A Mixed Initiative for Teaching and Learning HTML in Intelligent Tutoring Systems

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Abstract Our goal with respect to a student learning process is threefold: we want him to learn from his mistakes, we want him to learn from others' mistakes, and we do not want him to repeat his own mistakes.
For this purpose, a learning strategy called Double Test Learning (DTL) involving three agents, two simulated pedagogical agents (the tutor and the classmate) and one real agent (the learner), was elaborated recently. The DTL strategy has been implemented in an intelligent tutoring system called HITS designed to teach HTML.
In our implementation of the DTL strategy, the classmate receives the same training as the learner and both have the same level of knowledge. Once the training is completed, the tutor will then test the classmate *(Post-Test 1)*. When the classmate finishes the Post-Test 1, a *Revision phase* is granted to the learner, where he can view the notes he took on his agenda during Post-Test 1. The tutor then turns to the human learner and *Post-Test 2* is started. During this phase, the learner only has access to his memory and the knowledge that he recently acquired through the classmate's answers. The most important point to emphasize is that the learner benefits from the classmate's mistakes.

Key words : Intelligent tutoring systems, pedagogical agents, learning strategy, double test learning.

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1. Introduction

Intelligent agents have ushered in a sense of renewed vigor and activity in artificial intelligence research over the last couple of years (Bradshaw, 1997). Agents are being applied to many areas, from Internet assistants to entertainment, even being found in domains such as Virtual Reality (Rickel & Johnson, 1997). In this paper, we are interested in pedagogical agents (Frasson *et al*, 1997), (Lester *et al*, 1997), who are also intelligent agents dealing with learning environments and especially with Intelligent Tutoring Systems (ITS).

In their early stages, ITS were conceived in order to reproduce a tutor's intelligent behavior, who could adapt his rhythm to that of the learner's. Tutorial strategies, like One-On-One, using classical tutoring, were developed in the ITS domain and could be classified as 'traditional'. Otherwise, recent ITS's take into consideration the co-operative approach between the learner and the system by using the co-learner concept. In fact, the idea of introducing a co-learner in the learning process arose with the perception that knowledge should result more from a building process rather than from a transmission process (Gilmore & Self, 1988). In this scope, the learner could co-operate with a co-learner having quite similar objectives and level of knowledge. A learner is inclined to better understand explanations given by a co-learner, who has understood and knows what to do rather than those given by the teacher.

Chan proposed to add to the picture a companion (Chan & Baskin, 1990) with whom the learner can co-operate to solve problems assigned by the tutor. Since then, a large number of strategies have evolved to include an agent, co-learner, which had the same role as Chan's companion. Among these is an inverted model of ITS called "learning by teaching" in which the learner could teach the learning companion by giving explanations to justify his answers (Palthepu *et al*, 1991; Vanlehn *et al*, 1994).

Despite the fact that these learning environments are very beneficial for the human learner, these strategies fail to demonstrate that the learner can also benefit from the co-learner's mistakes. The Double Test Learning strategy (DTL) is based on five phases : Pre-Test, Training, Post-Test 1, Revision and finally Post-Test 2. Early implementations of this strategy (RACSY (Aïmeur & Fahmi, 1998), an ITS aimed at teaching racquet sport rules), didn't take into consideration the Revision phase. In this paper, we propose a new implementation (HITS) that allow the learner to benefit from a certain period of time (Revision phase). We are going to demonstrate that this newly added phase will help the learners reinforce their knowledge and therefore improve their performance in the next phase (Post-Test 2).
DTL is aimed at making the learner learn from his classmate's mistakes. In short, the common proverb " *Let yesterday's error be your teacher today* " becomes " *Let your classmate's error be your tutor* ".

In this article we introduce a newly developed learning strategy, the Double Test Learning (DTL). The strategy's description and theoretical foundations are given in the next section. In section 3, we discuss the many aspects of the system HITS, such as the application domain, the agents' properties, and the interaction protocols. Preceding the conclusion, the fourth and the fifth sections present respectively an example of a learning session and the interpretation of the obtained results.

2. The Double Test Learning strategy

In the following section we will give a description of the DTL strategy, and we will also discuss its theoretical foundations.

