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Investigating Learner Trust in Adaptive Learning Systems

Norasnita Ahmad[1]
e-mail: norasnita@utm.my

Susan Bull[2]
e-mail: s.bull@bham.ac.uk

Author(s) Contact Details:
[1] *Faculty of Computer Science and Information Systems, Universiti Teknologi Malaysia, 81310, Skudai, Johor, Malaysia*
[2] *University of Birmingham, Edgbaston, United Kingdom*

Abstract — Open learner models (OLM) is an adaptive learning system that externalise the learner model contents to the user. OLMs assist learners in tracking their knowledge, and promote independent learning by offering information about their knowledge that the learner would not usually see (e.g. a breakdown of concept understanding or descriptions of misconceptions held) which may allow learners to identify areas to target their study. Opening the learner model to the learner may increase their perceptions of how a system evaluates their knowledge and updates the model. Furthermore, some OLMs giving learners to have some control over their models contents. Therefore learners can influence the system in the modeling process. Learners may underestimate or overestimate their knowledge in a self-assessment, and provide incorrect information to their learner model. This raises questions of trust relating to whether the learner believes the evaluations are correct, and whether they trust the system as a whole. This paper investigates learner trust in various open learner model features: the complexity of the model presentation; the level of learner control over the model contents; and the facility to view peer models and release one's own model for peer viewing. An experimental study is done with postgraduate students using two OLM systems – OLMlets and Flexi-OLM. They were instructed to answer questions, explore the learner model views and the system-specific features (persuading and negotiating; use of peer models), and then continue to use the OLMs as best suits their approach to learning. Results suggest that different users may find different features of OLMs important for developing trust.

Keywords – adaptive learning system; open learner model; user trust

1. INTRODUCTION

In student-centred learning students are encouraged to recognise their needs and manage their learning, deepening their understanding using complimentary activities [1]. Student self-knowledge is essential for self-directed learning or student-centred learning [2]. One aim of open learner models (OLM) – learner models that are externalised, and so accessible to the user – is to encourage reflection, independent learning and formative assessment/progress monitoring [3], which fits well with student-centred learning approaches. Learners may also access information about their difficulties and any misconceptions held, through their OLM, where this information is modelled.

Learner models can be externalised using simple or more detailed representations of understanding. Simple representations often display learner knowledge using skill meters that show achievements as a set of progress bars for a set of domain concepts [4]. As simple model views are more limited in information, while they may take different forms, these are often similar in content to skill meters. Detailed presentations of learner models use a variety of methods of showing the model contents, for example: hierarchical tree structures [2]; textual descriptions of knowledge and misconceptions [5]; conceptual graphs [6]; Bayesian networks [7].

The level of control over learner access to their model may differ. For example, users may be able to: simply inspect the model contents [4]; directly provide information to the model [2]; be required to demonstrate their knowledge or skills in order for the model to be changed [8]; jointly negotiate the model with the system [5]. Learners may also be able to release their model to peers and instructors [9]. Such interactions with OLMs raise questions of user trust that may not arise as strongly in other learning environments, as students do not usually see inferences about their knowledge. We here define trust in the learner model as *the individual user's belief in, and acceptance of the system's inferences; their feelings of attachment to their model; and their confidence to act appropriately according to the model inferences*. A lack of trust in an electronic system is likely to discourage a user from using it. In this paper we ask: do learners trust systems that open the learner model to them? Might an OLM make a system more trustable because users can see the information it is using to adapt to them; or might it make a system less trustable - e.g. if the learner can identify errors in the model, or if they consider the information too course-grained to be useful? Which features of an OLM might make a system more 'trustable'?

This paper investigates learner trust in various features of OLMs. The following sections introduce the aspects of OLMs to be investigated in relation to this issue; discuss trust in electronic systems; and present the results of a study to identify OLM features which may help to increase levels of trust in a system.

2. FEATURES OF OPEN LEARNER MODEL

In our investigation of user trust, we consider the following features of OLMs: complexity of model presentation; level of control over the model contents; and release of the model to other users. These are described in the following sections.

A. Complexity of the Learner Model Display

OLMlets is an example of simple learner model presentation, developed as a means to help students identify their strengths and weaknesses as a starting point for their independent study in a range of subjects. It has five learner model presentation formats to allow learners to view their understanding as suits their preferences: skill meter, graph, text, table, and boxes surrounding topic names [3].

