

'Do It Yourself' Student Models for Collaborative Student Modelling and Peer Interaction

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Abstract: An approach to student modelling is presented where learners build their own student models. A more accurate model may thereby be obtained, and learners may reflect on their beliefs while constructing their model. The diyM system is illustrated in four environments: two collaborative student modelling systems, and two learner modelling systems with peer interaction as their focus.

1 Introduction

Interest is growing in student models which involve the student in their construction and repair, as illustrated by the recent development of systems using this approach. One thing these systems have in common is the aim of achieving greater accuracy in the student model by taking account of student contributions. Other reasons for the involvement of learners in the modelling process are varied. MFD (Beck et al, 1997) seeks to afford the learner some feeling of control over the interaction. Mr Collins (Bull & Pain, 1995) uses a process of negotiating the student model to promote learner reflection. ADI (Specht et al, 1997) allows the openness of the model to become an additional method of accessing target educational material. The student models in the latter two systems are inspectable by the learner, thus may "help, or challenge, the student to be aware of what the system thinks she believes" (Self, 1988).

This paper presents DIY ('do it yourself') modelling in the form of diyM, to offer a method for learners to construct their own inspectable student models as a supplement to system-created inspectable models. An example of the diyM environment is presented, and possible uses of diyM in different collaborative student modelling and peer interaction settings are introduced. The focus is accuracy of the student model to improve the educational potential of learning environments; and promoting learner reflection through the self-evaluation which takes place when constructing the model.

2 The diyM Environment

DiyM is applicable to different learning environments. The illustration below is object pronouns in European Portuguese—implemented to supplement collaborative student modelling in Mr Collins (Bull & Pain, 1995). The environment has menus for student initiated interaction, with the options *build model*; *run model*; *clause types*.

2.1 The 'Build Model' Menu Option

Build Model displays a task to construct the student model (which then remains accessible). Fig. 1 shows the first method of model construction: for each rule of pronoun placement the learner selects the option they believe correct. The choices are: *pre-verbal*; *post-verbal*; *infix*, except for 'aux & pp', which has the options:

before aux; between aux & pp; after pp. Students also state whether they are *sure* or *unsure*. In this example a student is in the process of constructing their model: they have stated their beliefs for five rules. The student believes the pronoun to be pre-verbal in negative clauses and open questions, but is more confident about negatives. They think the pronoun is post-verbal in affirmative main clauses and adverbial phrases, being sure in the latter case. The fourth rule was not attempted. They think the pronoun is probably an infix with infinitives, but are unsure. Selections will continue for each rule.

I think			
the pronoun is	pre-verbal ▼	in NEGATIVE CLAUSES.	I am sure ▼
the pronoun is	pre-verbal ▼	in OPEN QUESTIONS.	I am unsure ▼
the pronoun is	post-verbal ▼	in POSITIVE MAIN CLAUSES.	I am unsure ▼
the pronoun is	▼	in POSITIVE IMPERATIVES.	I am ▼
the pronoun is	infix ▼	with INFINITIVES.	I am unsure ▼
the pronoun is	post-verbal ▼	in SOME ADVERBIAL PHRASES.	I am sure ▼
the pronoun is	▼	in RELATIVE CLAUSES.	I am ▼
the pronoun is	▼	in SUBORDINATE CLAUSES.	I am ▼
the pronoun is	▼	with AUX & PP.	I am ▼
the pronoun is	▼	in YES/NO QUESTIONS.	I am ▼
the pronoun is	▼	in the FUTURE TENSE.	I am ▼
the pronoun is	▼	in the CONDITIONAL TENSE.	I am ▼

Fig. 1: Constructing the student model (method 1)

In Fig. 1 the learner's selections for the first three rules are correct. For imperatives the learner has made no selection, indicating they are less confident than if they had selected an option and the confidence 'unsure'. In the last two attempts the learner is wrong both times. The selection of 'unsure' with infinitives shows that the difficulty with this rule may be less problematic to resolve than with adverbial phrases, where the learner holds a misconception they strongly believe.