2.1. Description

A typical learning session using DTL (Figure 1) begins with a *Pre-Test* phase in which an initial learner model is created. It contains the identification of the learner, the *Pre-Test* score and the trace of his answers. The second phase is a *training* session that both the classmate and the learner will perform. In the third phase, the tutor tests the classmate (*Post-Test 1*). The human learner will find himself in the position of an " active observer " where he will follow the question/answer session between the tutor and the classmate. The learner also has access to an agenda where he can write down any observations (e.g. tutor's questions, classmate's answers and reactions). Whenever the classmate solves a problem, his answer is evaluated by the tutor. If his answer is false and that of the learner is correct, the latter must justify and explain his answer to the classmate. When the classmate finishes the Post-Test 1, a *Revision* phase is accorded to the learner. A restrained time is defined by evaluating the learner's performance in both Post-Test 1 and Pre-Test (actually, by evaluting the difference). The tutor then turns to the human learner and *Post-Test 2* is started. In this phase, the learner only has access to his memory and the knowledge that he recently acquired through the classmates' answers and the Revision phase. Finally his answers are evaluated by the tutor.

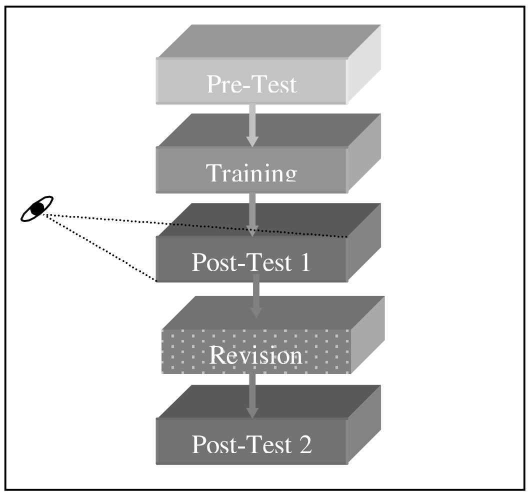

Figure 1: The five phases in the DTL

2.2. Theoretical foundations

The DTL strategy is mainly based on the social learning theory of Bandura (1971) which emphasises the importance of observing and modeling the behaviors, attitudes, and emotional reactions of others. Bandura states: "Learning would be exceedingly laborious, not to mention hazardous, if people had to rely solely on the effects of their own actions to inform them what to do. Fortunately, most human behavior is learned through modeling: by observing others, one forms an idea of how new behaviors are performed, and on later occasions this coded information serves as a guide for action".

3. The HITS System

We first present the agents, by detailing their properties. Then we present the interaction protocols.

3.1. The pedagogical agents

Our agents possess some properties such as reactivity, autonomy, adaptability and co-operation. We will now explain how these properties are represented in HITS.

Reactivity
During the Pre-Test whenever the learner replies to the tutor's questions, the latter simply reacts by asking another question. In Post-Test 1, when the classmate answers incorrectly, he automatically asks the learner's help without attempting to understand his mistake. It is the same for the tutor who gives the right answer and the explanation when both learner and classmate answer incorrectly during Post-Test 1.

Autonomy
The simulated agents (tutor and classmate) are autonomous in the sense that they can carry out activities in a flexible and intelligent manner that is responsive to changes in the learning environment, without requiring human intervention. For example the tutor and the classmate adapt their explanations to the knowledge level of the learner (see 3.2.3). Moreover, in Post-Test 1, when both learners are submitted a question, the classmate can give a wrong answer in order to force the learner to react. The questions for which the classmate does this will be referred to as *dissonance questions.*

Adaptability
The classmate learns how to assist the learner by observing and following his behavior in Post-Test 1. In fact, the classmate will have the same knowledge level as the learner by maintaining a balance between the number of their correct answers and explanations. At each question, the classmate will adapt his answer or the level of the explanations according to the answer or the explanation given by the learner to the previous question.

Co-operation
Since the classmate is aware that he is not going to take advantage of the tutor's answers and explanations in order to improve his score in Post-Test 1, he accepts that the learner participate in this phase, knowing that he will take advantage of it during Post-Test 2.

3.2. Interaction protocols
The purpose of this section is to discuss the underlying protocols, which illustrate the cooperation between three agents in all phases except revision phase.

