy [3] suggests that the computer can simulate two agents: a tutor and a *troublemaker*. The level of competence of the troublemaker is superior that of the learner in order to provide reasonable competition. In addition it has some pedagogical knowledge which can help it to efficiently plan its interactions. A problem is submitted to both the learner and the troublemaker. The troublemaker can have different behaviours: give an erroneous answer to the problem (in order to force the learner to react and propose the right solution), wait for the solution of the learner and give an erroneous suggestion, a solution or a counter-example. The learner explains his decisions to the troublemaker in a process controlled by the tutor.

For the strategy to be pedagogically sound the troublemaker proposes erroneous suggestions to the student emphasising some of the finer points of the exercise at hand.

## 3. THE LEARNING BY DISTURBING STRATEGY

In this section we describe the learning by disturbing strategy by : describing the participants and their roles, comparing the strategy with that of the learning companion, and finally, presenting the links with cognitive dissonance theory.

### 3.1 Description

The troublemaker strategy implicates three participants [3] [6] :

- The tutor presents to the team of students both the *lessons* and the *exercises* to be solved. It is the tutor who controls both the content and the length of the session. At any time, the tutor may intervene to help one of the students in their task. Finally, it is the tutor who evaluates the performance of the learner.
- The learner is the human student who is using the ITS. The learner interacts with the other participants via either natural language or symbolic dialogue. The system maintains at all times a model of the learner which describes the state of the student's knowledge relative to

the system's objectives and the student's emotional state. The later is particularly relevant to the troublemaker strategy since it is important to gage the student's confidence levels to plan the troublemaker's actions.

- The troublemaker appears to be a simulation of a student working with the learner. In fact the troublemaker possesses both pedagogical expertise and a level of knowledge of the domain comparable to that of the tutor [3]. The troublemaker uses this pedagogical expertise to maximise the impact of its interventions. The role of the troublemaker is to unsettle the student by proposing solutions which are sometimes truthful but other times erroneous. This tests the student's self-confidence and obliges him to defend his point of view. We believe that this argumentation increases the student's motivation and increases learning.

In the current implementation of the troublemaker strategy there are three participants present (one of each type) but in the future we envisage an environment with more than one tutor and/or troublemaker, each with their own 'personality'. In this article we only discuss the simplified system.

An experiment with the troublemaker strategy led in 1996 has decisively shown that this strategy has a better effect on learners who have a strong background in the domain. In particular, students who received a grade of 76% or better in the pre-test benefited from the troublemaker strategy while those who received a grade less than 76% were better served by the learning companion.

This experiment, necessary to understand the impact of the troublemaker on different learners, is but a first step towards a true implementation of the strategy. A more recent version of the troublemaker which includes more interaction between the learner and the troublemaker is described in [7].

The different experiments mentioned here were conducted under the SAFARI project [8]

### **3.2 Qualitative comparison between the learning companion strategy and learning by disturbing**

The learning by disturbing strategy is relatively new and is still under development. Those who are accustomed to the learning companion strategy may well ask themselves : why do we need the learning by disturbing strategy? One justification is given in [3]: « 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 of the learner. »

However, 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 the self-confidence of the learner, his motivation in learning and the pedagogical knowledge implied. In the following we briefly review the form of these criteria in the two strategies: the companion and learning by disturbing.

- **Learner's self-confidence**

We define self-confidence as follows: self-confidence in one's knowledge, in acquired knowledge, a capacity to link the knowledge with the different sources of knowledge, a feeling of responsibility, a feeling of implication in a goal.

With the learning companion, the learner needs to be self-confident in order to discuss with him.

Learning by disturbing forces the learner to be even more self-confident in his actions or conclusions and to distinguish between wrong and correct solutions. In addition, it strengthens the knowledge acquisition process. The learner confronts the troublemaker, facing its position and needing to prove that he has learned correctly. Ultimately, he would feel a certain pleasure to give proof of his capacity in front of the troublemaker.

- **Motivation in learning**

A learner can be motivated for several reasons. We can say that there is a motivation 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, identification with a model.

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.

As we have mentioned earlier we need to know 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.

- **Pedagogical knowledge**

Unlike the learning companion, the troublemaker possesses pedagogical knowledge. Despite the fact that it appears to be a student, in this respect it is akin to the tutor. Two points are to be noted:

- Both the troublemaker and the tutor have complete knowledge of the domain. This is not necessarily the case for the learning companion.
- In addition the troublemaker possesses certain pedagogical knowledge that the tutor does not have: When to disturb ? How far to argue a erroneous point ? etc.

