

'Did I say what I think I said, and do you agree with me?': Inspecting and Questioning the Student Model

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Abstract

This paper describes a student model which is open to learner inspection, and whose contents may be jointly negotiated by the student and system. Both the learner and the system have the opportunity to defend their own, and argue against the other's beliefs about the student. This discussion between the learner and system is designed on the one hand to result in a more accurate student model, and more importantly, also to promote learner reflection and therefore to contribute directly to learning. A preliminary evaluation shows that students are willing to inspect their student model, and moreover, they will challenge the model if they disagree with its contents.

1 Introduction

With the move away from the traditional intelligent tutoring system (as described in Wenger, 1987), interest has been gathering in the idea of student-system collaboration. Systems such as Dillenbourg and Self's (1992) People Power, Chan and Baskin's (1988) learning companion system, and a range of new social learning systems (described in Chan, in press) use various combinations of real students competing against or working together with other real students or with simulated co-learners, and with or without intervention from a computerised tutor. A major claim for many of these cooperative systems is the potential for improvement in learning, which arises from the need for dialogue.

A similar method of improving learning through promoting reflection is to have the student defend his views to the system by discussing and arguing against the system's assessment of *his* knowledge and beliefs, rather than to discuss with a peer or co-learner whose arguments will be related more to their knowledge and beliefs. This idea has been implemented in Mr. Collins, a collaboratively maintained, inspectable student model. Nevertheless, although Mr. Collins is designed primarily to discuss the student's own beliefs, the student model also contains a range of representations of the domain between the novice and expert states (see Bull, Pain & Brna, in press), and as Mr. Collins is inspectable, this enables learner consideration of alternative viewpoints as is possible in other types of collaborative system. However, with Mr. Collins the focus can remain on the student in a way which would not be possible in other collaborative systems.

Student models which are inspectable by the learner have been proposed by Self (1988), Brusilovsky (1994), Paiva and Self (1994), and implemented in systems such as described by Kay and Crawford (1991). An advantage of Mr. Collins is that it defines an approach of actively and explicitly using the student model to enhance learning. As stated above, the focus of Mr. Collins is on the idea of *promoting reflection through discussion and negotiation of the student model*; on deliberately using the model to directly provoke students into thinking (about their learning and the

domain, in this particular implementation to promote the learner's language awareness). This is achieved through discussion between the student and system about the student's own beliefs, and the beliefs of Mr. Collins about the student. (This approach has some features in common with Baker's (1990) 'negotiated tutoring', for example emphasis on explicit negotiation and metacognition.) An important result of our approach is that due to its central role in the system, the student model also becomes a learning resource in its own right. Further, discussion of the model will lead to more accurate representations inside the model. We do not claim that the current implementation of Mr. Collins will necessarily be the best method of providing student models which are accessible to learner viewing and negotiation: this is an issue for further research'. The aim here is to define an initial approach of promoting reflection through making the student model externally explicit and open to discussion, in order to determine student reactions.

The current domain of Mr. Collins is object pronouns in European Portuguese for second language learners. There are twelve rules for pronoun placement in the system (see Bull, Pain & Bma, in press); this paper will use just one of these rules to demonstrate how this collaboratively maintained student model functions.

Section 2 of this paper describes the manner in which inspection and discussion with the student model is conducted. Section 3 describes student reactions to using the system, including questions such as whether learners agreed or disagreed with the system, and whether they would challenge the student model.

2 Mr. Collins: Implementation of an Inspectable, Negotiable Student Model

Mr. Collins maintains two separate belief or confidence measures.¹ The first reflects the student's own confidence in his performance, and is provided by the student himself each time he offers input to be assessed by the system. The second confidence measure is the system's evaluation of the student, which is based on the learner's actual performance. This parallel assessment is necessary in a system which can allow the learner to influence the student model through negotiation, as such interaction necessarily involves a knowledge of the other's viewpoint. Each agent must know what he is agreeing with and arguing against in order for discussion to be feasible and effective. Learners have been shown to be capable of stating their degree of confidence in their performance on this type of task, and have also indicated a willingness to revise their beliefs if confronted with contradictory evidence (Bull, Pain & Brna, in press).

