

Chapter 15: Open Learner Models

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Abstract. An Open Learner Model makes a machine's representation of the learner available as an important means of support for learning. This means that a suitable interface is created for use by learners, and in some cases for others who aid their learning, including peers, parents and teachers. The chapter describes the range of purposes that Open Learner Models can serve, illustrating these with diverse examples of the ways that they have been made available in several research systems. We then discuss the closely related issues of openness and learner control and the ways that have been explored to support learning by making the learner model available to people other than the learner. This chapter provides a foundation for understanding the range of ways that Open Learner Models have already been used to support learning as well as directions yet to be explored.

15.1 Introduction

Open learner models are learner models that can be viewed or accessed in some way by the learner, or by other users (e.g. teachers, peers, parents). Thus, in addition to the standard purpose of the learner model of maintaining data to enable adaptation to the individual according to their current learning needs, the learner model contents can also be of direct use to the user.

There are a variety of ways in which a learner model might be helpful to the learner, identified in the SMILI[©] (Student Models that Invite the Learner In) Open Learner Modelling Framework [1] as:

- Promoting metacognitive activities such as reflection, planning and self-monitoring;
- Allowing the learner to take greater control and responsibility over their learning, encouraging learner independence;
- Prompting or supporting collaborative and/or competitive interactions amongst groups of students;
- Facilitating interaction between learners and peers, teachers and parents;
- Facilitating navigation to materials, exercises, problems or tasks, etc., where links are available from the learner model;
- Supporting assessment - in particular providing formative assessment opportunities for students, but also enabling the learner model to be used as a summative assessment;

- Increasing the accuracy of the learner model data if the user is allowed to contribute additional or corrective information, to enable a more precise adaptive interaction to follow;
- Increasing learner trust in an adaptive educational environment by showing the system's inferences about their knowledge;
- The (non-educational) issue of people having the right to access electronic data about themselves.

A learner model that is inferred using any learner modelling technique could potentially be opened to the learner, if viewing the information in their learner model may be of benefit to the user. For example, learner models have been opened in simple weighted numerical models [2], fuzzy models [3], constraint-based models [4], Bayesian models [5], transferable belief models [6], knowledge tracing [7], and models constructed using conceptual graphs [8]. The modelling technique does not necessarily determine the form in which the learner model will be presented to the user, or the level of interactivity the learner can have with their learner model.

Similarly, learner models can be opened in a variety of domains. As with adaptive learning environments that do not open the learner model to the user, they are often in programming [9], mathematical [6], scientific [5] or second language [10] domains. However, in line with increasing interest in less traditional domains in the field of artificial intelligence in education, open learner models are also becoming available in a broader selection of subjects. Examples include music theory [11] and historical text comprehension [12]. Domain-independent open learner models have also been developed [13], [14], [15], [16], [17], [18]. Furthermore, learner model attributes presented to the learner are not only cognitive, but may also include, for example, affective or social attributes [19].

In this chapter we give an overview of the presentation of open learner models, including common and less-traditional learner model externalisations; user/system control of the learner model and learning; and learner models open to other users such as peers, instructors and parents.

15.2 Presentation of Open Learner Models

Opening the learner model generally involves more than simply showing the learner the representations from the underlying system's model of their knowledge (or other attributes modelled), as these representations are not usually designed for interpretation by humans. In particular, learner models may not be designed for interpretation by those who are still learning a subject. While there is a case for ensuring that the underlying representation is designed explicitly to support the valuable roles that the open learner model can provide, this has generally not been the approach adopted. Regardless of the internal representation, a key challenge in opening a model to serve one of the purposes listed above, is to create an effective interface for presenting the model and supporting interaction with it.

As noted above, the method of model presentation does not necessarily match the underlying complexity of the model. For example, simple learner model overviews in the form of skill meters have been used to display a learner's knowledge level in a constraint-based model [4] (Figure1), and in a simple weighted numerical model [20] (left of Figure 2). Moreover, the complexity of a view of the learner model may differ within a system. Figure 2 shows both skill meters and a structured view of the learner model data available to the user in a single system (colour of nodes shows level of knowledge in the structured view) [20].

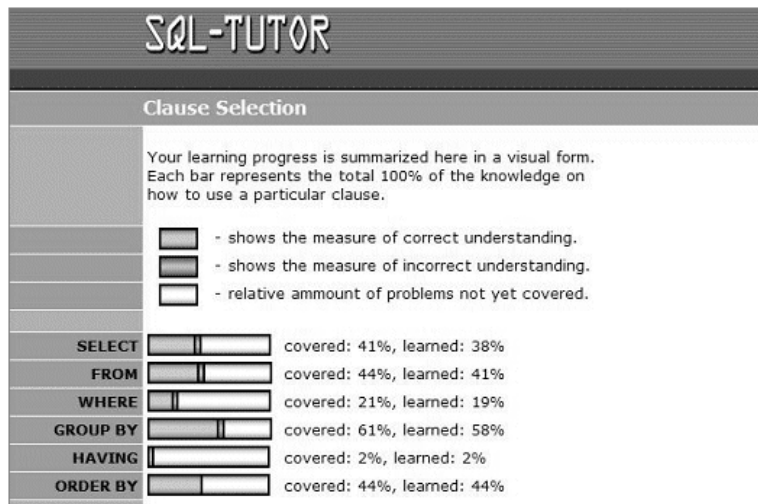


Fig. 1. Skill meters in SQL Tutor [4]