### **3.3 Psychological foundations of the learning by disturbing strategy**

Before proceeding to an implementation of the learning by disturbing strategy, we found it necessary to establish a clear link between this strategy and existing theories of the psychology of learning. This was done and has allowed us to:

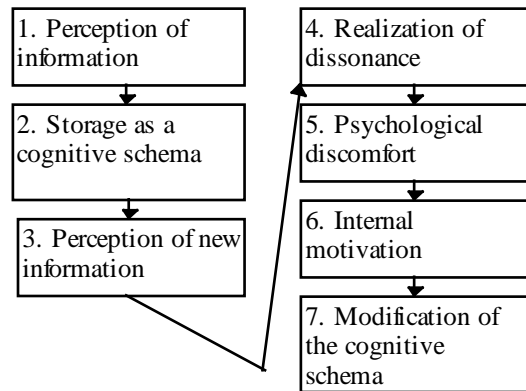
- better predict the impact of this strategy on various learners
- validate the strategy by psychologists and experts in teaching
- better direct the development of the strategy under a clear theoretical framework

One can find two types of motivation in a student: internal or external. External motivation, which we do not focus on in this work, depends upon factors which are outside the student: performance, social acceptance, etc. Internal motivation is defined by Tardif [9] is a motivation

which comes from within an individual and accordingly the actions which this person undertakes correspond to needs, likes, or preferences which are specific to that person.

In his description of the WEST system, Chan [10], highlights the two most significant factors in internal motivation. The first is particularly relevant: "The first is in terms of incongruity. Organisms are seen as needing to encounter stimulus events that are moderately discrepant from their accustomed stimulation. That is, an organism is intrinsically motivated by a need to encounter a moderate difference between his experience and his environment."

*Cognitive dissonance* theory [4] develops this observation further. His definition of cognitive dissonance is the perception, by a subject, of a difference, of variable intensity, between that which has been previously perceived and learned and new information. This process is illustrated by figure 1.



**Figure 1: Steps in the cognitive dissonance process**

Festinger links strongly cognitive dissonance and internal motivation: "The existence of dissonance, being psychologically uncomfortable, will motivate the person to try to reduce the dissonance and achieve consonance. (...) In short, I am proposing that dissonance, that is the existence of non-fitting relations among cognitions, is a motivating factor in its own right." [4]

A key feature of Festinger's theory is the expectations that the subject has. In fact, the subject seeks to corroborate his conception of the environment by what he perceives. "New information may become known to a person, creating at least a momentary dissonance with existing knowledge, opinion or cognition concerning behaviour. Since a person does not have complete and perfect control over the information that reaches him and over events that can happen in his environment, such dissonance may easily arise." [11]

An individual experiencing cognitive dissonance may lead to negative consequences:

- the individual may incorporate inconsistent and contradictory knowledge into his cognitive schemas and then use them in a dysfunctional manner. This is exemplified when a student, who believes from childhood that two objects of unequal mass will fall at different velocities, is taught the contrary. It is possible that this student will maintain both beliefs,

being able to state the law of physics correctly but answering incorrectly an exercise on an exam. (It is important to note that a single piece of information can be represented in different manners and then stored as different cognitive schemas. This poor assimilation of information is precisely the type of error that an ITS can detect and correct, see step 2 of figure 1.)

- the individual may attempt to avoid the situation which has caused the dissonance, even if this means committing an error. This reflex is instinctive, unconscious and depends on the personality of the subject and his perception of the resources available to him. For example, a student who does not understand a subject may decide to no longer study it unless forced to. Another student in the same circumstances may simply refuse to ask questions in class from fear of being mocked.
- the individual may become suspicious of new information and so therefore his confidence when interacting with others may diminish

Festinger adds that, essentially, inertia makes us accept what we believe to be true. Additionally, any information which does not seem relevant to the subject does not motivate. Nevertheless, there exist situations when we are exposed by force to contradictory information. A feeling of cognitive dissonance so triggered will start the process illustrated in figure 1.

Therefore all individuals will experience cognitive dissonance while interacting with their environment. A very common source is the interaction individuals have with other people: "When a person is confronted with an opinion contrary to its own which is held by people like himself, he experiences dissonance" [11].