Negotiation in Mr. Collins occurs through menu format. This enables easy indication to the student of possible alternatives which he may not otherwise have considered or realised were available. Discussion may be initiated by either agent. Baker's (1990) notion of interaction symmetry applies to all discussion: i.e. the same dialogue moves are available to both agents involved in the negotiation. The system may request information from the student if it requires clarification of a particular point in order to be sure of its own choice of representation in the student model. For example, the learner may be asked if he is overgeneralising a Portuguese rule to an inappropriate context, or if his knowledge of English word order is affecting his Portuguese, or if he has mistaken the tense being used and for this reason produced incorrect word order (see Bull, 1994a). The system will also challenge the student if the student's belief measure is too distant from that of the system - i.e. if the two strongly disagree.

The student may view the student model or initiate discussion at any time. An unprompted attempt at learner alteration of the student model is likely to occur in cases where the student suddenly understands a problem he had previously been experiencing, and therefore no longer agrees with his own confidence assignment. Alternatively he may disagree with the system's assessment of his performance, and therefore wish to challenge the system's confidence measure. For example, if the student had been guessing and getting right answers by chance, the system may consider the learner more competent than he really is. Alternatively, if the learner has suddenly understood a problem, the

system may not yet have any evidence of this. The student may prefer to argue with the system rather than go through another series of exercises in order to persuade the system.

Although either agent is potentially capable of influencing the other as a result of convincing argument, the student has ultimate control over his own confidence measure as the system has no right to dictate the student's belief, and the system has the final say in its confidence in the student's performance.

2.1 Inspecting the student model

If a learner chooses to inspect the student model (either after prompting, or on his own initiative), statistical information is provided about his overall performance for each rule attempted. He is also given a summary of his recent performance which is based on his last five attempts to use a rule. This is in order that assessment does not depend only on the very last attempt, but nor may it be influenced by earlier attempts which may no longer be valid. This information is retrieved from the student model and presented via tabular and text templates in order to make it accessible to the student. The learner and system confidence measures for each rule are also displayed, e.g. for a learner who has attempted pronoun placement in negative sentences and in affirmative main clause statements:

The pronoun is:	YOUR CONFIDENCE (a – d)	SYSTEM CONFIDENCE (1 – 4)
pre-verbal in negative clauses e.g. Não os compra	• unsure (c)	• very sure (1)
post-verbal in positive main clauses e.g. Compra-os	• almost sure (b)	• unsure (3)

This indicates that the system is very sure that the student knows the rule for pronoun placement in negative clauses, but the student himself is unsure. The system is unsure that the student knows the rule for the positioning of pronouns in affirmative main clauses, but the student is more confident (almost sure). As with the summary of the learner's performance, the confidence levels are also based on a learner's last five attempts to use a rule, i.e. the learner's most recent five statements of confidence associated with sentences using a particular rule will be 'averaged' to determine his confidence in using this rule, and his actual performance over his last five attempts at the same rule will determine the system's confidence in his use of the rule (see Bull, 1994b). These confidence values are on a four point scale (very sure / almost sure / unsure / very unsure). The learner's confidence is indicated by the values a - d ('a' being the highest level), and the system's confidence in the student by 1 - 4 ('1' portraying the highest level of confidence).

In the above example, the two confidence measures for negative sentences are incompatible - the learner has low confidence (c) in his knowledge of the rule, but his performance leads the system to be very confident (1) in his use of this rule. For positive main clause statements, although the belief values differ (3 and b), they are still close enough to be compatible (a step down for the system, or a step up for the student - i.e. 4b or 3a would be necessary before the values became incompatible). The aim is that through discussion, the values should become identical (1a, 2b, 3c or 4d), or at least within one value on the scale. This will result in a student model which is more faithful to the true situation (as the student may have information which the system alone cannot take account of), and will also encourage the student to reflect on his learning, thereby also contributing to his learning (ultimately resulting in increased student and system confidence measures).

