The Role of Pedagogical Context in Intelligent Tutoring Systems

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Abstract

Our work consists in designing and implementing an *Intelligent Tutoring System* (ITS) for college students taking a Mechanical Physics course. The primary goal of this system is to increase the learning ability of the learner while creating strong links between the concepts learned.
Using a *pedagogical context,* which include cognitive and affective contexts we give an adapted teaching to each learner.

Based on the concepts he already possesses and on his experiences, the learner transfers his knowledge onto new notions and situations, which he may encounter.

For this purpose, we use a learning strategy called "*Experiences Transfer Learning Strategy*"(ETLS). This strategy is based upon the notions already known by the learner to teach him a new notion, showing the similarities and the differences between these concepts. Our ITS teaches the notion of kinetic friction using the students knowledge on static friction. Only two agents are implied in the ETLS: the tutor (machine) and the learner (human).

This strategy puts into application three fundamental pedagogical aspects: *find, use* and *remember.* This is done in our ITS by dividing it into four phases: two learning phases implementing the "find" aspect, a practice phase and an evaluation phase both using the "use" and the "remember" aspects.

We have implemented an intelligent tutoring system named KITS for teaching kinetic friction

Keywords: Intelligent tutoring system, Pedagogical context, Cognitive context, Affective context, Experimentation.

Introduction

Even though *Intelligent tutoring systems* (ITS) are recent compared to other domains of computer engineering,they have been largely documented (Burns, Capps, 1988), (Frasson, Gauthier, 1990). In fact, these systems have only existed in their final forms for the past few decades. The ITS are one of the children of *Artificial Intelligence* (AI), (Allen, *et al.* 1995) perhaps one of the most technically advanced and certainly one of the most known by the public. AI's field of study is in itself recent. Emerging in the fifties, this domain was born with the idea of giving the machine human intelligence, or at least giving it some of its characteristics! Of all aspects of the human intelligence, learning ability is undoubtedly the most fantastic. And so was born the idea to create an intelligent system capable of reproducing, simulating and stimulating the learning mechanism: the ITS

We are now entering the learning and computer assisted teaching context. The ITS's first goal is to provide an adapted, personalized teaching. To do so, we have to take into account the context of training and learning (Aimeur,
into account the context of training and learning (Aimeur, n, 1995).

The context in which a user is generally placed can be considered according to various points of view. The IJCAI workshop (Brezillon, Abu-Hakima,1995) address several major problems and notions related to the context, particularly through a series of questions concerning the nature of context, its elements, representation and use (Brezillon *et al,* 1998).

The first international conference on context (Brezillon, Cavalcanti, 1997) provided several meanings for context with a special focus on applications. New trends in the formalisation of context at a theoretical level, as well as in the use of context in real-world applications

Brezillon (1999) made an excellent survey about context especially in domains related to Artificial intelligence. He distinguished context in natural language processing (Iwanska, 1995), context in databases and ontologies (Oracle, 1996), context in communication (Grant, 1994), context in electronic documentation (Boy, 1995), and context in vision (Bremond, Thonnat, 1997). What appears obvious is that there is no common agreement on the definition of context.

Our definition of context

We have a *global context,* which concerns learning, and a *local context* illustrated by the domain of physic and more specifically the kinetic friction

Moreover we define a **pedagogical context** by two elements the *cognitive context* which includes the knowledge level of the learner and the *affective context,* which includes motivation and self-confidence.