The intensity of the dissonance depends on two factors:

- the perceived competence of the person or group expressing the contradictory opinion (in our case this is the perceived competence of the troublemaker)
- the emotional relationship to the person or group expressing the contradictory opinion (in our case this is related to the emotional relationship with the troublemaker)

The individual experiencing cognitive dissonance triggered by another person can react in four ways:

- (1) Dismissing the subject of dispute as being unimportant
- (2) Dismissing the other person as being unimportant
- (3) Attempting to eliminate the dissonance by:
  - changing his own opinion (by letting himself be convinced)
  - attempting to change the opinion of the other person (in particular by initiating a debate with that person)
- (4) Seeking new information in his environment which would support his opinion. For example in a community (such as a system with several participants) the individual could seek social support.

The following points describe the learning by disturbing strategy in the context of cognitive dissonance theory :

- (1) A cognitive dissonance is triggered by the troublemaker's interventions

- (2) At that time, the troublemaker is the only available source of information.<sup>1</sup>
- (3) In order to reduce the dissonance the learner is motivated to search for new information in his environment.
- (4) The mechanisms used are dialogue and debate with the troublemaker and this process has two outcomes:
- the student can let himself be convinced
  - the student can change his environment by convincing the troublemaker

Finally, two factors influence the outcome of this debate:

- the confidence that the student has in his cognitive schema
- the ability the troublemaker has to express its ideas in a convincing manner

The student-troublemaker interaction is described in figure 2.

<b>Troublemaker's suggestion</b>	<b>Student's opinion</b>	<b>Student's reactions</b>
Correct	Erroneous	<ul style="list-style-type: none"> <li>• maintain the original erroneous cognitive schema<sup>2</sup></li> <li>• revise his beliefs and correct the error</li> <li>• accept the information presented by the troublemaker and construct a dysfunctional schema<sup>1</sup></li> </ul>
Correct	Correct	<ul style="list-style-type: none"> <li>• confirm his cognitive schema and reinforce his confidence<sup>3</sup></li> </ul>
Erroneous	Erroneous	<ul style="list-style-type: none"> <li>• maintain the original erroneous cognitive schema</li> <li>• accept the information presented by the troublemaker integrate it to schemas in a consonant manner</li> <li>• accept the information presented by the troublemaker integrate it to schemas in a dissonant manner<sup>1</sup></li> </ul>
Erroneous	Correct	<ul style="list-style-type: none"> <li>• maintain his cognitive schema and reinforce his confidence<sup>2</sup></li> <li>• accept the information presented by the troublemaker and integrate it to schemas in a consonant manner</li> <li>• accept the information presented by the troublemaker and construct a dysfunctional schema<sup>1</sup></li> </ul>

**Figure 2: Student-troublemaker interactions**

<sup>1</sup> However, one can imagine a strategy in which the tutor is accessible during the debate between the student and the troublemaker.



In case (1) the student is tempted to accept the information of the troublemaker even though it contradicts his own cognitive schema. This situation indicates weaknesses in either the student's intellectual effort, cognitive strategies or self-confidence. In all cases the student may not be ready to be exposed to the learning by disturbing strategy. Case (2) can not occur if the system imposes the constraint that the student and the troublemaker must reach a consensus. Finally, situations which cause the creation of dysfunctional cognitive schemas are caused by a poor intervention by the troublemaker and must be avoided at all costs. These situations can lead the student to confusion or even to frustration.

In all cases except (3), there is cognitive dissonance and therefore internal motivation. This motivation is shown by a need to dialogue with the troublemaker, especially when it is the only available source of information. There is also cognitive dissonance when the tutor corrects the student. This situation is less interesting because it happens at the end of the problem resolution process and because the student knows that the information being presented is correct. The student may still not integrate the information correctly as described above.