3.2.1. Pre-Test
Upon the entry of the learner into HITS, he is given a brief description of what is to follow. He is informed of all the different sessions (Pre-Test, training, etc...) and he is also told about his classmate Bart. Once this is done the Pre-Test begins. The tutor asks the learner a series of questions, which he must answer. These answers are evaluated by the tutor but no explanation of the correct answer is given should the learner be mistaken. Both the system and the tutor know the learner's score for this phase. Once all the questions are answered the tutor informs his student that the training session will follow.

3.2.2. Training
During the training the tutor will present a series of problems which are immediately followed by their solutions and explanations. Here, the learner and the classmate simply follow what the tutor teaches.

3.2.3. Post-Test 1
With the training session completed, the learner chooses to take notes while the tutor is testing Bart the classmate. In fact during this time, the learner has in his possession an agenda in which he may write anything he thinks might help him answer the questions correctly.

No interaction takes place between the two learners until both have answered the questions. However, Bart's answers as well as his score are available to the learner. The learner will undoubtedly take into consideration his classmate's answer before giving his own answer. Once both answers are submitted, the tutor then gives the students the correct one. Only the classmate's answer is evaluated by the tutor. If his answer is correct his score is increased. In the case where Bart is mistaken and the learner is correct, Bart will ask the learner for some explanations. The latter provides an explanation, reinforcing his own knowledge. As well, if the learner is incorrect and Bart gives the right answer, the latter will explain it to the learner. In all cases, a set of multiple choice explanations gradually defined (one bad and 3 ranging as follows: good, very good and excellent), are used by Bart and the learner (see Figure 4). Whenever the excellent explanation is not found, it is the tutor who gives the best one. In the learner's case, it is the system that keeps track of his score, but the tutor has access to the learner's answers. His score is increased whenever he answers correctly; however, this point is lost if the explanation given is inadequate. When both learners answer incorrectly the tutor will provide them with an explanation of the correct solution. The details of the tutor's explanations depend on the learner's knowledge level. In this stage the tutor knows only the score of the classmate.

3.2.4. Revision

Taking notes in Post-Test 1 helps the learner encode the knowledge, but revising his notes will enable him to consolidate his encoded knowledge. For this a revision phase is accorded to the learner where he will fully benefit from the notes taken in his agenda, allowing him to review the errors committed in Post-Test 1 and for which the tutor gave the right answers and explanations. A restrained time for this phase is defined by evaluating the learner's performance in both Post-Test 1 and Pre-Test (actually, by evaluating the difference).

3.2.5. Post-Test 2

At the end of Post-Test 1 the classmate disappears and the tutor will now begin Post-Test 2 where the human agent will be tested. The agenda is no longer available for consultation, and at no point will the tutor give any answers or explanations. At the end of this question/answer session the whole process comes to an end.

3.3 Interpretation of the learner's score

Using the learner's scores in the different phases we can calculate his final score.

S_{pre} , S_{pt1} and S_{pt2} are respectively the scores for the Pre-Test, Post-Test 1 and Post-Test 2 phases. We must mention that S_{pt1} is biased by the influence of the classmate's answers.

B_T is the performance of the learner for the training phase. It is equal to the difference between the score of Post-Test 1 and that of the Pre-Test. $B_T = S_{pt1} - S_{pre}$

The performance of the learner for the Post-Test 2 phase is called B_{OM} referring to the benefit gained through observation and memorization. It corresponds to the difference between both Post-Test scores.

$B_{OM} = S_{pt2} - S_{pt1}$

The final score attributed by the system corresponds to the sum of the benefit gained during both Post-Test 1 and Post-Test 2. $S_F = B_T + B_{OM}$

4. Example of a learning session

HITS (HTML Intelligent Tutoring System) is a user friendly program including five phases all based on multiple choice questions: Pre-Test, Training, Post-Test 1, Revision and Post-Test 2. We chose HTML as an example because it is an easy programming language and not complicated to understand. However, the DTL could be implemented for any other subject.

HITS was written in Java v.1.1.6. One of the many great advantages of Java is its portability to many platforms. In our case both Windows95 and Unix versions were used. Another advantage that Java possesses is that its libraries are very complete for making all the necessary art-work and design as well as bringing any desired learning strategy to life.

Pre-Test, the first phase in HITS (Figure 2), is aimed to detect the user's knowledge level. He has to answer 20 questions and depending on his result he is classified in the following categories (Poor, Average and Good).