In this manner students construct their own simple student models. DiyM stores a series of facts from which it can infer information, and from which it can present alternative viewing modes as requested. The facts are recorded as follows:

`clause_type(Clause, Position, Confidence, [Method])`. So, the first clause type in the current example is: `clause_type(1, pre_verbal, sure, [1])`. At this stage the goal is not necessarily to get answers right, but to create an accurate model of learner beliefs. The knowledge that accuracy may lead to more effective system help should provide motivation. The task is also an exercise in self-evaluation and promoting learner reflection. The ways a system will use information from a DIY student model will depend on the aims, domain and educational philosophy of the system.

Methods 2 and 3 of building the student model are similar to method 1 (the default), but the information is submitted in a different form (illustrated for rule 1):

Method 1: I think the pronoun is pre-verbal / post-verbal in negative clauses.

Method 2: I think the following sentence is correct: Não os compra / Não compra-os.

Method 3: I think the rule for pronoun placement in negative clauses is:

s --> neg, obj-pronoun, v. / s --> neg, v, obj-pronoun.

With method 2 the learner selects the sentence they believe is correct. *Não os compra* ('he does not buy them') is right—i.e. the pronoun (*os*) is before the verb (*comprar*). Method 3 offers the grammar. All methods use the same representations in the underlying (system's) student model. Students may, if they wish, repeat the task of constructing their student model using more than one method. In such cases conflicts may occur, for example, as given above for clause type 1 the representation might be: `clause_type(1,pre_verbal,sure,[1])`. A student may also submit information by another method, producing:

`clause_type(1,post_verbal,sure,[2])`.

This produces a conflict: with the different methods the learner states explicitly that they believe both P ('The pronoun is pre-verbal in negative clauses'), and ¬P:

	<i>learner choice:</i>	<i>representation:</i>	<i>belief:</i>
<i>system's model:</i>	---	<code>clause_type(1,pre_v)</code>	P
<i>student model (1):</i>	pre-verbal	<code>clause_type(1,pre_v,sure,[1])</code>	P
<i>student model (2):</i>	Não compra-os	<code>clause_type(1,post_v,sure,[2])</code>	Q (¬P)

Fig. 2: Representing conflicts in the student model

The way in which this situation is dealt with is as follows:

1. On submitting a second (or third) set of beliefs, the learner is asked which method should be considered most reliable. In the above example they select from:
 - o Method 1 (statement of pronoun position)
 - o Method 2 (example sentence)
 - o Both 1 & 2

The resulting representation is: `priority(Methods)`, where *Methods* is a list of the methods which should be given priority.

2. DiyM uses the representations from the method with highest priority, if only one is listed. If more than one method is assigned priority, for each clause type where there is *no* conflict of beliefs the representations are combined—e.g. if the following were provided for clause 3:

`clause_type(3,post_verbal,sure,[1])`
`clause_type(3,post_verbal,unsure,[2])`

the representation used is:

`clause_type(3,post_verbal,unsure,[1,2])`.

The value *unsure* is recorded because its weighting is greater than that for *sure*. This can be amended afterwards by the student if they wish.

3. Where there is a conflict of beliefs, all are represented. DiyM regards the representation(s) assigned the confidence *sure* as likely to be more reliable. There may be more than one of these: each is given equal weighting. On viewing their model, all representations for each rule are displayed to the student, so they remain aware of conflict. Depending on the system using diyM, the student's attention may be drawn to the conflict at the time, and they may be expected to resolve it.

In summary: in constructing their student model, learners provide their views directly to the system, thereby experiencing some degree of reflection. DiyM allows the model to be built in a number of different ways, to suit the preferred representation.

2.2 The 'Run Model' Menu Option

Run Model has two sub-menus: *System's Model*; *Student Model*. Selecting *System's Model* instructs the system to run its domain model, and present the results. The information is displayed three ways: grammar rules; example sentences; statements of the rule for the position of the pronoun as illustrated in the grammar and examples. Reference to clause types for each rule is also available—i.e. *1 negative clause*; *2 open question*, etc. Students may view all information types, or just those they wish. Information is displayed on the right of the screen, on a blue background to emphasise to the viewer that these are the system's 'beliefs' about the domain (Fig. 3).