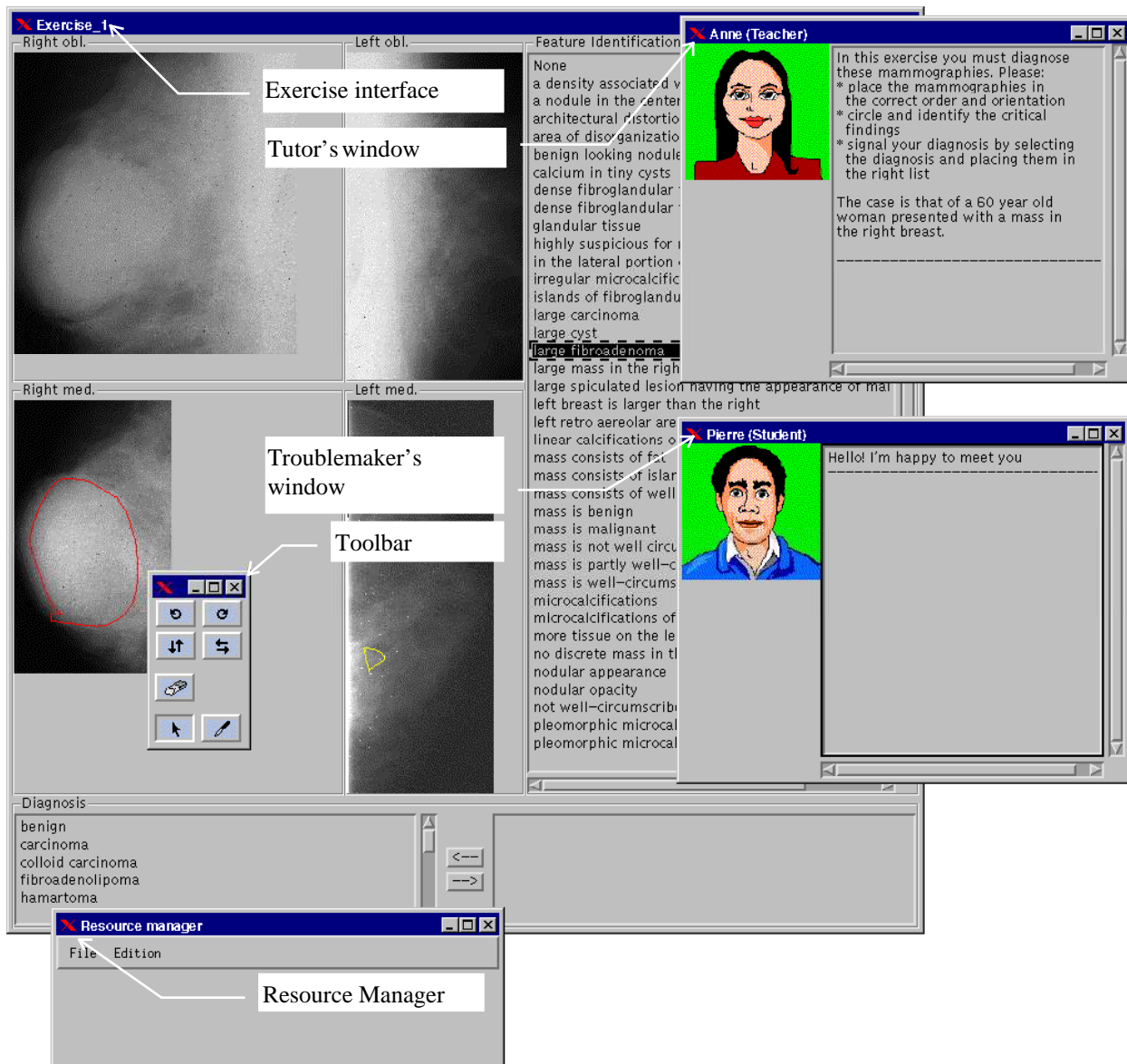
It is interesting to ask what impact each intervention of the troublemaker should have. It is clear that cognitive dissonance should not be the result each and every time, so when is it important to disturb the student? A few important points to keep in mind are:

- If the student's confidence is dropping even though they are correct it is interesting to have the troublemaker present correct suggestions to reinforce the student's beliefs.
- In some cases the troublemaker can make such a large error that there is no doubt that the student can correct it. This will increase the student's confidence and give him a feeling of competence.
- When the student begins to develop self-confidence, the troublemaker's suggestions should become more aggressive in order to disturb the student. It is at these moments that the tutor can intervene to demand consensus so that the student does not dismiss the troublemaker out of hand.

#### **4. SPECIFICATION OF THE LEARNING BY DISTURBING STRATEGY**

In the course of our research, both the learning companion strategy and learning by disturbing have been experimented on various domains such as the highway code, college level computer science and the spreadsheet application Microsoft Excel.

In this section we present an experiment in the medical domain, in particular in the diagnosis of mammographies.