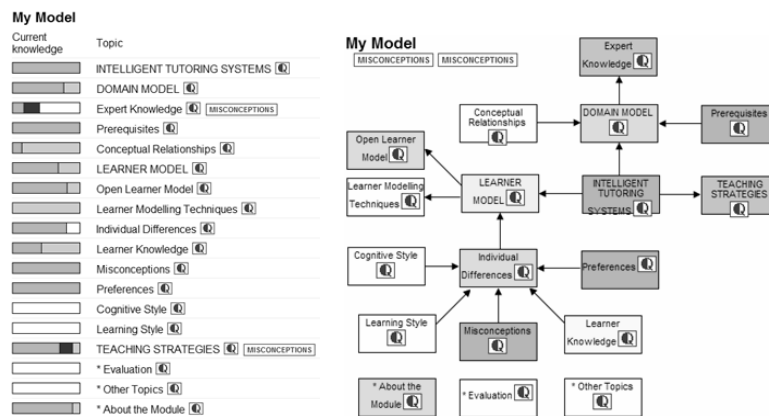


Fig. 2. Skill meters and structured view in OLMlets [20]

Skill meters are the most commonly used simple overviews of the learner model contents, with a meter assigned to each topic or concept, which may include separate

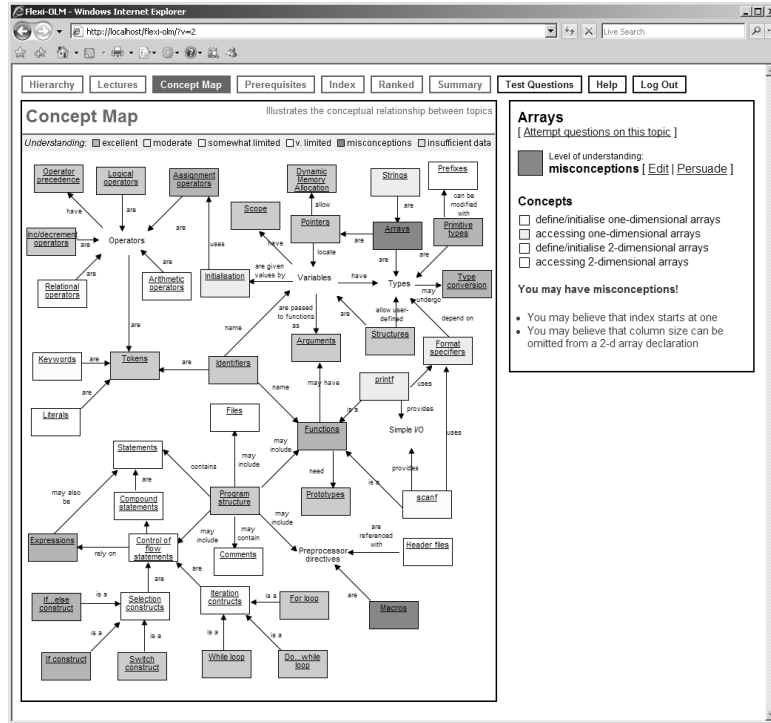


Fig. 5. The Flexi-OLM concept map [29]

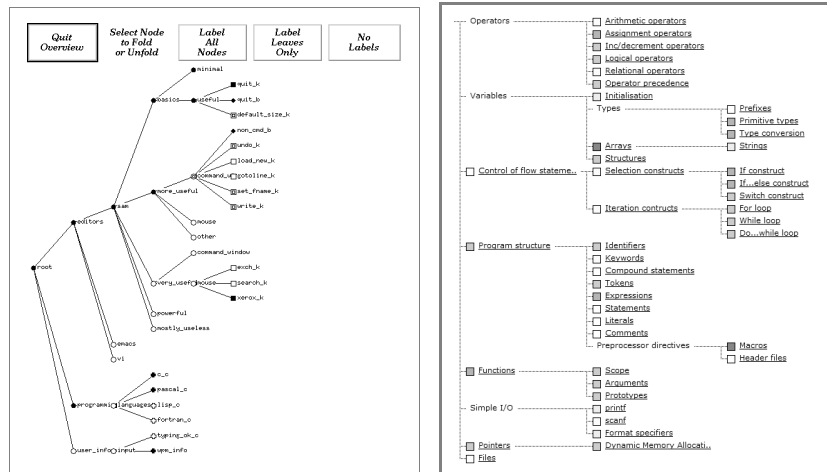


Fig. 6. Tree structures in UM [30] and Flexi-OLM [27]

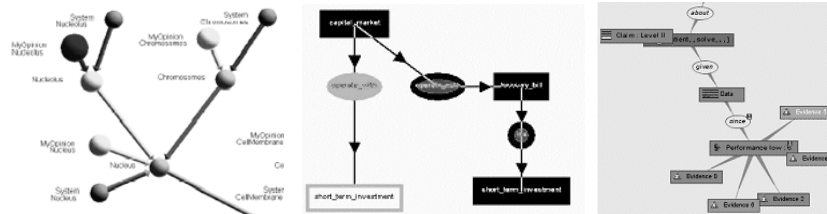


Fig. 7. Other structured open learner model presentations [5], [8], [6]

Consideration needs to be given to cases where detailed complex or structured learner model information is to be presented to the learner. UM [32] (left of Figure 6) allows the learner to expand and contract nodes to accommodate this requirement; SIV [17] uses size, position and colour of text to display a large amount of learner model data (left-hand panel of Figure 8). (Other uses of text in open learner models include [3], [10], [33].)