2.2 Changing the student's own beliefs

If, after viewing information in the student model, the student disagrees with either his own confidence level, or that of the system, he may select the option allowing the possibility of changing the model. If he chooses to alter his own confidence measure he is asked what level he wishes to change this to. If the new value exactly matches that of the system, the system acknowledges that it agrees with the choice. If it almost matches (as in the above example for main clause statements), the system will indicate that there is a difference between their two confidence measures (here that the system is a little less confident), but it will acknowledge that this difference is not great enough to be incompatible. If the student were to change his confidence measure to a value which is very different from that of the system (in this example where the system is 'unsure (3)', if the student were to select 'very sure (a)'), the system would state that the two belief measures were not compatible, and ask the student if he wishes to ignore this incompatibility, and maintain his new selection. The student may insist on his own choice, or may ask the system to justify itself, and then may or may not be convinced by the system's reasons. System justification involves presentation of the student's sentences, together with an assessment of his performance. Below is an example showing part of an interaction occurring as a result of a student changing, his own confidence measure to one which is incompatible with that of the system.

system:

Currently your own confidence in your use of the rule applicable in positive main clause statements is:
almost sure / b (system's confidence = unsure / 3)

What is your new confidence level?:

- unsure (c)
- very unsure (d)
- (cancel)

student (selects):

very sure (a)

system:

You have changed your confidence measure from 'b' to 'a'. This new confidence value is a lot higher than that of the system, the two confidence measures are incompatible. Your last five attempts to place the pronoun in positive main clause statements were the following:

- * Manuel a mostrou no mapa.
- * O Manuel mostrou a no mapa.
. O manuel mostrou-a no niapa.
- * O homem o comeu rapidamente.
- . O homem comeu-o rapidamente.

These recent attempts have demonstrated that you are still having some difficulties. Confidence measure 'a' is too high for your actual proficiency. What do you wish to do?

- system justify itself
 - change belief
 - view student model
 - keep new belief
-

Up to this stage in the discussion of the student model, although the system has indicated which sentences contain an error through the use of an asterisk, it has not indicated which type of error

is involved. This is because this part of the interaction is concerned with the level of confidence in the correctness of a rule, rather than an attempt to overcome a particular problem (though through increased reflection, this may also lead the student to realise his mistakes). The system will explain errors at this point only if the student requests a justification of its assessment of his performance. Alternatively the student may select to once again inspect the contents of the model in order to reconsider before making a final decision. The student may decide (immediately, or after inspection of the model, or justification from the system) that the alteration of his own confidence (here from 'b' to 'a') was inappropriate, and may decide to change it back (to 'b') or select another alternative ('c' or 'd'). A final option available to the student is to insist on maintaining his new confidence value, an option to which he is entitled, as it is, after all, his own belief. The student is not required to justify his decision here in order to allow the discussion to come to an end. The student will only have to justify himself if he is trying to alter the system's confidence measure (see below).

2.3 Challenging the system's beliefs

If the student disagrees with the system's level of confidence in his performance, he may challenge the system in an attempt to make it alter its own representation in the student model. However, if then requested, the student must be willing to defend his beliefs explicitly. If he is unable to convince the system it will maintain its own original confidence measure.

On challenging the system, the student is first asked whether he is happy with the representation of *his own* confidence measure (as the system must be sure of the student's current views in order to know what it is defending itself against). The student is then asked what he feels the system's confidence in his ability should be changed to. An example attempt at changing the system's beliefs (again for affirmative main clause statements) follows.

system:

The system's confidence in *your use* of the rule for positive main clauses is currently:
unsure / 3.

What do you believe the system's confidence should be?