**Figure 3 : Mammography diagnosis prototype user interface**

The exercise illustrated by figure 3 consists of diagnosing the various ailments afflicting the patient in question. The central element of the interface is a set of four mammographies. We have chosen for our initial work simple cases where the student does not need to refer to past case history and can make the diagnosis from the presented mammographies. The exercise consists of four distinct steps :

1. Ordering of the mammographies : thanks to the tools located in the toolbar the student must place the four mammographies in the correct order and orientation. The troublemaker does not participate in this part of the exercise. When the student has finished, they select the feature identification tool. At this time the tutor will intervene, either congratulating the student or to correct him. The type of correction depends on two parameters : the number of

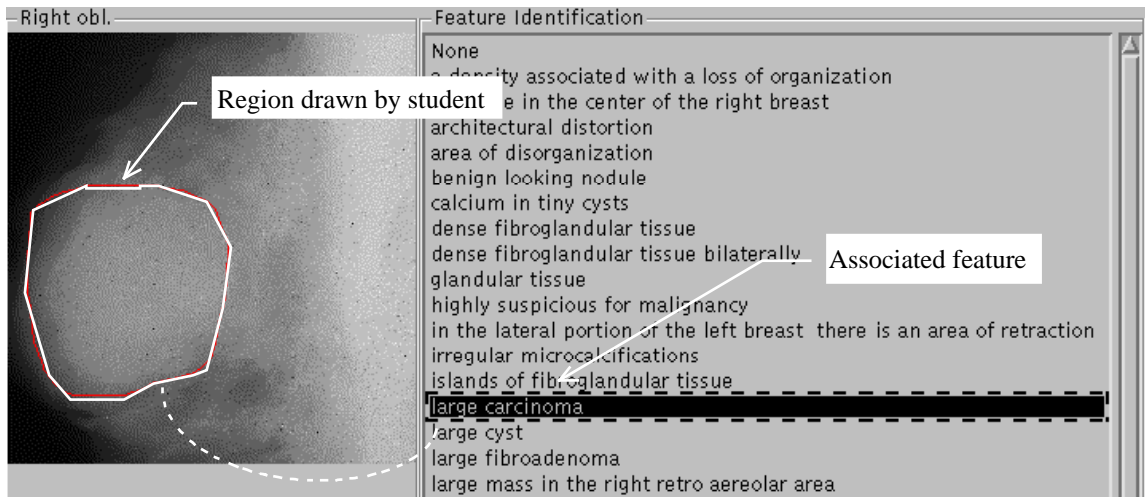
errors in the placement of the images (order, rotation, etc.) and the number of errors committed in the past. If the error is not severe, the tutor takes on a surprised expression and simply suggests that the student try again. If the error is severe or has been repeated several times, the tutor takes on an angry expression and places the mammographies in the correct order. The student then proceeds to the next stage.

2. Location critical features : the student draws the outline of the regions which seem relevant to the diagnostic. It is always possible to select a previously drawn feature and to erase it. When the student is done identifying a feature, a background process is launched (in a thread) which calculates the similarity between the student's identification and the expert's. Each of the expert's regions is associated to a minimum threshold that the student must meet if his finding is to be accepted. Other calculations are made in order to assess the type of error committed, for example is the student region too small, too large, too imprecise, etc. If a certain type of error is committed repeatedly the student should receive instruction to remedy that misconception.

When a region is accepted the tutor congratulates the student. When a region is rejected the tutor will seem surprised, erase the student region and ask him to try again. Should the student fail several times, the tutor will correctly identify the feature for him. These interactions are reinforced by the tutor's cursor which points to the objects the tutor speaks of.

3. Identification of the findings : at all times the student can select a feature previously identified and associated to that feature a finding (see figure 4).

It is at this moment that the troublemaker really comes into play. The troublemaker can decide to remain silent but can also decide to contradict the student. In this case it will present a suggestion (either truthful or erroneous) to the student. This will be followed by a modal dialogue box asking if the student is in agreement. Should the student agree, the troublemaker's identification is made and the tutor will correct the student team. Should the student disagree, the troublemaker will present a justification for its opinion and ask the student's agreement again. This cycle continues until the troublemaker runs out of reasons or the student agrees. The tutor can of course intervene at all times to propose the correct solution or make some remark. The facial expression of the troublemaker changes according to its state of agreement with the student (happy, surprised, angry, etc.)



**Figure 4 : Association of findings to features**

4. **Diagnosis :** the student chooses the diagnosis that they wish to propose from the left-hand list sorted by the importance that they feel should be associated to each diagnosis. The troublemaker can intervene at each step to show either agreement or disagreement and can justify its opinions as described above. If the student has not found all the critical findings, the tutor intervenes immediately to instruct the student that they are not yet ready to diagnose. The exercise ends when the correct diagnosis is found or when the student has failed too many times in which case the tutor presents the correct solution.