Fig. 8. Textual learner model presentation in SIV [17]

- Work has also investigated less traditional learner model presentations, including:
- audio and domain-specific representations for open learner models – e.g. MusicaLM [11] provides learner model information to the learner using a text description of learner beliefs, but also audio (music notes) and music notation (Figure 9);
 - haptic feedback in an open learner model, where strength of knowledge is portrayed by the ‘hardness’ or ‘softness’ of a sphere representing each area of the domain, and misconceptions feeling ‘soft and sticky’ [34] (Figure 10);
 - open learner models for simulation tasks, such as the operation of a pole and cart device simulator [35] (Figure 11);

- animations of a learner's misconceptions for comparison to the correct domain concepts, currently implemented for programming and chemistry [36] (Figure 12).

Fig. 9. Non-traditional open learner model presentation I: music notation and audio (extended from [11])

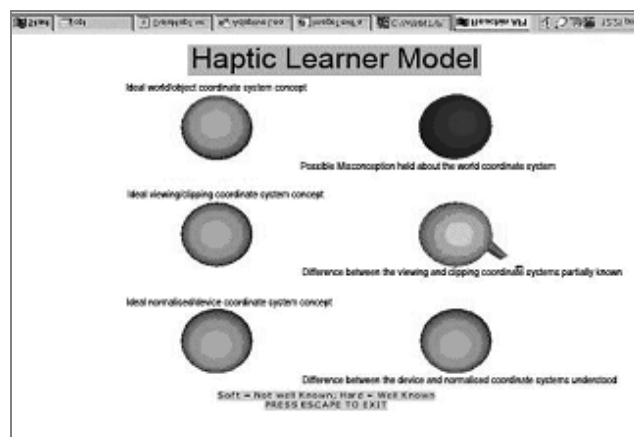


Fig. 10. Non-traditional open learner model presentation II: haptic learner model feedback [34]

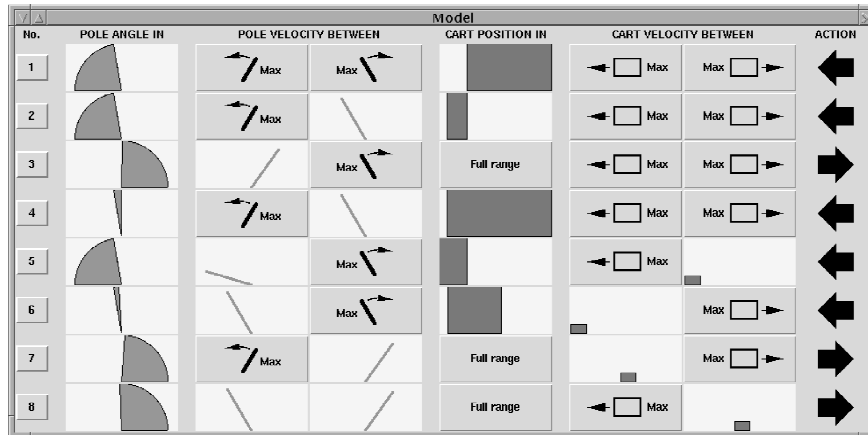


Fig. 11. Non-traditional open learner model presentation III: simulation task (operation of pole and cart device) [35])

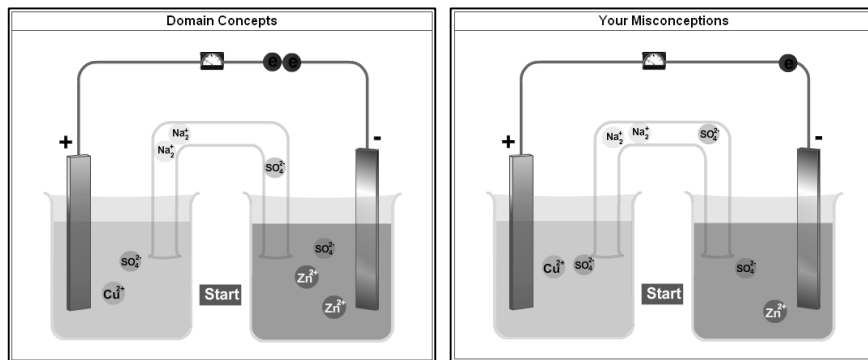


Fig. 12. Non-traditional open learner model presentation IV: animating learner beliefs (extended from [36])

In addition to learner models that contain a single view of the learner model data, systems can offer multiple views of the same (or similar) model data for learners to explore (as many as seven views have been available in a system, with users able to select their preferred views without difficulty [29]); or multiple views with different aspects of the model information (e.g. [6]). Furthermore, the presentation method of the learner model may be adapted to the individual [37]. Both user choice of view to access, and adaptive model presentations, are feasible – the most appropriate likely depending on the context of use.

15.3 Learner/System Control

As well as different methods of presentation of open learner models, the type of interaction a learner may have with their model and the level of control they have over the model contents, may differ. The question of learner/system control in open learner modelling is closely related to issues of metacognition in this context [38].

15.3.1 System Control over the Learner Model Contents

The most straightforward form of open learner model is where the model is available for user viewing, but with no additional interactivity possible. These are known as *inspectable* learner models, and are completely under the control of the system - i.e. although the learner may view (or inspect) their learner model, they cannot make or suggest any changes to the system inferences about their understanding (or other attributes modelled). Most open learner models are in this category, including many of those introduced above. Inspectable learner models address the requirements for people to be allowed access to electronic data about themselves; but they also have the function of raising learner awareness of their knowledge, and prompting reflection, planning and formative assessment. Inspectable learner models are likely also to influence user trust in a system by confronting users directly with the system's inferences about their understanding.