The system that we have developed is an ITS aimed at teaching the concept of *kinetic friction.* Kinetic friction is a force created between two objects **in movement**. We chose the Physics domain because we had the opportunity to experiment on a sizeable population of students. Since computer assisted teaching is more and more common, we were very much encouraged to develop this ITS. We had to take into consideration and adapt our system to several things: academic environment, course outline, and the scientific notation found in student textbooks (always important in science). We will now present a brief overview of our *Kinetic Friction Intelligent Tutoring System: KITS.*

Since the learner meets for the first time the kinetic friction concept, we have developed a section called *First Learning Session,* which is very complete (see the following section for a deeper description). This session is the equivalent of a first course on kinetic friction. Following that first session is the *practice session* where the learner has to differentiate kinetic and static friction by the means of problems. This last section will help us to adapt the next one, which is called *Second Learning Session.* The second learning session is based on the results of the practice session and is therefore adapted to the learner. Finally, the *evaluation session* verifies whether the learner has understood and assimilated the concept of kinetic friction in order to react positively in the future tutorials. (This point is important, particularly for the teacher so he can pursue his work and to provide his students with better help.) In short, our ITS's objectives are to, realize the best possible integration of concepts and then, ensuring that this integration goes naturally and that the integration's pedagogical point is personalized to each learner. Furthermore, our ITS aims at teaching the learner as much as it wants, in order to ease the teacher's process of following the students (especially the ones in difficulty).

Pedagogical context

In this section, we will concentrate on the pedagogical strategy used by KITS. We saw that this strategy is divided in four phases and is based on the knowledge that the learner already possesses. In our case the learner is supposed to understand the concept of static friction because it is used as a prerequisite. Indeed, the strategy that we call "*Experiences Transfer Learning Strategy*" is based on a beforehand acquired notion (here the static friction), ideally totally understood, to explain a new one: kinetic friction. To do this, we have developed a series of examples, definitions, problems and methods to help the learner understand the link between the two concepts and to stay in a good cognitive context, which in pedagogy is a fundamental concept.

The context of KITS

As the process in question relies on knowledge communication, it is fundamental to know as precisely as possible the level of knowledge of the learner in order to adapt the level of the system. Taking into account the elements discussed above, our definition of **pedagogical context** will include the following elements:

- the ***cognitive context*** at which the learner is placed,
- the ***affective context*** of the learner.

The cognitive context

According to Gagné (Gagné, 1984), 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. The different levels (seven 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, etc.), *initiation* (learner mastery of knowledge in particular simple situations), *integration* (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 to 4 represent the conditioning steps (the student is prepared to learn), while **levels 5 to 7** correspond to the steps of effective **knowledge acquisition.** 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. In conclusion, an important part of the context will be to identify the learning level at which a learner is placed.

The cognitive context will play a role during the initialization session, second learning session and after the valuation session.

The affective context

The learning level is a first indication to adapt the level of knowledge to transfer. The affective context is a second type of information composed by the *style*, the *intentions* and the *characteristics* of the learner. The *style* contains information on the behaviour of the learner in training situation (preference of image, sequential explanation, guided training or discovery attitude,...). The *intentions* are a group of information related to the beliefs of the learner about a subject to be taught. The *characteristics* of the learner are additional information concerning his/her motivation and self-confidence.

The affective context will play a role for the whole training session since the students are split into two categories one being motivated by the professor while the other is not.

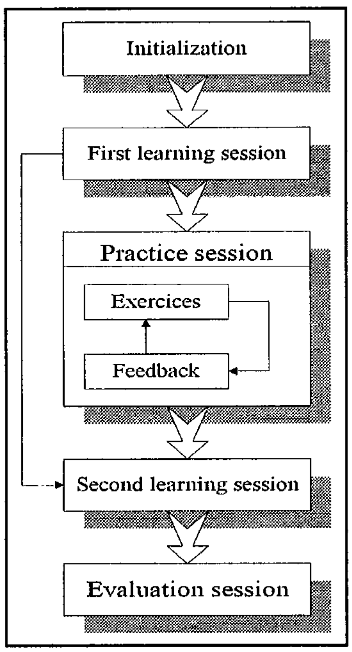


Figure 1: General schema

Our pedagogical strategy is based on M.D. Merrill's "*Component Display Theory*" (CDT) (Merrill, 1998). The CDT insists on the fact that the learner must have the control of the learning experience so that his training can be adapted to his preferences and style. Furthermore, the theory of Merrill specifies four different ways of presenting new notions: definitions, examples, recall and practice. Each of theses methods can be present in two fashions, *expository* and *inquisitory*, and it is capital that theses two techniques are included (Merrill, 1994).