Figure 1 shows the skill meter and table views as examples. Different colours are used to indicate knowledge level, areas of difficulty and misconceptions in the skill meter, graph and boxes presentations. Misconception statements can be accessed by clicking on the misconception links, for example: "you may believe that the '=' operator can be used for comparison". Clicking on the numbers below the heading displays an additional set of representations depicting the instructor's expectations for learner knowledge at that stage of their course, for comparison.

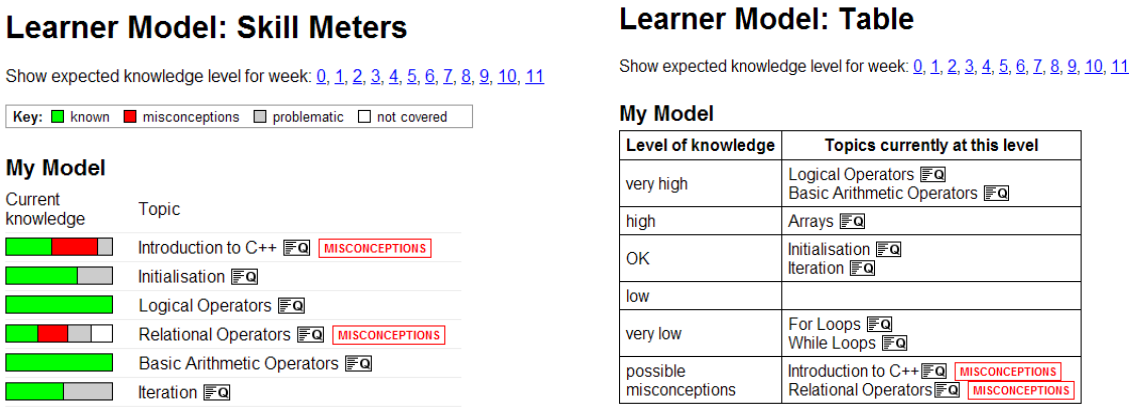

FIGURE 1: Simple skill meter and table learner model views

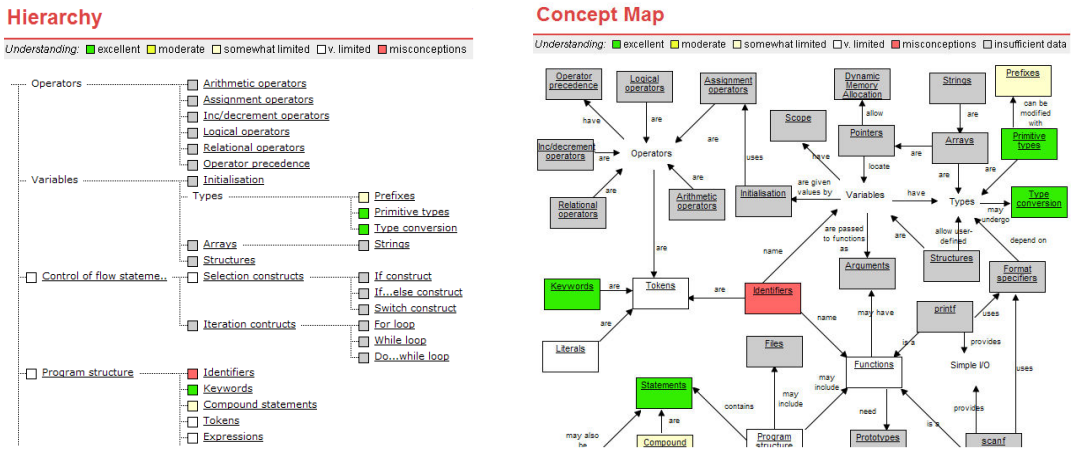

FIGURE 2: Detailed/structured hierarchical tree and concept map learner model views

Our second example, Flexi-OLM, is an OLM that includes complex model presentations. The seven formats are: hierarchy of concepts, lecture structure, concept map, pre-requisites, alphabetical index, list ranked according to

knowledge, text summary [5]. Figure 2 illustrates the concept hierarchy and concept map for C programming. As with OLMlets, students can use those representations that suit them best. Flexi-OLM also uses colour to indicate student understanding, problematic areas and misconceptions, with misconception descriptions and breakdowns of knowledge accessible from the concept links; and similarly to OLMlets, its aim is to help students identify the state of their knowledge in order to help them focus their study appropriately.