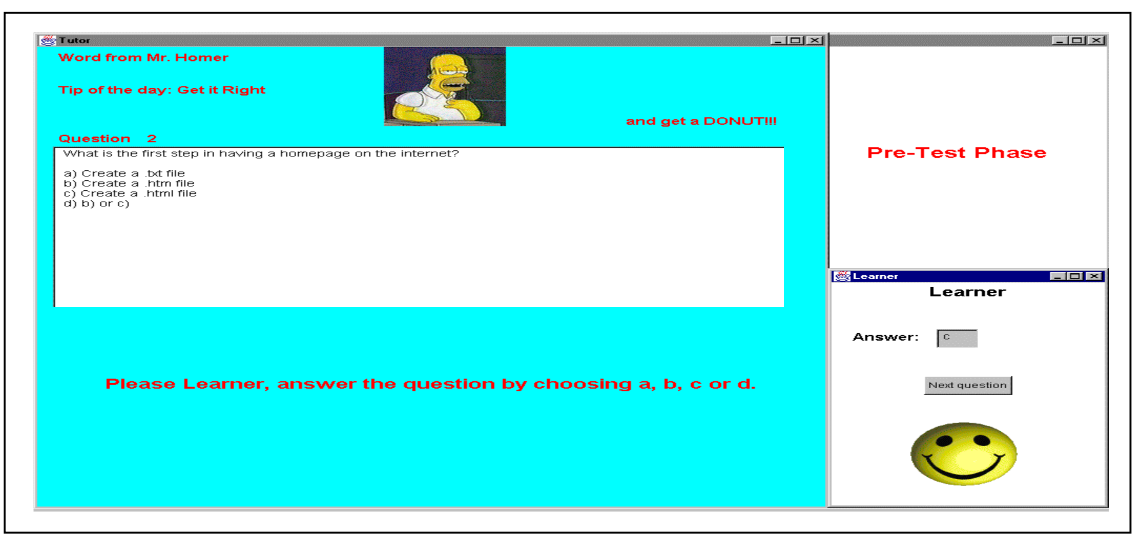

Figure 2: Pre-Test phase

Once Pre-Test is over, a Training session embarks. The tutor (Mr. Homer) presents 35 questions, among which 10 are repeated from Pre-Test, with the corresponding answers and explanations (Figure 3).

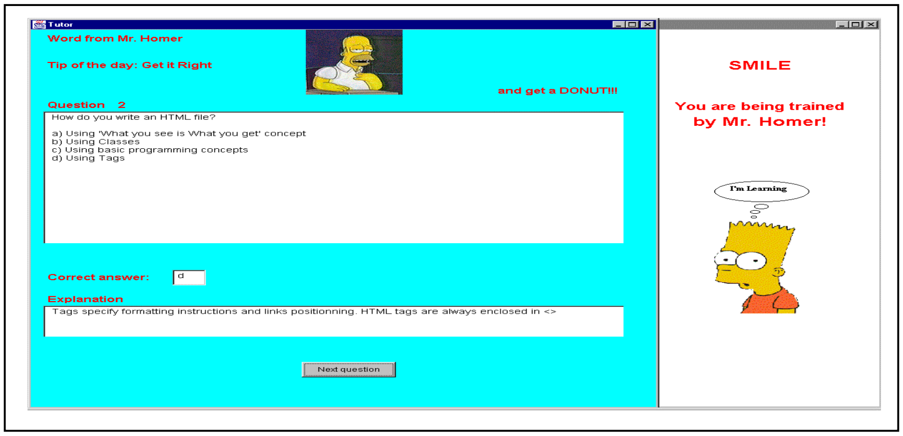

Figure 3: Training phase

Next is Post-Test 1 (Figure 4), where Bart, the classmate, is effectively being tested on 35 questions including the 10 questions remaining from Pre-Test, 15 from Training among which 8 dissonance questions, newly introduced. Dissonance questions are questions that are critical in HTML comprehension (Aïmeur 1998). The Learner is also involved. A possible situation could be that Bart gives the wrong answer while the user is correct. Bart will, in this case, ask the Learner for some help in order to understand the solution (1). The Learner should choose the best explanation[1]. It is up to Mr. Homer to judge if the Learner gave the best explanation or to correct him (2).