- very sure (1)
- almost sure (2)
- very unsure (4)
- (cancel)

student (selects):

very sure (1)

system:

Your choice of '1' is very different from the system's assessment. What do you wish to do?

- accept system's decision
- system justify itself
- view student model
- accept compromise (2)
- justify myself
- (cancel)

student (selects):

system justify itself

system:

You are trying to change the system's confidence measure from '3' to '1'.

This new confidence value is too high.

Your last five attempts to place the pronoun in positive main clause statements were the following:

- * O Manuel a mostrou no mapa.
- * O Manuel a mostrou no mapa.
- * O Manuel mostrou a no mapa.
- . O Manuel mostrou-a no mapa.
- * O homem o comeu rapidamente.
- . O homem comeu-o rapidamente.

These recent attempts have demonstrated that you are still having some difficulties.

You have probable transfer from Spanish for pronoun placement twice.

You have omitted the hyphen once.

You actually have only two correct sentences in your last five attempts.

Because the student has selected a value for the system which is distant from the system's own view, the system will not automatically allow itself to be persuaded. The student is offered the option of simply accepting the system's decision without argument; of viewing the student model once more before making a decision; of accepting a compromise (here '2' is the mid-point between '1' and '3' – had the system's confidence in the student been at level '4', no such compromise would have been offered as the distance between '1' and '4' is too great; of system or student justification of their standpoint. If the student requires the system to explain its position, the system will present the student's most recent five attempts, together with its reasons for its assessment, as in this example. The student may or may not be convinced, and is again offered the above choices for how to proceed. If the student chooses to justify himself to the system, he will be offered a test sentence. If he is able to demonstrate to the system that his own claims about his proficiency are right (in this case that he can use the rule correctly), the system will be convinced by his argument. In the following example the student is offered a test, and proves his argument by producing a correct sentence.

system:

Please place the pronoun 'a' into the correct position in the following sentence:

'O João confirmou.' (João confirmed / it)

student:

O João confirmou-a.

However, if the student is not able to demonstrate the validity of his claims (in this example if he had been unable to produce a correct sentence), the system will try to confirm the correctness of its own representation by generating an identical sentence to that produced by the student, but based on the representations it has constructed in the student model. For example, in this case the system could predict that the student may use Spanish word order, e.g. * *O João a confirmou*. Similarly, using the student model the system could also predict that the learner may omit the hyphen with a correctly placed pronoun, e.g. *O João confirmou a*. If the student had offered either of these sentences as their response to the system's test, the system would have been

satisfied that its own representation was correct, and therefore would not have allowed the student to override it.

3 Do Students Inspect and Challenge the Student Model?

The student may or may not choose to inspect the student model. Although the system may try to prompt inspection, or specifically question the student about his knowledge and beliefs, the student is not obliged to react. Therefore a study was conducted to determine the answers to the following questions:

1. Would students inspect their student model?
2. Would they challenge the contents of the model in cases where they disagreed?
3. Would they prefer (a) no access to the model; (b) access, but no power to change the contents of the model; (c) access and power to change the model?
4. If 'c' above, would they prefer (a) power to alter the model, but no challenge from the system; (b) power to change the model with challenge from the system where it disagreed with changes?

Nine adult beginners (i.e. learners with no previous knowledge of Portuguese) were involved in the study: five postgraduate students (group A: A1-A5); and four non-university educated adults (group B: B1-B4). The sessions lasted between thirty minutes and two hours, the length being determined by the learners themselves. It was assumed that where students disagreed with the contents of the student model, they had understood the model (i.e. the use of two sets of confidence measures). It was also expected that inspection of the student model or an attempt to alter the contents of the model would lead to some degree of reflection.

Each learner was observed using the system in which the model was embedded. All actions were also automatically recorded by the system. Students were instructed to use the system as they wished, and were provided with a summary of menu options which they could use. A structured interview took place on completion of each session. The results presented below follow from analysis of these observations and interviews.