Thus, KITS possesses and uses all of these techniques to give the learner the best education possible. Let's begin with the presentation of the general schema of a *learning session* in KITS (Figure 1).

Initialization

This step is a starting point for the elaboration of the learner's model. The learner is asked to identify his general knowledge level in physics. In fact, we asked him if he is poor, average or excellent in the domain of physics. Even if he answers we have to check with general questions if he underestimates or overestimates his knowledge level.

We can ask the following questions :
Do you know the three laws of Newton ?
Do you know the impact of friction ?
Can you give an example of a situation where there is no friction ?

As we will see, after each session, we will ask the learner other questions about his comprehension to update his learning model.

At the end of this session, the learner will be told if his final performance will be considered or not for his final mark on the "real" course of which this training is part. This will affect his overall attitude towards the training.

First learning session

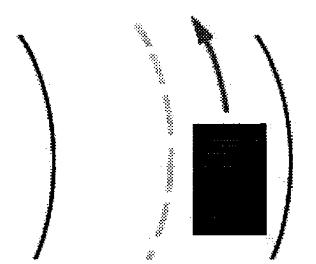
When the initialization is over, the learner is directly immersed in the first learning session. In the beginning, this section was more classical, static, we could compare it to the simple reading of a Physics book. To justify the use of a computer and to increase the personalization, we transformed this section into a more dynamic learning tool. We have included the hypertext technique (Schmidt 1991). Some words were highlighted and colored in blue. When the learner needs to obtain more information on one of these words he could simply click on it to instantaneously see some information and definitions about it. This technique focuses on the autonomy of the learner during his training. He accesses the different information depending on his particular needs and confidence level. This section contains four sub-sections accessible by the learner without restrictions. These sub-sections are: "*introduction and historical background,*" "*definitions,*" "*examples,*" and "*resolution method.*" Each of them introduces the kinetic friction under different angles because this notion is present in a variety of situations. For example, in the resolution sub-section we talk about the importance of force diagrams, in Definition one, we introduce the attributes of kinetic friction and in the examples sub-section we present 5 numerical problems. In this second step, the kinetic friction is always introduced with a reference to the static friction. The goal of the first learning session is to provide a first contact with the concepts, with real life situations in which these concepts are involved.

Practice session

The practice session is divided into two phases: the *question* phase and the *feedback* phase. The practice is, in our opinion, the most important section because it is there that we obtain the first information on the profile of the learner. The learner must answer ten exercises. These exercises were judiciously selected in regards of specific characteristics. All of them are typical kinetic or static friction cases; they are different from the problems presented in the examples sub-section of the first learning session, since our goal is to test comprehension and not memorization. Moreover, all of the exercises differ from one another (in regard of their attributes) for the same reason as above. In the practice session, the exercises have to establish the link between the two types of friction; the questions test only the comprehension of the principles. Figure 2a is a typical example of the kind of exercises in the practice session.

Once the learner has entered his answer, the system gives him the correct answer along with the feedback (figure 2b). The feedback is not only used to announce to the learner whether his answer was good or not but rather to bring him to think about his error (if this is the case) and to modify his cognitive context in a way that eliminates *cognitive dissonance*. (Aimeur, 1998), (Aimeur, 1999).

A car travels on a country road. This road is perfectly plane and turns as shown in this figure below. Is the friction involved between the road and the car's tires kinetic or static? And in which direction is it?