Figure 4: Post-Test 1 phase

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[1] Learning By Teaching effect.

Depending on the user's performance in both Pre-Test and Post-Test1 a certain time is provided for the revision phase, where the user has access to the notes taken in his agenda during Post-Test 1. The revision time is directly related to the gap between Post-Test1 and Pre-Test scores. In fact, the revision time took between 2 and 10 mn and was inversely proportional to B_T (see 3.3).

Finally, in Post-Test 2, where the user is supposed to answer 35 questions, 15 newly introduced (without any dissonance questions), the 8 dissonance questions, and the remaining questions are repeated proportionally from Training and Post-Test 1 (Figure 5). Automatically after this phase, Mr. Homer gives answers and explanations, to the missed questions. Finally the results of Pre-Test, Post-Test 1 and Post-Test 2 are displayed and Virtual Donuts are given to the Learner, based on his performance.

Figure 5: Post-Test 2 phase

5. Interpretation of results

A group of 30 persons, professors and students from University of Montreal, were chosen randomly to test the system and the results came as follows:

The Pre-Test allowed us to classify the group in 3 categories. Persons with scores less then 50% were classified as having a *poor* HTML knowledge level. Those who scored between 50% and 75% were classified as having an *average* HTML knowledge level while the ones who scored 75% and above were in the *good* category. The percentage of people per category is shown in Figure 6.
The subjects then went through the four remaining phases of HITS and the results came as shown in Figure 7. Analysis of the results shows that all three categories had an increase in the knowledge level.

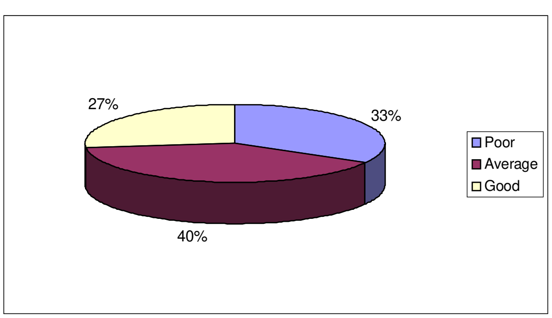

Figure 6: Percentage of users per category

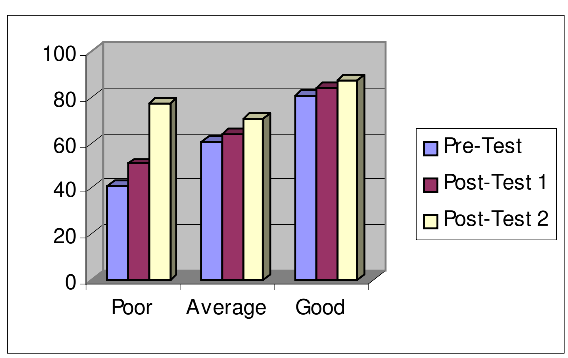

Figure 7: Categories performance in the three tests (in percentage)

It is interesting to note that the percentage of increase in the scores between Post-Test 1 and Post-Test 2 is higher than the one between Pre-Test and Post-Test 1 as shown in Figure 8. We also observe, that the total improvement is flagrant (more than 35%) for the poor category, while the one for the other categories is far less glaring (less than 10%).

Figure 9 illustrates how the three groups did when it came to answering the dissonance questions correctly. In fact, in the three categories, we observe a certain advantage taken from the errors committed by the classmate during Post-Test 1. All the categories seem to have improved their scores. This shows that the learners remembered what they previously saw in Post-Test 1 and Revision.

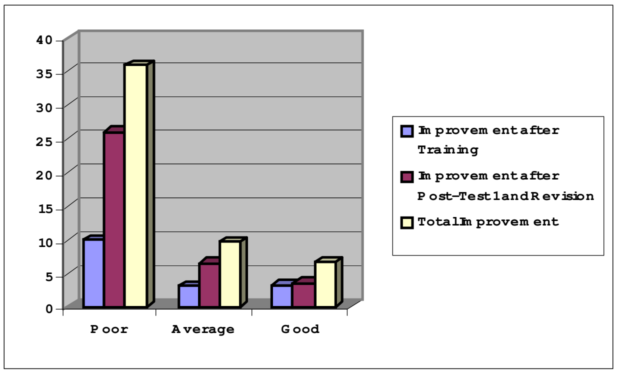

Figure 8: Categories improvement (in percentage)