<p>student's rules THE POSITION OF THE PRONOUN IS:</p> <p>1 pre-verbal 7 1 *post-verbal 8 2 pre-verbal 9 3 post-verbal 10 4 11 5 *infix 12 6 *post-verbal</p>	<p>system's rules THE POSITION OF THE PRONOUN IS:</p> <p>1 pre-verbal 7 pre-verbal 2 pre-verbal 8 pre-verbal 3 post-verbal 9 betw aux & pp 4 post-verbal 10 post-verbal 5 post-verbal 11 infix 6 pre-verbal 12 infix</p>
<p>student's examples</p> <p>1 Não os compra. 1 *Não compra-os. 2 Quem os compra? 3 Compra-os. 4 5 *infix[†] 6 *Também compra-os. 7 8 9 10 11 12</p>	<p>system's examples</p> <p>1 Não os compra. 2 Quem os compra? 3 Compra-os. 4 Compra-os! 5 Quer comprá-los. 6 Também os compra. 7 Vejo o homem que os compra. 8 Sei porque os compra. 9 Tem-nos comprado. 10 Compra-os? 11 Comprá-los-á. 12 Comprá-los-ia.</p>
<p>student's grammar</p> <p>1 s --> neg, obj-pronoun, v. 1 *s --> neg, v, obj-pronoun. 2 s --> q-word, obj-pronoun, v, ? 3 s --> v, obj-pronoun. 4 5 *s --> v(1), inf(2), obj-pronoun, v-end. 6 *s --> adverb, v, obj-pro. 7 8 9 10 11 12</p>	<p>system's grammar</p> <p>1 s --> neg, obj-pronoun, v. 2 s --> q-word, obj-pronoun, v, ? 3 s --> v, obj-pronoun. 4 s --> v, obj-pronoun, ! 5 s --> v(1), inf(2), obj-pronoun. 6 s --> adverb, obj-pronoun, v. 7 s --> MC, rel-pronoun, obj-pronoun, v 8 s --> MC, sub, obj-pronoun, v. 9 s --> aux, obj-pronoun, pp. 10 s --> v, obj-pronoun, ? 11 s --> [inf, obj-pronoun, fut-end] 12 s --> [inf, obj-pronoun, cond-end]</p>

Fig. 3: The learner's student model and the system's domain model

[†] Pronouns are infixes in future and conditional, between infinitive stem and verb ending. In other tenses an infix cannot be used this way. An example therefore cannot be given.

Selecting *Student Model* leads to the system running the student model built by the learner. Information is displayed in the same three ways, illustrated in Fig. 3 for the first six rules (as completed in Fig. 1). These representations are on the left of the screen, on a yellow background to show that these are the student's beliefs. As stated above, conflicts within the model are displayed. If both *System's Model* and *Student Model* are selected, the models can be directly compared.

2.3 The 'Clause Type' Menu Option

The student model can also be displayed by clause type, coded according to correctness (compared to domain model), and sureness of the learner. Combinations of correctness and sureness are awarded a 5-point grading to determine how to present each rule (Table 1). For example, if a student's entry in their student model reflects 'correct knowledge', and the learner is sure of their view, the score awarded by the system for the clause type is 5. The window with the representations for that rule uses the pen colour green (illustrated in Fig. 4 by bold text). All backgrounds are yellow.

- *green* (bold) indicates the student knows the rule, and knows they know the rule.
- *black* (plain text) shows the learner knows the rule, but is unsure of the knowledge.
- *red* (italic) is 'danger'. The student does not know the rule but recognises a problem.
- *strong red* (italic/underline) shows a learner does not know a rule, but thinks they do.
- if no text is entered the learner does not know a rule and knows they do not know it.

Table 1: Determining presentation according to correctness and sureness

COMBINATION	SCORE	PEN COLOUR	EXAMPLE
correct + sure	5	green	bold text
correct + unsure	4	black	plain text
no selection	3		
incorrect + unsure	2	red	italic
incorrect + sure	1	strong red	italic + underlined

<p>negative clauses</p> <p>s --> neg, obj-pronoun, v. Não os compra. pre-verbal <i>*s --> neg, v, obj-pronoun.</i> <i>*<u>Não compra-os.</u></i> <i>*<u>post-verbal</u></i></p>	<p>imperatives</p>
<p>open questions</p> <p>s --> q-word, obj-pronoun, v, ? Quem os compra? pre-verbal</p>	<p>infinitives</p> <p><i>*s --> v (1), inf(2), obj-pro, v-end.</i> <i>*infix</i> <i>*infix</i></p>
<p>main clauses</p> <p>s --> v, obj-pronoun. Compra-os. post-verbal</p>	<p>some adverbials</p> <p><i>*s --> <u>adverb, v, obj-pronoun.</u></i> <i>*<u>Também compra-os.</u></i> <i>*<u>post-verbal</u></i></p>

Fig. 4: The student model presented according to clause type

Varying presentation helps learners notice problems. Conflicts in the model are clear.