O kinetic - to the right
O static - to the right
O kinetic - to the left
O static - to the left

Figure 2a: Example of problem in practice session

Right answer :
STATIC - TO THE LEFT.
Static friction is involved
because the car
does not skid
Here is a schema of this situation

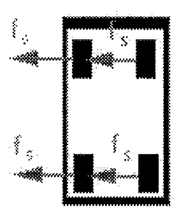


Figure 2b: Example of the feedback

Second learning session

The second learning session is not unique. This section is designed from the learner's model which was updated at the end of the practice session. The cognitive context will play an active role in the sense that there are four types of second learning sessions based on the four error types that a learner can commit. Each choice of answer is already associated with the appropriate error type and the correspondent level of the Gagné scale in the error database. Theses error types are:

- Correct classification : the learner has made only small errors (5 errors on 15 problems)
- Overgeneralization : the learner identifies most cases of static friction as kinetic friction cases. (i.e. the correct answer is static friction but the student identifies it as a kinetic friction problem)
- Undergeneralization : the learner identifies most cases of kinetic friction as static friction cases. (i.e. the correct answer is kinetic friction but the student identifies it as a static friction problem)
- Misconception errors : the learner has made as many overgeneralization as undergeneralization mistakes.

The error type is chosen in function of the learner's results in the practice session. In fact, in the practice session we add one point in the category of error corresponding to the answer that the student gives. Thus, we simply look at which error type has the highest score (for the three first cases) or if the student has made as many overgeneralization as undergeneralization mistakes.

To mark these errors, we use an adapted marking strategy. In the case of a correct classification we only give a simple revision (recall of the definitions and new examples). For the overgeneralization, we present some examples of static VS kinetic friction. In the third case, undergeneralization, we present more complex examples and for the last case, misconception errors, we show some examples of kinetic friction applied in a very different context. This series of new examples helps the learner identify the attributes of each type of friction and thus improving his performance. Another tactic used in the second learning session is the "*attribute isolation*" which, if done properly, highlights on each concept's critical attributes (Merrill, 1977). We use this technique by putting some words in bold and focusing the learner's attention on the important characteristics of the concepts. This will enable the learner to identify the cases involving kinetic friction with greater ease.

Evaluation session

The last step of KITS, it verifies for a second time the understanding of the concepts and update the learner's cognitive context. This time, problems are presented without any feedback and are focused only on kinetic friction because we consider that the training is over and the concepts are well assimilated. This evaluation could be used by teachers to identify the students in difficulty and also to answer them with better precision knowing their weaknesses.

Experimentation

Since our ITS corresponded to a real need, we had the opportunity to test it easily. A group of 49 students taking a mechanical physics course at the Collège de Maisonneuve in Montreal used our system. Due to schedule and computer availability constraints, the experimentation was made in teams of two students (we had 25 teams). Each team had one hour to complete the tutorial.

The goal of this test was to gather information about our work. This information was threefold:

1. To give sufficient and adequate scientific content
2. To justify the use of the second learning session
3. To present a pleasant graphical environment

First of all, the entire scientific content, terms and notations were reviewed and corrected beforehand by an expert (the Physics teacher of the students who tested KITS). Thus we were sure of the quality of the content of each section of the system. Furthermore, after the first learning session we asked each team of learners to specify their understanding level (excellent, average, and poor). More than 75 % of the teams affirmed they understood well or very well the new notions (figure 3). This result was verified when at the next section, the practice session, every team performed very well. This shows that the learners were not overrating nor underrating their comprehension.

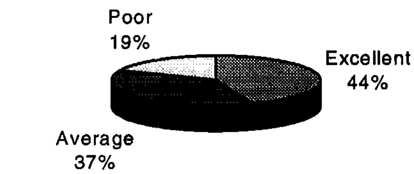
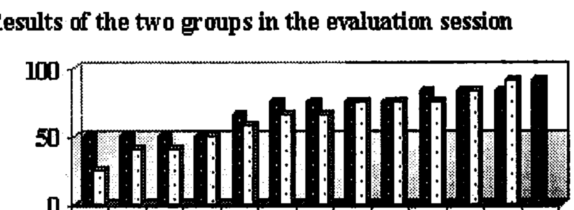


Figure 3: Understanding of the first learning session

Secondly, to justify the use of the second learning session, we tested the tutorial with the second learning session on 13 teams (group A) and without this particular session 12 teams (group B).