B. Learner Control over the Learner Model

OLMlets can be viewed, but the learner cannot change the contents of the model except in the usual way (by answering further questions). Flexi-OLM, as well as being inspectable, also allows students to edit or try to persuade the system of their knowledge if they disagree with the system's representations [8]. Students can edit their model by simply changing the knowledge level, and the system will provide evidence for its views but will accept the changes if the learner wishes to override the system's viewpoint. Persuading the system means students need to demonstrate that they have (or do not have) the skill by answering a few additional targeted questions about a topic. Only if the student convinces the system will the model be altered based on their proposed model changes. Figure 3 shows: (i) the learner requesting to change their knowledge of a topic ('very limited' to 'moderate'); (ii) evidence provided by the system for its beliefs; (iii) the outcome ('somewhat limited'), as the learner demonstrated some additional knowledge in further questioning, but not to the extent they had claimed. (For editing the first two steps are used, with the learner able to confirm their choice if there is disagreement between the user and system.)

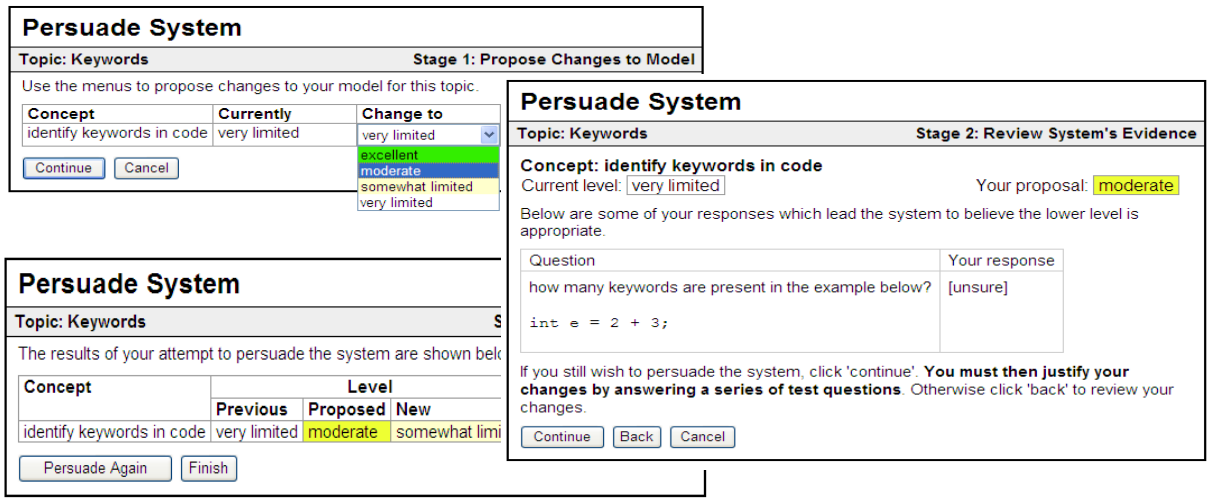

FIGURE 3: Persuading the learner model in Flexi-OLM

C. Releasing the Learner Model to Other Users

In OLMlets students can optionally release all or parts of their learner model to instructors and other students of their choosing, named or anonymously. All peer models accessible to a user can then be viewed together. Students can also access data on the group's knowledge for each topic, with a star indicating their own knowledge. These two types of peer model information are shown in Figure 4. The peer models can be useful to help learners identify areas found difficult generally, and to initiate collaborations with peers [9].