2.4 Methods of Building the Student Model: Early Reactions

A small-scale early study was undertaken to determine whether potential users would use the different approaches to building their student models with diyM.

Subjects: The subjects were 3 lecturers; 6 postgraduate students; 4 undergraduate language students; 6 undergraduate students of other subjects; 5 'others'—a total of 24.

Method: Subjects were shown paper versions of the 3 methods to construct the student model. They completed a questionnaire stating how often they would use each.

Results: There was no difference in choice of methods across groups, except for 'other', which had only one instance of method 3 (as first choice). The groups are therefore not distinguished in the analysis below.

Table 2: Combinations of method chosen by experimental subjects

none	1 only	2 only	3 only	1 & 2	1 & 3	2 & 3	1, 2 & 3
1	0	3	1	6	4	1	8

Table 3: Frequency of choice of method

	1st choice	2nd choice	3rd choice	never chosen	total choices
method 1	6	5	3	5	14
method 2	11	6	1	5	18
method 3	3	9	2	9	14

Table 2 shows most potential users would use a combination of more than one method to describe their beliefs. Only 4 subjects stated they would use one method only. 11 of the 24 subjects would use a combination of two methods, and 8 would use all three. 1 student would not use any. The most common combination was method 2 as first choice, and 1 as a second option (4 subjects). The second most common combinations, with 3 subjects each, were: 2 only, and 1 followed by 3.

Table 3 shows that most users would opt for method 2 as their first choice, and a total of 18 subjects would use this method at some time. The other methods would also be used—each by 14 users. The questionnaire options were as follows:

	always	mostly	sometimes	occasionally	never
Method 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Method 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Method 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

14 subjects stated there was a method they would *always* use. For 4 subjects–method 1; for 8 subjects–method 2; and for 4 subjects–method 3. Amongst these were the 4 who would use one method only. 6 would use two, and 4 would use all. 2 of these subjects wanted to be able to use two methods simultaneously in all cases: 1 subject methods 1 & 2; and 1 subject methods 2 & 3 as a combined first option.

Of the remaining 10 who would not always use the same method(s), there were varying, but not significantly different spreads of two or three methods across *mostly*, *sometimes* and *occasionally*, except for the 1 subject who chose *never* for each.

Discussion: This study, although small, indicates that inclusion of different methods of constructing diyM in this context is important: a large majority of users would use more than one method; and there was a wide range of order of preference and frequency of choice for each method, irrespective of user group.

Limitations to this study include the following. Subjects were not asked whether they would like further methods of constructing their model—it might be necessary to allow more choices. Although subjects were able to identify the methods they would use in model construction, it has not yet been shown that they will do so in practice. It is also not known whether users would continue to maintain their student model longer term. Finally, results from this study are not necessarily transferable to other contexts in which diyM may be used, as it applies to different types of learning environment (see section 3). More studies need to be undertaken. It is suggested that these issues be considered further to determine the extent to which it is practical to promote learner reflection and achieve a more accurate student model with DIY modelling.

3 Uses of diyM

DiyM aims to address a specific problem: how to enable students to provide information to student models explicitly. The two main aims are to facilitate construction of a more accurate model by taking account of what a learner says they believe; and to enhance learner reflection through the need to state their beliefs, as self-evaluation is important in learning (e.g. Klenowski, 1995). DiyM may be used alone, or combined with a learning environment sharing at least one of diyM's aims. Implementations were designed for collaborative student models and systems encouraging peer interaction. The further use to which a DIY model will be put depends on its context of use.

3.1 DiyM by Itself

Explicit access to the contents of a student model has been argued to be useful in increasing learner awareness and reflection (Bull & Pain, 1995; Crawford & Kay, 1991; Morales et al, 1998; Paiva et al, 1995; Self, 1988). DiyM is inspectable. Its construction encourages students themselves to make explicit their views, to help them reflect on their knowledge. Moreover, it practices their skills of self-evaluation. DiyM also allows comparison of learners' own beliefs, to the rules or concepts of the domain.