## 5. CONCLUSION

In this article we have described the learning by disturbing strategy, In particular we have shown the differences and similarities between it and the learning companion strategy. We have justified the troublemaker thanks to cognitive dissonance theory, stating that the dissonance caused by the troublemaker acts as a motivating factor.

The learning by disturbing strategy is not only a tutoring strategy but can also serve as a method for evaluation which, rather than being summary, can contribute greatly to the learning process. In fact, in addition to the social role the troublemaker plays, the learner is evaluated throughout the session by it this increases his self-confidence.

That being said we do not ignore the limitations of learning by disturbing. This strategy is useful only for learners who have already acquired a minimum amount of knowledge and should not be used on novices since it could discourage them.

In conclusion we would like to highlight that the learning by disturbing strategy :

- favours the construction of arguments and the exchange of these between the student and the troublemaker
- encourages the learner to question his own knowledge
- motivates the learner

- accentuates immediate feedback
- helps the learner face failure more responsibly
- reinforces a favourable perception of the tutor since they are not the ones who commit mistakes

## ACKNOWLEDGMENTS

The medical prototype has been developed at the University of Montreal by Daniel Leibu and Hugo Dufort. The radiological expertise was provided by the cognitive science team at McGill University based on the doctoral work of Roger Azevedo. The prototype is based in part on software designed by Charles De Léan.

This work has been supported by the Ministry of Industry, Trade , Science, and Technology (MICST) under the Synergy program of the Government of Québec.

## REFERENCES

1. Gilmore, D. & Self, J. The application of machine learning to intelligent tutoring systems. In J. Self, (Ed.) *Artificial Intelligence and Human Learning, Intelligent computer-assisted instruction*, New York: Chapman and Hall, pp. 179-196, 1988.
2. Chan, T.W. & Baskin, A.B. Learning Companion Systems. In C. Frasson & G. Gauthier (Eds.) *Intelligent Tutoring Systems: At the Crossroads of Artificial Intelligence and Education*, Chapter 1, New Jersey: Ablex Publishing Corporation, 1990.
3. Aïmeur, E., Frasson, C. "Analyzing a New Learning Strategy according to different knowledge levels", *Computer and Education, An International Journal* , vol 27, no 2 , pp 115-127, 1996.
4. Festinger, Leon . *A theory of cognitive dissonance*, 291 p., Stanford University Press, pp.1-31,260-279, 1957.
5. Sleeman D. H. and Brown J.S., *Intelligent Tutoring Systems*. Academic Press, London 1982.
6. Dufort, H., Aïmeur, E., and Frasson, C. "Systèmes tutoriels intelligents: quelques aspects de la stratégie du perturbateur", publication départementale, Département d'Informatique et de Recherche Opérationnelle (D.I.R.O.), Université de Montréal, Publication No. 1055, Décembre 1996, 23 pp.

7. Frasson, C., Mengelle, T., Aïmeur, E., Gouardères, G. "An Actor-based Architecture for Intelligent Tutoring Systems", Proceedings of ITS'96 Conference, Lecture Notes in Computer Science, No. 1086, Springer Verlag, pp. 57-65, 1996.
8. Frasson, C., Aïmeur, E. "SAFARI: a University-Industry Cooperative Project", International Conference on Success and Pitfall of Knowledge-Based Systems in Real-World Application, Bangkok, Thailand, pp. 225-253, Edited by D. Batanov & P. Brezillon, 1996.
9. Tardif, Jacques. *Pour un enseignement stratégique: l'apport de la psychologie cognitive*, Éditions Logiques, Montréal, pp.191-209, 1992.
10. Chan, T.W., Chung, Y.L., Ho, R.G., Hou, W.J. & Lin, G.L. Distributed Learning Companion Systems—WEST Revisited. The 2nd International Conference of Intelligent Tutoring Systems, *Lecture Notes in Computer Science*, 608, Springer-Verlag, pp. 643-650, 1992.
11. Festinger, Leon. "The Arousal and Reduction of Dissonance in Social Contexts". *Extending Psychological Frontiers. Selected Works of Leon Festinger*. Russell Sage Foundation: New-York. Edited by Stanley Schachter and Michael Gazzaniga. pp. 238-257, 1989.