The second learning session's goal is to help correct the mistakes made in the practice session; its utilization should be reflected by better results during the evaluation session for the group A as opposed to group B. We have observed indeed that the average at the final evaluation was superior by almost 10% for group A, this is not a negligible increase of performance (figure 4).



	1	2	3	4	5	6	7	8	9	10	11	12	13
■ Group A	50	50	50	50	66	75	75	75	75	83	83	83	91
□ Group B	25	41	41	50	58	66	66	75	75	75	83	91	

Figure 4: Results of the groups A and B in the evaluation session

In the third place, the only mean to determine if KITS was user-friendly was to observe the students at work and to note their final comments. They found the working environment simple and pleasant. None of the students blocked on the interface but rather on the Physics problems! They clicked naturally on the hypertexts when the cursor changes to a little hand. The section to section navigation was without problems. Furthermore, we got many positive comments from students and even from other Physics teachers curious to try this tutorial. Unfortunately, a lot of students didn't have enough time to complete correctly the tutorial so they skipped some sections. In the first class, the professor told his students that up to ten points could be added to their last class exam, consequently they were more motivated and this fact changed our results positively for the evaluation session (affective context). On the other hand, the second class, less "serious" because they were not evaluated, completed the tutorial at full speed without paying attention to details in the last two sessions.

We think that our goals were almost achieved. KITS is a pleasant, complete ITS, but mostly useful from a pedagogical point of view. KITS was completely integrated to the normal execution of a Mechanical Physics course, even breaking the monotony of lectures. Many appreciated KITS for that and for the fact that the tutorial gives concrete examples of real world application, not only theoretical problems.

Conclusion

We saw in this article an intelligent tutoring system where we implemented the Experiences Transfer Learning Strategy (ETLS). This strategy uses experiences with static friction already known to the learner to teach a new concept, kinetic friction. These past experiences can be theory, examples, exercises, facts, etc. The teaching always made reference to the differences and similarities between the two concepts; this method helps the student to understand and to improve his knowledge level (cognitive context). We have also demonstrated that the addition of the second learning session where the cognitive context changes for one person to another is profitable provided that it is personalized according to the error type committed by the learner.

We also talked about KITS, an ITS that teaches the concept of kinetic friction. This system possesses many advantages over lectures or Physics textbooks. For instance, we obtain a personalization of the training with hypertexts and the second learning session is personalized according to the learner's knowledge level. The feedback is also an important advantage of our software. Neither a textbook, nor a course can give immediately the correct answer and the explication **after** the student has solved a problem... Either the answer is not provided; or the answer is available but the student reads the solution before resolving the problem. Finally, we have introduced the attribute isolation technique which, when well executed, is a good pedagogical trick that we cannot bypass.

Obviously, KITS is not perfect since it is only a first prototype. For instance, the learner is not in full control of the process. The learner must pass in each session sequentially and without a possibility of turning back. Several improvements could be made to improve the personalization of the learning so that the ETLS can be more adapted to the learner. For instance, the questions of the practice or evaluation session could be chosen according to the learner's understanding and his previous results. This way, the learner with difficulty will follow a smoother and more detailed rhythm and tougher examples are given to the learner who wants a challenge. Or we could leave the choice of the number of exercises in the practice session to the learner.

To sum up, even though KITS is only at its beginning, this ITS has been developed on good bases which stood the test of time. These bases made KITS robust and ready to continue his development. Intelligent tutoring systems are becoming more and more present in academic environments and in industry. A great deal of work is still needed to be done if we want to replace the human-human teaching by an efficient dialog between a human and a machine...

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