3.2 DiyM and Student/System Collaborative Student Modelling

Student/system *collaborative student modelling* is a special case of inspectable student models: in addition to viewing their model, learners can *negotiate* the contents with the system (Bull & Pain, 1995). This differs from co-operative learner modelling (Beck et al, 1997) which more likely aims for accuracy in the model. While collaborative modelling will usually have this as a goal, it also strives to promote reflection.

The domain of pronoun placement above is identical to part of that in Mr Collins (*collaboratively maintained, inspectable student model*). Mr Collins has 2 exercise types: 1 placing a (given) pronoun in a (given) sentence; 2 translating an English sentence into Portuguese. The system infers its student model (Sys-SM) from a learner's input, and constructs the student's student model (Stu-SM) from learner statements of confidence. The inspectable model is viewed as in Fig. 5. A breakdown is available.

	YOUR CONFIDENCE	SYSTEM CONFIDENCE
Negative clauses:	• almost sure	• very sure

Fig. 5: The inspectable student model of Mr Collins

Learner access to their model (Stu-SM & Sys-SM) provides a focus for negotiation in cases of conflict, by menu-based discussion (Bull & Pain, 1995). This is designed to enhance learner awareness of beliefs and approaches to learning, while building a more reliable model. The addition of diyM to Mr Collins provides a means to indicate to both system and learner the presence of inconsistencies within Stu-SM, as well as those between Stu-SM and Sys-SM which are identified by Mr Collins—i.e. in addition to awareness of differences between their own beliefs and those of the system about their beliefs, students are presented with problems *in their own model*.

3.3 DiyM and Student/Teacher Collaborative Student Modelling

See Yourself Write (Bull, 1997a) is a different kind of collaborative student model: it does not use student/system discussion of the model, but rather, has an inspectable learner model to facilitate interaction between student and *teacher*. A (human) tutor gives feedback on a student's foreign language writing, which is supplemented by student responses. Qualitative and quantitative feedback is given in a number of categories. An inspectable student model is automatically created from this feedback, with additional system generalisations based on the teacher's quantitative comments. The aims of *See Yourself Write* are to provide feedback to learners in a form they will take notice of, also providing a method to help them reflect on their feedback, since many learners do little with feedback on writing (Cohen & Cavalcanti, 1990). At the same time, teachers are not restricted in the kind of feedback they give. Fig. 6 shows a learner's initial view when inspecting the student model built from teacher feedback. The quantitative evaluations from the tutor for each category are displayed for each assignment completed to date. By clicking any of the cells, the learner may view qualitative feedback for that category and assignment. A summary column contains system-inferred comments to give an overview of performance in each category across all assignments so far. These are also accessed by clicking on the cell (see Bull, 1997a).

In addition to viewing structured feedback, learner reflection is achieved by system prompts about the student's approach to the task, based on the contents of the student model; by teacher requests for clarifications; by encouraging learners to state

whether they agree with feedback, and allowing them to argue if they feel this is justified. This latter facility is designed as much to provoke self-explanation as to offer a route for student views to reach the tutor. The aim of a more accurate student model has a different purpose in *See Yourself Write*: the accuracy is more important for the *teacher*, as student contributions will help them to understand the student's problems and misconceptions. This is crucial with a domain such as writing where system reaction to a student's text can only occur if some kind of constraints are placed on input.

<i>See Yourself Write</i>	assignment1	assignment2	assignment3	summary
content	SUPERFICIAL	SUPERFICIAL	GOOD	OKAY
struct / arg	INCONSISTENT	INCONSISTENT	INCONSISTENT	INCONSISTENT
grammar	GOOD	OKAY	OKAY	OKAY
spelling	WEAK	GOOD	WEAK	OKAY
punctuation	OKAY	GOOD	GOOD	GOOD
style / vocab	GOOD	GOOD	GOOD	GOOD

Fig. 6: The inspectable student model of *See Yourself Write*

diyM See Yourself Write name:

assignment number:

Please state your assessment of your performance in the following categories. Remember to justify your comments.

content coverage	spelling
structure/argument	punctuation
grammar	style/vocabulary

Fig. 7: DiyM for *See Yourself Write*

DiyM with *See Yourself Write* offers another way to help learners reflect—at the time of writing. Fig. 7 shows diyM for *See Yourself Write*. It is necessarily simpler than diyM for Mr Collins, designed primarily to get learners thinking about their writing from different perspectives. They are reminded of some of the criteria of assessment, and may experience some of the benefits described by Mowl and Pain (1995) for self-assessment in undergraduate essays—they may: think about how they are writing; better understand assessment; improve their future writing. As with Mr Collins, feedback can be viewed with the learner's own assessment when teacher and system comments are available.