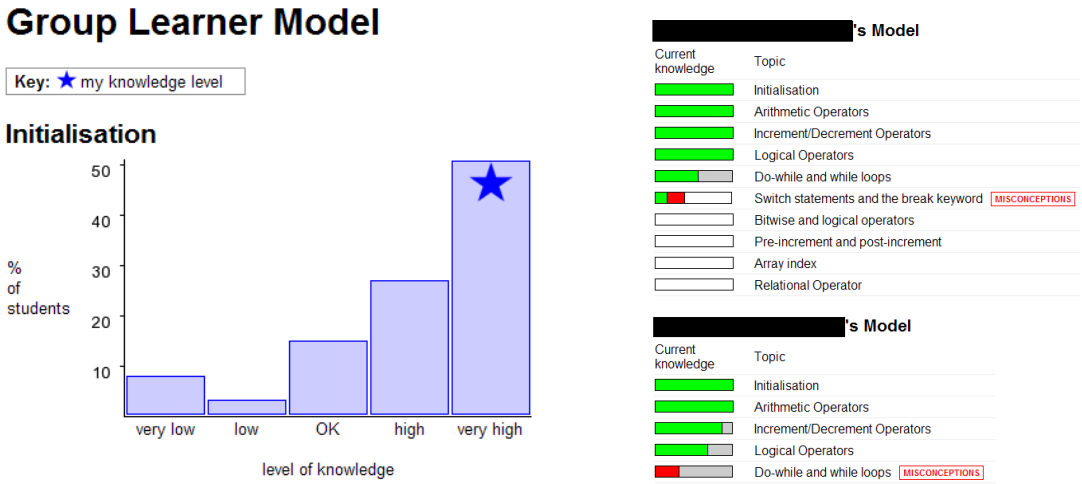

FIGURE 4: The OLMlets group comparison view, and individual peer models view

3. TRUST AND OPEN LEARNER MODELS

Trust is an important issue when there may be potential risks [10], and the topic has been of interest to researchers in many fields. Trust in psychology focuses on personal qualities that deal with belief and expectation of an individual [11], while in sociology trust is seen as a mutual relationship [12]. Trust in e-commerce often relates to user uncertainty concerning vendor activities, and overcoming the perceptions of the risk of sharing personal information [13]. In human-computer interaction, a key question is the extent to which a user has sufficient confidence in a system's actions, decisions or recommendations, in order to act on these [14]. Minimum system performance is necessary for the development of trust in automated systems; and the level of trust in a system may affect user decisions regarding manual or automated control and whether they follow the system's advice [15].

In open learner modelling, aside from issues of privacy and the protection of personal data, the kind of risks that might apply could result from learner control over their model. For example, the learner may underestimate or overestimate their knowledge in a self-assessment, and so provide incorrect information to their learner model [16]. The validity of the model can be affected by model tampering by students [17]. Such inaccuracies introduced into a learner model may affect the appropriateness of subsequent adaptations to the user. Inadequate adaptations may weaken learner trust in the system if they do not realise that these inaccuracies result from their own decisions. However, it has been suggested that students may be less comfortable with simply editing the model: they may prefer to use an OLM that offers less direct control [8]. For example, when persuading the OLM, the learner can disagree with the model and demonstrate their competencies in order to effect a change in the model – i.e. they have the opportunity to challenge their model, but the system makes the final decision over whether the model will be changed. It seems, then, that some learners may trust an OLM to infer their knowledge to a greater extent than they trust themselves to identify it. We hypothesise, therefore, that persuading the learner model may be a more 'trustable' feature than direct editing of it.

With inspectable learner models, students can view (some of) the information about themselves without the possibility of suggesting alterations to it. Trust in the system's representations of the learner's understanding may be particularly relevant here – even if some learners do trust the model generally, if they see even one thing with which they disagree, this may reduce their trust in the system as a whole. Trust in the accuracy of the model may therefore be even more important if learners have no control over its contents.

A different aspect of trust is relevant when considering whether users may be likely to release their learner models to others. This can be useful both for individual learning where learners can identify their position in the group, and for collaboration where students may identify peers that could help them or who may wish to work together with them on a subject [18]. Here questions concern not only user trust in the representations in the learner model, but also in the manner other people might use this information.

The next section addresses learner trust with reference to the complexity of the OLM, level of control over the model, and the release of the model to others.

4. STUDENTS TRUST IN OPEN LEARNER MODELS

We describe an experimental study using the two OLMs presented above, to help identify which aspects of OLMs may increase user trust in a system. Specifically we investigate advanced level students' trust in simple and detailed OLM views, learner control over their model, and the option to release the learner model to others.

A. Methodology

Participants were 9 Masters level students and 9 beginning PhD students: a total of 18 participants. Students used OLMlets and Flexi-OLM during a lab session. They were instructed to answer questions, explore the learner model views and the system-specific features (persuading and negotiating; use of peer models), and then continue to use the OLMs as best suits their approach to learning. Interaction with each system lasted around one and a half hours, including completion of a post-use questionnaire. Responses were given on a five point scale (strongly agree, agree, neutral, disagree, strongly disagree). For clarity of comparison we combined the results for strongly agree and agree, and for strongly disagree and disagree.