15.3.2 Learner Control over the Learner Model Contents

In contrast to the above, *editable* learner models are learner models that are available for user viewing (as are inspectable models), but where the learner is able to change, or edit the contents. This is illustrated in Figure 13 by Flexi-OLM [29]. While the system may offer evidence or information to demonstrate where it disagrees with the learner's viewpoint (as is the case in Flexi-OLM, which can provide evidence in the form of the learner's responses to recent questions), the learner can in all instances override this if they wish, and so ensure that their desired changes to the model are effected.

Other examples help the learner to understand why and how the model was adapted to them, as illustrated in Figure 14 by SASY-unix, where the right-hand panel summarises the reasons for adaptation (e.g. "you want to get more than a pass grade", "you know the unix file system but haven't passed the quiz") [18]. Users of any SASY-based system can click the *why?* to see the reasons that the system believes this part of the learner model has its current value. They can inform the system of their own assessment of this part of the model. They can see if this will directly alter the value, as is the case for the belief "you want to get more than a pass grade". Or, if they cannot alter it directly, as in the case of "you know the unix file system but haven't passed the quiz", they can see that doing the quiz could change the value. The upper right of the display shows how the page was adapted; in this case, 2 items were removed and 5 added, because of the current learner model components listed. The learner can click this to see just how the presented content was personalised, which parts added or omitted. Each of these presents details of the parts of the learner model that controlled that personalisation. Therefore the learner can scrutinise the

personalisation to see what has been personalised. They can also see the precise parts of the learner model that caused this, as well as the reasons that the learner model has its current value.

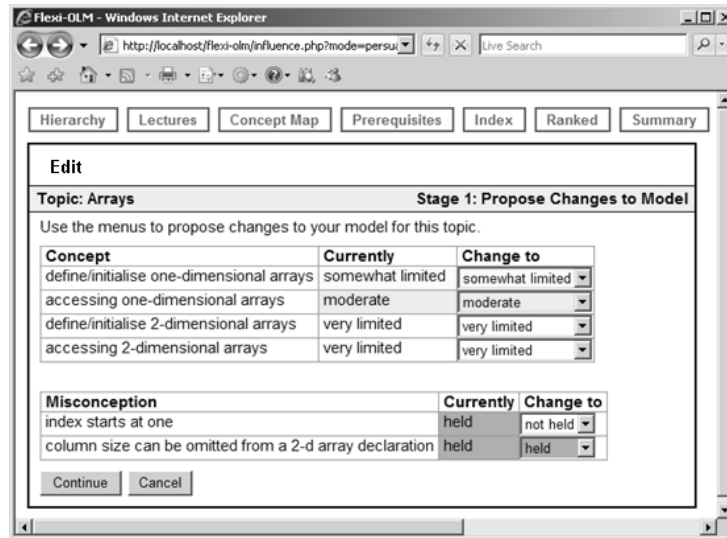


Fig. 13. Editing the Learner Model in Flexi-OLM [29]

Similar to learner model editing is an approach where the learner may *challenge* their model, and justify the changes they make to the model. The system will still accept the user's changes (and therefore the learner can still be said to be editing their model), but this additional information from the learner can feed back into the learner modelling process [6].

Reasons for allowing learners to edit their model include enabling them to inform the system directly if: (i) their knowledge has increased (e.g. after a lecture or their own reading); (ii) they have forgotten information or techniques (to allow the system to consider or recommend appropriate revision); (iii) they were guessing (to allow the system to reevaluate the learner model contents accordingly). Editable learner models place the learner in full control, inviting them to take responsibility for their learning interactions. The fact that a learner will need to be sure of any permanent changes they make to their learner model should also lead to them considering the options carefully, and so promote metacognitive activities as is the case with inspectable models. It may also increase user trust in a system as the user can control the data that determines adaptations in the interaction, if they wish.

Home Contents Your Profile Make Notes Change Topic Help

UNIX File System overview

UNIX Joke:
Costello calls Abbott with some questions about UNIX:
Costello: What is the command that will tell me the revision code of a program?
Abbott: Yes, that's correct.
Costello: No, what is it?
Abbott: Yes.
Costello: So, which is the one?
Abbott: No, 'which' is used to find the program.
Costello: Stop this. Who are you?
Abbott: Use 'who am i' not 'who r yoo'. You can also 'finger yoo' to get information about 'yoo'.
Costello: All I want to know is what finds the revision code?
Abbott: Use 'what'.

The File System is responsible for the management of data and files within your computer. It is responsible for storing your files on a permanent storage device (e.g. a hard-disk), allowing you to retrieve, view, modify and return them to storage.

In UNIX, all your data is stored in files and directories, in a hierarchical structure. A directory is a logical container of files and more directories. This is the same as the concept of folders in a Windows operating system. A UNIX file stores data, for example, text or an image.

Did U know ?

In actual fact, in UNIX directories are just special files that contain the names of the files they contain. However, the system knows to interpret these files differently to regular files. In UNIX, all data in the file system is stored as files and inodes. Inodes store system information about files that tell the file system where the data physically is stored on disk (i.e. the disk address of the data chunks).

A UNIX File System holds system files/directories user's private files/directories. Typically, the system administrator will restrict access to the system area and provide users with their own private areas.