All nine learners chose to view the student model. Six viewed the model after prompting from the system (A3, A5, all of group B). The remaining four learners were generally happy with the contents of the model (both student and system confidence measure) on the occasions on which they inspected it, and therefore felt there was no need to change anything. The following table shows each learner's actions in the student model: whether they changed their own confidence measure; whether they challenged the system's confidence measure; whether they would have changed their own confidence measure, or challenged the system's, had they disagreed with it (in cases where they were content with the representation in the model).

subject	changed own confidence measure	would change own confidence measure	challenged system's confidence	would challenge system's confidence
A1	yes		yes	
A2	yes		no	yes
A3	no	?	no	yes
A4	no	?	yes	
A5	no	?	yes	
B1	no	yes	no	yes
B2	no	yes	no	yes
B3	no	yes	no	yes
B4	yes		yes	

Three learners made changes to their own confidence measures. Of the six who did not, three stated that they would have, if they had started to disagree with the representations in the

model. Three learners were not asked whether they would have altered their own confidence measure in such a situation – though the fact that two did challenge the system, and the other learner would have, had the situation arisen, suggests that they probably would also change the representation of their own confidence if this were felt to be no longer true.

Four learners challenged the system's confidence in their performance. All five who made no such challenge stated that they would, if the (persistently or strongly) disagreed with the system's assessment.

In a situation of conflict when challenging the system – what each subject did/would do:

A1* preferred the option of the system defending itself when in conflict. She would only try to justify her own beliefs if she very strongly disagreed with the system.

A2** would normally choose to see the system's justification first, before justifying herself, but if she was very sure about her own assessment of the situation, she would try to justify herself first. She may also view the student model again. She would accept a compromise only as a last resort.

A3** at first continued with more exercises, believing the system's assessment to be probably more reliable than her own views. If she had later still disagreed with the system, she would have challenged it. She would prefer to view the system's justification first, and if unconvinced, would attempt to justify herself.

A4* chose to justify himself, as he had high confidence in his own beliefs.

A5* preferred the system to justify itself, and if still unconvinced she would offer her own reasons afterwards.

B1/B2/B3** would first request the system to justify itself. If unconvinced they would then try to justify themselves, finally accepting a compromise if offered, if there was continuing conflict.

B4* initially requested the system to justify itself. She would never accept a compromise, but would try to justify herself to the system.

* *students who challenged the system*

** *students who did not challenge the system, but would if this were appropriate.*

We will return now to the four questions presented at the beginning of this section. Questions 1 and 2 are straightforward to answer: all learners demonstrated an interest in inspecting the contents of the student model, and all either changed or argued with the model, or stated that they would have, had the need arisen. It is of course possible that some students viewed the model out of simple curiosity, though no learner offered this as a reason in their interview. Nevertheless, this possibility needs to be considered. However, even if curiosity is the reason for some inspections of, and attempts to change the student model, such activities may still result in subsequent learner reflection – the main aim of the negotiable model.

After the interaction with the system, learners were asked for their reactions to the approach (questions 3 and 4). In the interview they were asked for their preferences between the following options: did they prefer (3a) no access to the student model; (3b) access, but no power to change the model; (3c) access with the possibility of changing the model; (4a) changing the model with no challenge from the system (4b) changing the model with system challenges where appropriate?

All nine students stated that they would prefer access and power to change the student model (3c). Seven would prefer the system to challenge their actions if it disagreed (4b), and two would prefer no challenge from the system (4a). The answer to question 3 is clearly straightforward: learners *are* interested in having access to information in their own student model. Most wanted to be able to inform the system of changes in their situation (e.g. if they had forgotten something, or if they suddenly understood something with which they had previously been having difficulty). They wanted to be able to help the system to adapt to their new state. Two learners also thought that they would think more about their learning if they were able to view the student model. One learner felt that she would get a sense of satisfaction in being able to prove the system wrong about her.