B. Results

Table 1 represents the results of students' stated trust in an OLM with reference to the complexity of the model presentation. Two thirds of users claimed to understand the detailed learner model views, while half understood the overview representations. There were also more students agreeing that the detailed views were accurate. Nevertheless, there was a higher level of trust in the overview information. In all cases there were some students who were not positive about these issues with reference to overview and detailed model presentations.

TABLE 1: Learner trust in complexity of model presentation

Complexity of model presentation			
Understand overview of knowledge level	9	9	0
Believed overview learner model was accurate	9	5	4
Trust overview (simple) model information	14	4	0
Understand detailed model information	12	5	1
Believed detailed learner model was accurate	14	3	1
Trust detailed (complex) model information	10	7	1

Table 2 represents the results of students' stated trust in an OLM with reference to the issues considered level of learner control over the model contents. The facility to edit the learner model did not appear to foster trust, whereas there were a higher number of users who placed trust in the persuade feature. More users edited and tried to persuade their learner model when they considered it correct, than when they believed it to contain errors - especially for editing.

TABLE 2: Learner trust in learner control of the model contents

	Agree	***Neutral***	***Disagree***
Level of learner control over model contents			
Trust because can edit model	4	7	7
Edited features believed correct	8	4	6
Edited features believed incorrect	3	5	10
Trust because can persuade system to change model	10	4	4
Tried to persuade features believed correct	9	5	4
Tried to persuade features believed incorrect	6	7	5

Table 3 represents the results of students' stated trust in an OLM with reference to the release of the model for peer and instructor viewing.

TABLE 3: Learner trust in release the model for peer and instructor viewing

	Agree	*Neutral*	*Disagree*
Peer models			
Trust because can compare to peers	9	8	1
Trust because can compare to instructor expectations	11	6	1
Believed correct and opened to peers	12	6	0
Believed correct and opened to instructor	12	4	1
Believed incorrect and opened to peers	7	5	5
Believed incorrect and opened to instructor	6	5	6

The ability to compare one's own model to peer models and instructor expectations increased some learners' trust in their own model (1/2 in the case of peer models; 3/5 with reference to instructor expectations). The majority (around 2/3) would release what they believed to be a correct model to instructors and peers, with fewer releasing what they considered an incorrect model.

B. Discussion

This section discusses the results according to the issues under investigation: (i) learner trust in relation to complexity of the model presentation; (ii) level of learner control over the contents of their learner model; and (iii) use of peer models.

Complexity of model presentation. Presentation of the learner model may play an important role in the likely uptake of OLMs, as students must to some extent understand the model externalisations in order to use them effectively. In our study, two thirds of learners claimed to generally understand the information in the detailed model views, but only half stated that they understood the overview information. Given that learners have different preferences for detailed model presentations [8], it is not surprising that some learners rated this unfavourably - it may be that these users had one or two preferred views (out of seven - which is sufficient for successful use), but in general they found the majority of views less helpful. This is worth further investigation. However, what is surprising, given extensive previous use of the overview model in university courses [18], is that so many users claimed not to understand the simple representations. We hypothesise that this is because users can more easily see the model update precisely because it is so simple. Students are accustomed to receiving simple feedback that reflects an overall score. As OLMlets models knowledge over the most recent five responses for each topic, with heavier weighting on the more recent of these responses, the skill meters (and other views) change in noticeable (and perhaps unexpected) ways. Therefore it may be that users did understand that a 'more filled' skill meter represented greater understanding of a topic, but did not realise that the recency of responses affected weightings in the model. This issue is related to the question of the user being able to predict the system's adaptive behaviour based on their actions in the environment [19]. In line with the above, only half the students believed that the overviews of their knowledge were accurate. This may be due, for example, to the fact that because modelling occurs over several questions, a single (or a few) correct responses will not immediately eradicate any problems shown in the learner model - although the weighting of problematic issues will decrease. Similarly, a misconception will not immediately disappear from the model once a student recognises their misconception: the weighting of the misconception will first decrease before it disappears completely. Thus students may know that they no longer have a misconception even though it is still shown as possibly held. Nevertheless, despite half the students neither fully understanding how the model was updating nor believing it accurate, most students still trusted their overview model. Therefore it seems that, even if not fully understanding and being able to predict the system's actions, learners can still have trust in a system. The reverse was true for the detailed model views: while more understood the representations and had confidence in their accuracy, a lower number claimed to trust them. Perhaps the complexity of the views, although fostering confidence in the model, made them harder for some students to actually *use* and therefore trust in their utility for supporting one's own learning might be reduced.