Henrik's Hint : This topic is here because you need to know these things:

- How to navigate around the file system
- How to use relative and absolute paths
- How to view the security permissions on a file or directory

According to your profile, you know about the UNIX File System but haven't passed the quiz:

You can either [review these topics](#) or [attempt the UNIX File System Quiz](#)

Personalisation

[2 items removed](#)
[5 items added](#)

because your profile has:

- You want to get more than a pass grade [why?](#)
- You know the UNIX File System but haven't passed the quiz [why?](#)
- You want Henrik's hints [why?](#)
- You want UNIX jokes [why?](#)
- You want lots of practice quizzes [why?](#)

Page: Courses/UNIX3/FS_1.xml

Fig. 14. Explaining the Learner Model in SASY-unix [18]

15.3.3 Mixed Control over the Learner Model Contents

Interactive open learner models that allow an intermediate level of learner control include *co-operative* models [39], where the user and system provide different and complementary information for the learner model; *persuasion*, where the learner aims to change the model data (as in editable models), but the system will only subsequently alter the model if the learner can demonstrate that their self-assessment is accurate (e.g. by an additional short test) [29]; where additional information is provided for the learner model, to be considered alongside system inferences - i.e. the user may *add evidence* [30]; and a truly balanced distribution of control of the learner model contents between the user and the system, where a negotiation process aims to

achieve an agreed learner model. If this is not possible, any conflicts between the learner's and the system's representations are maintained in the model. This is illustrated in Figure 15 with Mr Collins (in the domain of pronoun placement in European Portuguese) [10].

Currently your own confidence in your use of the rule applicable in positive main clause statements is: 'almost sure'. (system's confidence = 'unsure')
 What is your new confidence level?:

You have changed your confidence measure from 'sure' to 'very sure'. 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:

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

These recent attempts demonstrate that you are having difficulties. Confidence measure 'very sure' is too high for your proficiency. What do you wish to do?

<input type="button" value="view student model"/>	<input type="button" value="system justify itself"/>
<input type="button" value="keep new belief"/>	<input type="button" value="change my belief"/>

Fig. 15. Negotiating the Learner Model in Mr Collins [10]

Negotiation can be undertaken in a variety of ways, for example: by menu selection [10]; dialogue games [8]; and chatbots [40]. Whatever technique is used, the key point is that the system and the user have equal rights to initiate and end discussions in negotiated learner models; and have the same negotiation moves available (e.g. offer information, request information, confirm, accept, critique, challenge, refute, justify).

Intermediate levels of interactivity in learner model maintenance may also require users to think carefully about any evidence they wish to add or remove, or discuss with the system. Therefore opening the learner model has a strong reflective element at various levels/types of interaction. While the learner is not able to edit the model to increase its accuracy, they do have the opportunity to directly influence the contents (though any proposed changes may not be agreed by the system). This increased involvement in the modeling processes may also affect user trust. Indeed, it has been suggested that learners may have greater trust in an environment where there is mixed control over the learner model, than full user control [41]. The most appropriate approach will likely depend on the context in which the open learner model is to be used.

15.3.4 Independent Open Learner Models

Open learner models are usually integrated into an adaptive learning environment for consultation by the learner during their personalised interaction. This takes various forms, but well-known examples include skill meters for display alongside problem-

solving and other tutorial support in an intelligent tutoring system [4] and in adaptive educational hypermedia providing navigation support [9].

Whereas traditionally, adaptive learning environments (including those with open learner models) often have greater control over an interaction, independent open learner models [14] are *independent* of a larger tutoring system. The learner model is constructed as in any system, but there is no additional (or only limited) tutoring or system guidance based on the learner model. The control and responsibility for decisions in their learning rest entirely with the learner: their planning and activity choices are facilitated by the contents of their learner model (we are therefore not concerned in this sub-section with control over the learner model contents, though the above distinctions are also applicable in independent open learner models). Although most open learner models are part of a larger system, independent open learner models have been successfully trialled in a variety of contexts (e.g. with trainee pilots [42], language learners [43], university students [14] and schoolchildren [40]). Figures 2 (OLMlets) and 5 (Flexi-OLM) show examples of independent open learner models.

15.4 Open Learner Models for Other Users

Open learner models are applicable not only to individual learning scenarios, but can also be used in group learning. This may include individual models released by the learner to other group members – i.e. instructors or peers will see the specific information that the learner releases to them, as in OLMlets [44] (Figure 16). This enables learners to find collaborators (e.g. to seek help or to jointly work on an area where both individuals have weak knowledge; to compete with others; or simply to compare their progress against that of other users while preferring to work alone). Individuals may also be able to compare their own knowledge of a topic or concept (indicated by a star) on a five-point scale of very low to very high, to the knowledge of the group. Instructors can benefit from information about the progress of the group they are teaching, or from information about an individual's specific knowledge (or misconceptions). The learner model can be accessed in the format of choice of the viewer of the model (i.e. the same views are available to all users, but a peer or instructor who has been given access to an individual's learner model may select how to view it).