Six of the seven learners who wanted the system to challenge them if it disagreed with their attempts to change its confidence in their performance offered the following reasons, presented here as summarised from the interviews. (One learner was not able to state his reasons.)

A2/A3/A5/B4: I would learn more by seeing the system justify itself.

A2/B2: It is important to be able to prove what I think to the system.

B2: I would be able to prove to myself what I know (e.g. that I got something right for the reasons I think I got it right).

A2: I would feel more satisfied if I could put forward my point of view.

A3: Having to justify myself would make me think more about what I know.

A2/B1: It would make me think more about my learning (in general).

Two learners (A1 and A4) preferred not to be challenged by the system about changes they made to the student model. One stated that she would always want to alter her own confidence measure if it no longer applied, but would prefer not to be 'bothered' with that of the system. Although she liked having the two sets of confidence measures, she would prefer the system to covertly test her knowledge to 'make up its mind'. The other learner who would prefer his changes to remain unchallenged felt that if he were to try to alter something, he would 'want to be sure it got altered!'. He would have more faith in himself than in the system. Nevertheless, he also stated that this was only a preference, and he would not be irritated by the challenge.

Thus the responses for question 4 indicated that most learners wanted the system to challenge them if it disagreed with their attempts to change its confidence in their performance for a particular rule. Learners felt this would make them think more about their learning process. The two learners who would prefer no challenge from the system both actually challenged it in their sessions.

Seven learners liked using the system. Two felt that they would need to use it again before judging (A1 and B4). Eight learners found the system useful. Again, one learner (A1) felt unable to provide an answer without further interaction. Five found the system easy to use, and four found it difficult to find their way around, though three of these said that once they had got used to the system, it became a lot easier. The main problem appeared to be with the interface, for example 'difficult labelling' on menu items. Use of the system was made more problematic by the fact that, for the purposes of the study, students were not made fully aware of the potential benefits of using the system. They were provided with only a restricted version of the introductory information available to users (which includes the system aims, e.g. the idea of promoting reflection by inspecting and arguing with the student model, though some learners came across this through their browsing in the learning strategies component which contains general information and student specific use of strategies – see Bull, Pain & Brna, 1993). This introductory information about the system was withheld to avoid influencing students to think that they *should* be inspecting the student model and reflecting, as this may have biased their approach to the session.

Based on the results of this initial study it has been demonstrated that not only are students capable of inspecting and understanding their own student model, but they will also argue with it if they disagree with the contents.

This has two potential benefits: firstly the student model resulting from such discussion is likely to be more fine-grained and accurate, and secondly this discussion should promote learner reflection. The majority of students in this study did in fact prefer the system to argue back if it disagreed with their attempts at changing the contents of the model, and even those who preferred no such argument still argued!

4 Conclusion

This paper has described a student model which encourages learner inspection and modification of the model, with the aim of enabling the creation of a more accurate model while at the same time promoting learner reflection through discussion of its contents. In order to support discussion of the student model, two separate confidence measures must be maintained: one reflecting the system's views, and under the control of the system, and the other representing the student's own beliefs, and under the control of the student. Both agents must have the potential to influence the other through valid argument and defence of their own standpoint. The implementation of this student model has been described, and the results of a preliminary study to determine whether learners would actually inspect and suggest changes to the model have been presented and analysed. This study was small, and should therefore be considered only as a starting point, but it suggests that learners accept this approach: they did inspect their student model, and did suggest changes and argue when they disagreed with the system. The majority of learners in the study also liked the system to challenge them when it disagreed with their actions in the student model.

Future work includes testing of the system with more advanced language learners, to determine whether their reactions to this approach are similar. A comparison of different methods of making the student model explicit will also be useful. Alternative methods of less direct challenge from the system may be considered for Mr. Collins for use by learners who are less comfortable with the explicit approach. The possibility of implementing Mr. Collins in a different domain (electrical circuits) is being considered (see Bull, Brna & Pain, in press).

Note: 1. These terms are used synonymously in this paper.

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