Level of learner control over model contents. In line with previous findings that students may be more comfortable with a system having greater control over the model contents, than having full control themselves [8], our results suggest this extends to their trust in the learner model. Learners do not simply trust their own amendments to the model, but have greater trust in a method that requires them to demonstrate their skill (or lack of skill) before the model is changed. Particularly interesting is that users both edited and attempted to persuade attributes they considered correct, more than those they believed incorrect (despite the limited time of the evaluation where models could only be partially constructed, thus leaving areas not showing high knowledge where learners may actually have been proficient). This may have been due

in part to curiosity in this particular experimental setting. However, it may instead be because students thought there was little point in interacting about their learner model if it was inaccurate: perhaps they considered it a waste of time to try to change the model contents if the system was likely to continue making what they perceived as incorrect inferences. Indeed, users may have gained trust in the persuade feature by observing that Flexi-OLM would not change an accurate representation to an inaccurate one! There is clearly much further work needed here.

Peer models and instructor expectations. Half the users gained trust in their model from being able to compare it to the peer models. Perhaps this is because they could identify that their position in the group matched what they would expect to see, given their level of knowledge. Of course, half did not state that their trust was related to the ability to explore others' models. It would be interesting to find out whether these users found their relative position to be different from their expectations, or whether they simply did not regard this information as important for trust. Previous users have used peer models extensively [9], but some do prefer not to consult this information. It is unlikely that the latter students would consider the ability to use peer models as increasing their trust in the system. The figure for the facility to compare to instructor expectations was a little higher - for some this confirmation of their position in relation to what they were expected to have achieved, appeared useful for increasing trust. It would be worthwhile investigating whether this generally gave them a greater sense of where they should be, and trust was related to this feeling of understanding what their progress actually meant; or, for example, whether the trust was increased through the knowledge that the instructor had thought about what acceptable student progress would be, and defined these milestones. Most learners were willing to open their learner model to peers and instructors if they believed the model inferred by the system was accurate. However, some still released what they considered an inaccurate model to others. Since students could release their models anonymously if they preferred, this greater reluctance would not be due to the possibility of others identifying them with inaccurate data. The situation of perceived potential model inaccuracies may affect use of the model for initiating or supporting collaborations between learners: if learners have released their own 'incorrect' model (according to their belief) to other users, might they trust the models of others less? Might this make them less inclined to seek help according to the contents of peer models? Obviously another issue is the use peers might make of their own model - trust in colleagues is particularly important in this kind of context.

Issues for investigation. We have raised many questions relating to trust in OLMs. In terms of the complexity of the model, learners seem to understand detailed presentations better; however they seem to have greater trust in an overview. We have suggested that learners may not have understood the manner in which the overview model was updating, but since they did seem to trust it, this suggests understanding the manner in which the model is inferred, may not be crucial in creating trust. This would be an issue to investigate further. Some learners edited or endeavoured to persuade their models even when they believed the model content was correct, but fewer students challenged what they perceived to be incorrect attributes. We have hypothesised that this may be due to lower trust in the system's ability to continue modelling them correctly after the model was changed. This should be considered further. Finally, many learners appear to trust their model because they could compare it to instructor expectations, and some also because they could compare to peer models. It would be useful to investigate how trust might be developed amongst learners who have access to each others' learner models. Trustable OLMs are likely to be important to encourage users to continue using them, in order to gain the educational benefits that can be derived (e.g. metacognitive skills such as supporting planning, reflection, formative assessment). A key question is how to design an OLM that can incorporate a variety of issues that may enhance trust for a range of users.

5. CONCLUSION

This paper has considered trust issues in OLMs, focusing on (i) complexity of model presentation; (ii) level of learner control over the model; (iii) the facility to view peer models and release one's own model to peers. Results suggest that different users may find different features of OLMs important for developing trust. As designing trustable OLMs may be crucial for their maintained use, a key issue is how to design an OLM that might be trustable for a variety of users.

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