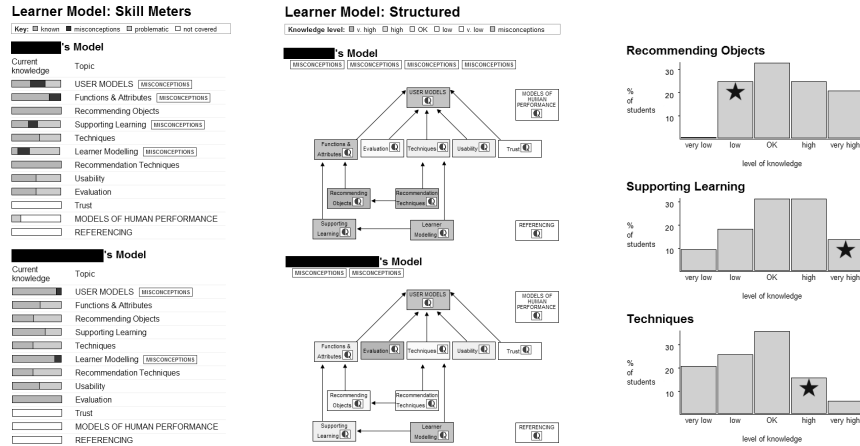


Fig.16. Individual learner models accessible to other users (student names hidden in this image), and group model in OLMlets [20], [44]

Similar approaches also allow the teacher to access information about an individual or groups of students, for example, using concept map, table, bar chart and text presentations for individuals or groups [45]. Systems may use different model presentation formats for different categories of user. For example, in DynMap [16], the student may view the concept map of their current beliefs in a simpler format than does the teacher, who can follow more detailed representations of the evolution of the student's knowledge. In Subtraction Master [24], the child views their learner model as a series of simple smiley faces representing the extent of their subtraction skills at different levels of difficulty. The teacher has more detailed information available, to help them to help a child individually. (This includes not only misconceptions identified, but also cases where misconceptions could have been demonstrated but were not, based on the subtraction questions that the child attempted.) This is illustrated in Figure 17. Similarly, as shown in Figure 18, Fraction Helper [25] provides additional information to parents, over the learner model representations seen by their child. Nevertheless, the information for parents is still quite simple, as it is not assumed that all parents will have sufficiently advanced skills to interpret complex information. (Adapting the learner model presentation for parents is an issue that may benefit from further research.) Other open learner models that permit instructor (and sometimes other user) access include REPro [46], CosyQTI [47], CourseVis [15], INSPIRE [48], Logic-ITA [49], MIM [50], PDinamet [51].

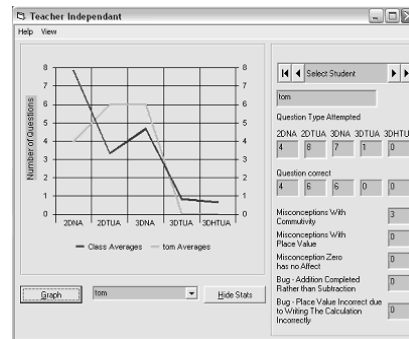
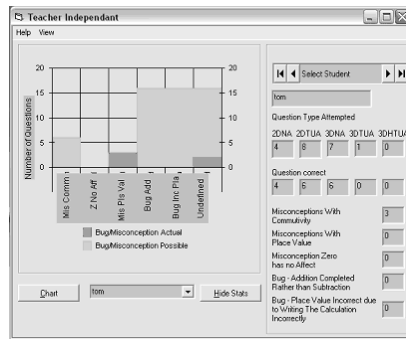
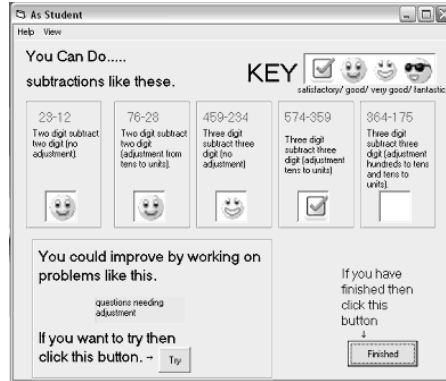


Fig.17. An open learner model for children (upper) and teachers (lower) in Subtraction Master [24]

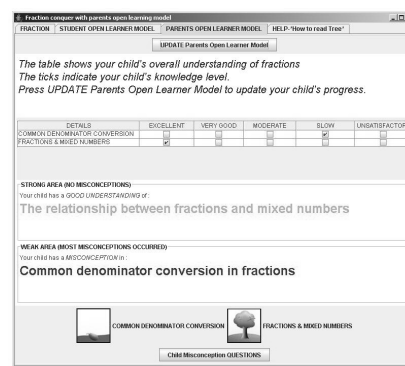
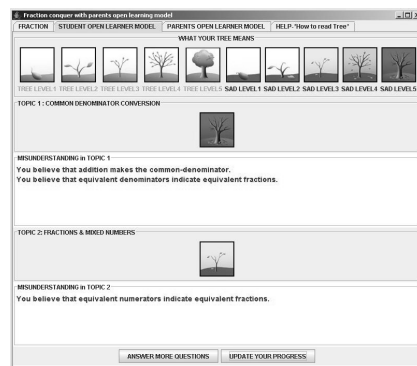


Fig. 18. An open learner model for children (left) and additional information for parents (right) in Fraction Helper [25]

Open learner models may also reflect group learning. A simple example was shown in Figure 16, but group open learner models can have much greater complexity. For instance, supporting long term group work based on evidence from

group work tools, with the aim of facilitating effective group functioning. Figure 19 shows individual contributions to the group over time (each column represents one group member, with the brightness of a square showing the level of activity at that time) [52] but as it uses very simple measures, it also links directly to the evidence and allows the learner to control the system decisions about when to make a square brighter. Evaluations of this and an earlier version [53] indicates that it helped team members identify group work problems and negotiate solutions. It was also used by the group facilitator (tutor) to help with group problems and it served as a way to navigate the information space, a new role for an open learner model.