3.4 DiyM and Peer Interaction

PeerSM (Bull & Brna, 1997) and S/UM (Bull, 1997b) are based on *See Yourself Write*, but involve *peer* feedback. The aim is similar in terms of promoting reflection with an inspectable model to prompt interaction about feedback. However, peerSM and S/UM also encourage reflection for educational benefit in the *givers* of feedback.

In peerSM the inspectable model is created from self-assessment, peer feedback and system inference from self- and peer evaluation of a linguistics exercise (Fig. 8). The inspectable model of S/UM is built from feedback on writing from peers (Fig. 9). In peerSM one peer is involved. S/UM mediates interaction of multiple peers—the model of an individual is usually open to all (unless permission has not been given). The two systems are designed for participants to be both feedback givers and receivers.

peerSM		
SELF ASSESSMENT	PEER ASSESSMENT	SYSTEM ASSESSMENT
A: very good B: very good C: problematic D: good	A: very good B: good C: good D: variable Why? I agree 'mi:stol' means 'cat', but I don't think it's because of word order. You could also say "kos 'o g mi:stol", which	A: very good B: good C: okay D: one of you is probably having difficulties
state your own problems	comments to peer	amendments to own work

Fig. 8: The inspectable student model of peerSM

Categories:	content	structure	argument	style	other
Summary:		OKAY	WEAK		
Feedback 2:		GOOD	WEAK		
I find the structure of your paper a little hard. Instead of introducing related work as a starting point in the introduction, you have weaved it in throughout the paper.					
Feedback 1:		WEAK			
Although you support your argument well, there are counter-arguments you have not given. (e.g. you could explain why other studies produced different results).					

Fig. 9: The inspectable student model of S/UM

System Evaluation	Category: Content
Overall the content of your document appears OKAY.	
The most recent feedback was GOOD, but no explanations or justifications were provided by the author of this feedback.	
Earlier feedback suggests that the content of your document was WEAK.	
Your improvement may be because you have considered these comments.	
Your own assessment of the content of your document is OKAY.	

Fig. 10: System comments based on S/UM and diyM

DiyM for S/UM is similar to diyM for *See Yourself Write*. However, students may also give quantitative evaluations which feed into S/UM's inspectable student

model, so that it may take the learner's own beliefs about their performance into account when making generalisations. Fig. 10 shows a system generalisation from peer feedback in S/UM and self-assessment through diyM. This is constructed using hierarchically structured templates. Although information is from system generalisations, it may be inaccurate as it is based on assessments of non-experts. Hence use of 'appears'; 'may'. The aim, as stated above, is to encourage learner reflection in *all participants*. Thus accuracy is not as important here as in a collaborative student model, though *interaction* to produce accurate contents to *promote reflection* still applies.

The peerSM exercise is one word answers input textually into edit boxes which can be evaluated by the system, and longer textual responses which cannot be evaluated computationally. DIY modelling in this context provides an alternative way of completing the exercise, using an interface similar to Fig. 1. As with diyM for Mr Collins this may result in conflicts in the model. This is handled in a similar manner: conflicts within the learner's own model (Stu-SM) are salient when viewed. Implementation of diyM for peerSM is not yet complete: although the diyM component can be viewed (in an additional field), the system does not take account of the information. Therefore the issue of learner reflection is served, but the question of increased accuracy in this version of diyM has not yet been addressed.

4 Summary

This paper has presented DIY student modelling to enable students to contribute information directly to their student models, to improve the accuracy of the models and to support reflection on learning. The approach was illustrated with four learning environments. Further work is required, to examine the extent to which students will embrace the approach in practice, in the different contexts of use.

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