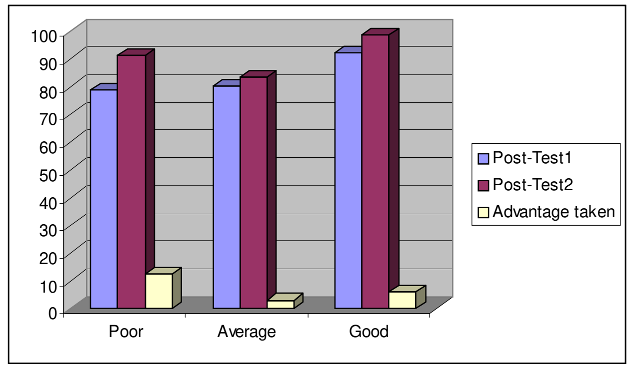

Figure 9: Performance in the dissonance questions (in percentage)

Note that 30 % of the newly questions introduced in Post-Test 1 and Post-Test 2 were correctly answered. In addition, 25 % and 40 % respectively for Post-Test 1 and Post-Test 2 of the questions answered incorrectly in the Pre-Test were answered correctly in Post-tests.

6. Conclusion

We have described, in this paper, pedagogical agents, in terms of properties and interactions within a learning environment. The DTL strategy has been successfully implemented in HITS where the subject to be taught was HTML. Its advantages are numerous: it improves the learner's ability to memorize, retrieve, and adapt the previously acquired knowledge; it also increases his attention, motivation, and self -confidence.

The DTL strategy is added to the list of existing strategies (Figure 10). In fact, it is the intersection of multiple strategies. The classmate is like the companion introduced by Chan (1990) and the troublemaker of Aïmeur and Frasson (1996). This is due to the fact that he sometimes helps the learner by giving the correct answer, but in other situations, he is forced to give incorrect answer to certain questions (dissonance questions). This is meant to motivate the learner to find the correct answers by himself. So, the classmate plays a double role and also he allows the learner to benefit from the committed errors. We also observe the Learning by teaching effect in Post-Test 1.

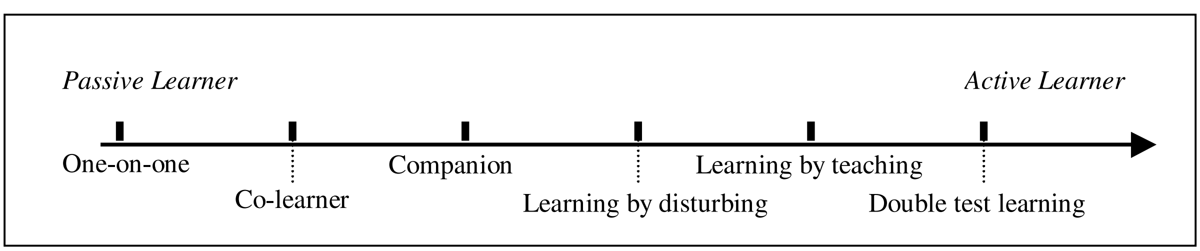

Figure 10: Tutorial Strategies Evolution

In this paper, we have studied different aspects of the DTL strategy. We also introduced a system, HITS, based on it. After testing the system, statistical results were deduced showing the efficiency of DTL. In addition, we have experienced that users with poor knowledge level are the ones who took most advantage of the Revision phase. In fact, their improvement in Post-Test 2 was by far better than the other categories. As well, we noticed that the latter results were better than the ones experienced in RACSY (Aïmeur & Fahmi, 1998). This is due to the revision phase. It is also important to note that users from other categories didn't really take advantage of the Revision phase because they didn't take notes during the Post-Test 1. This is due to the fact that they perhaps have self-confidence, which in our case didn't pay, because of the huge gap in improvement between the categories.

For further research, we plan to compare our results with other ITS experiments aimed to teach HTML or any other programming language.

Finally, we mention that DTL was presented in a psychological (social learning theory) and pedagogical (co-operative) way (Aïmeur & Fahmi, 1998). This helped prove that it is not only beneficial to profit from one's errors but also from others.

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