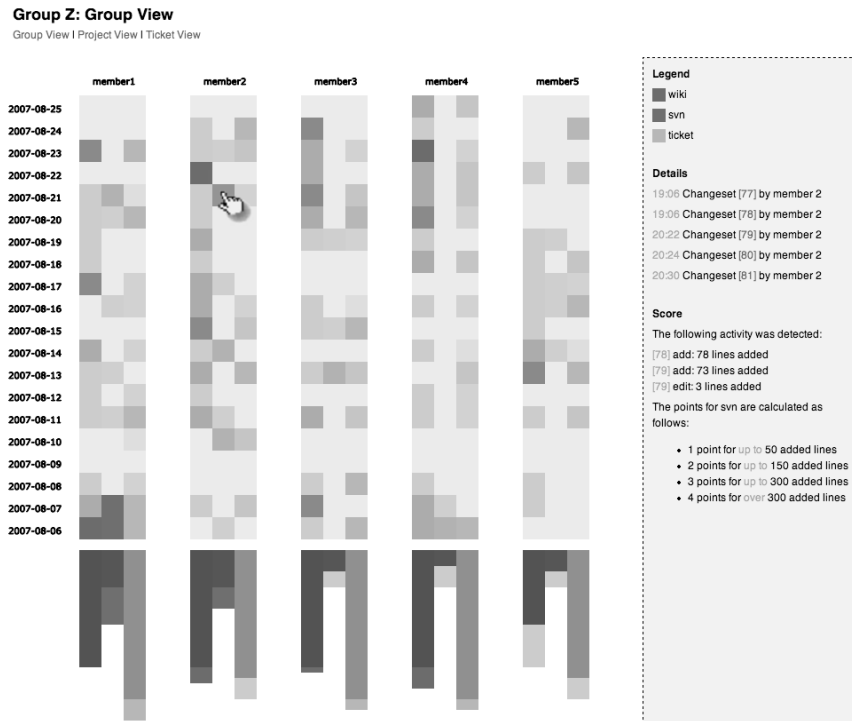


Fig. 19. Group activity model in Narcissus [52]

15.5 Summary

This chapter has provided an overview of some of the central issues in open learner modelling, with a particular focus on the ways in which open learner models are presented to the user; differences in user/system control over the learner model data and their learning; and learner models that are accessible to other users (e.g. peers, instructors, parents). While there are now many systems containing open learner

models, there remain a range of directions for research in this area, including those areas presented in the introduction (from the SMILI open learner modelling framework [1]), but new areas will likely also emerge.

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References

1. Bull, S., Kay, J.: Student Models that Invite the Learner In: The SMILI Open Learner Modelling Framework. *International Journal of Artificial Intelligence in Education* 17(2), 89-120 (2007)
2. Bull, S., Gardner, P.: Highlighting Learning Across a Degree with an Independent Open Learner Model, in V. Dimitrova, R. Mizoguchi, B. du Boulay & A. Graesser (eds), *Artificial Intelligence in Education*, IOS Press, Amsterdam, 275-282 (2009)
3. Mohanarajah, S., Kemp, R.H. & Kemp, E.: Opening a Fuzzy Learner Model. *Proceedings of Workshop on Learner Modelling for Reflection, International Conference on Artificial Intelligence in Education*, 62-71 (2005)
4. Mitrovic, A., Martin, B.: Evaluating the Effect of Open Student Models on Self-Assessment. *International Journal of Artificial Intelligence in Education* 17(2), 121-144 (2007)
5. Zapata-Rivera, J.D., Greer, J.E.: Interacting with Inspectable Bayesian Models. *International Journal of Artificial Intelligence in Education* 14, 127-163 (2004)
6. VanLabeke, N., Brna, P., Morales, R.: Opening Up the Interpretation Process in an Open Learner Model. *International Journal of Artificial Intelligence in Education* 17(3), 305-338 (2007)
7. Corbett, A.T., Bhatnagar, A.: Student Modeling in the ACT Programming Tutor: Adjusting a Procedural Learning Model Model with Declarative Knowledge. In A. Jameson, C. Paris & C. Tasso (eds), *User Modeling*, Springer, New York, 243-254 (1997)
8. Dimitrova, V.: StyLE-OLM: Interactive Open Learner Modelling. *International Journal of Artificial Intelligence in Education* 13(1), 35-78 (2003)
9. Weber, G., Brusilovsky, P.: ELM-ART: An Adaptive Versatile System for Web-Based Instruction, *Int. J. of Artificial Intelligence in Education*. 12, 351-384 (2001)
10. Bull, S., Pain, H.: "Did I say what I think I said, and do you agree with me?": Inspecting and Questioning the Student Model, in J. Greer (ed), *Proceedings of World Conference on Artificial Intelligence and Education*, Association for the Advancement of Computing in Education, Charlottesville VA, 501-508 (1995)
11. Johnson, M., Bull, S.: Belief Exploration in a Multiple-Media Open Learner Model for Basic Harmony. In V. Dimitrova, R. Mizoguchi, B. du Boulay & A. Graesser (eds), *Artificial Intelligence in Education*, IOS Press, Amsterdam, 299-306 (2009)
12. Grigoriadou, M., Tsaganou, G., Cavoura, T.: Dialogue-Based Reflective System for Historical Text Comprehension, *Proceedings of Workshop on Learner Modelling for Reflection (Supplemental Proceedings vol 5)*, *International Conference on Artificial Intelligence in Education*, 238-247 (2003)

13. Brusilovsky, P. Sosnovsky, S.: Engaging Students to Work with Self-Assessment Questions: A study of two approaches, Proceedings of 10th Annual Conference on Innovation and Technology in Computer Science Education, ACM Press, 251-255 (2005)
14. Bull, S., Mabbott, A., Gardner, P., Jackson, T., Lancaster, M., Quigley, S., Childs, P.A.: Supporting Interaction Preferences and Recognition of Misconceptions with Independent Open Learner Models. In W.Nejdl, J. Kay, P. Pu & E. Herder (eds), Adaptive Hypermedia and Adaptive Web-Based Systems, Springer-Verlag, Berlin Heidelberg, 62-72 (2008)
15. Mazza, R., Dimitrova, V.: Visualising Student Tracking Data to Support Instructors in Web-Based Distance Education, 13th International World Wide Web Conference - Alternate Educational Track, 154-161 (2004)
16. Rueda, U., Larrañaga, M., Ferrero, B., Arruarte, A. & Elorriaga, J.A.: Study of Graphical Issues in a Tool for Dynamically Visualising Student Models, Proceedings of Workshop on Learner Modelling for Reflection (Supplemental Proceedings vol 5), International Conference on Artificial Intelligence in Education, 268-277 (2003)
17. Kay, J., Lum, A.: Exploiting Readily Available Web Data for Scrutable Student Models, in C-K Looi, G. McCalla, B. Bredeweg & J. Breuker (eds), Artificial Intelligence in Education, IOS Press, Amsterdam, 338-345 (2005)
18. Czarkowski, M., Kay, J. & Potts, S.: Web Framework for Scrutable Adaptation, Proceedings of Workshop on Learner Modelling for Reflection, International Conference on Artificial Intelligence in Education, 11-18 (2005)
19. Chen, Z-H., Chou, C-Y., Deng, Y-C. & Chan, T-W.: Active Open Learner Models as Animal Companions: Motivating Children to Learn through Interacting with My-Pet and Our-Pet, International Journal of Artificial Intelligence in Education 17(2), 145-167 (2007)
20. Ahmad, N., Bull, S.: Learner Trust in Learner Model Externalisations. In V. Dimitrova, R. Mizoguchi, B. du Boulay & A. Graesser (eds.) Artificial Intelligence in Education, IOS Press, Amsterdam, 617-619 (2009)
21. Papanikolaou K., Grigoriadou M., Kornilakis H., Magoulas G.D.: Personalising the Interaction in a Web-based Educational Hypermedia System: The Case of INSPIRE, User-Modeling and User-Adapted Interaction 13(3), 213-267 (2003)
22. Bull, S., McEvoy, A.T.: An Intelligent Learning Environment with an Open Learner Model for the Desktop PC and Pocket PC. In U. Hoppe, F. Verdejo & J. kay (eds), Artificial Intelligence in Education, IOS Press, Amsterdam, 389-391 (2003)
23. Linton, F., Schaefer, H-P.: Recommender Systems for Learning: Building User and Expert Models through Long-Term Observation of Application Use, User Modeling and User-Adapted Interaction 10, 181-207 (2000)
24. Bull, S., McKay, M.: An Open Learner Model for Children and Teachers: Inspecting Knowledge Level of Individuals and Peers. In J.C. Lester, R.M. Vicari & F. Paraguacu (eds), Intelligent Tutoring Systems, Springer-Verlag, Berlin Heidelberg, 646-655 (2004)
25. Lee, S.J.H. Bull, S.: An Open Learner Model to Help Parents Help their Children, Technology, Instruction, Cognition and Learning 6(1), 29-51 (2008)
26. Perez-Marin, D., Alfonso, E., Rodriguez, P., Pascual-Neito, I.: A Study on the Possibility of Automatically Estimating the Confidence Value of Students' Knowledge in Generated Conceptual Models, Journal of Computers 2(5), 17-26 (2007)
27. Mabbott, A., Bull, S.: Alternative Views on Knowledge: Presentation of Open Learner Models. In Lester, J.C., Vicari, R.M., Paraguacu, F. (eds.), Intelligent Tutoring Systems: 7th International Conference, Springer-Verlag, Berlin Heidelberg, 689-698 (2004)
28. Kumar, A., Maries, A.: The Effect of Open Student Model on Learning: A Study, in R. Luckin, K.R. Koedinger, J. Greer (eds), Artificial Intelligence in Education, IOS Press, Amsterdam, 596-598 (2007)
29. Mabbott, A., Bull, S.: Student Preferences for Editing, Persuading and Negotiating the Open Learner Model. In M. Ikeda, K. Ashley & T-W. Chan (eds), Intelligent Tutoring Systems: 8th International Conference, Springer-Verlag, Berlin Heidelberg, 481-490 (2006)

30. Cimolino, L., Kay, J., Miller, A. Concept mapping for Eliciting Verified Personal Ontologies, *International Journal of Continuing Engineering Education and Lifelong Learning* 14(3), 212-228 (2004)
31. Mabbott, A. & Bull, S.: Comparing Student-Constructed Open Learner Model Presentations to the Domain, in K. Koedinger, R. Luckin & J. Greer (eds), *Artificial Intelligence in Education*, IOS Press, Amsterdam, 281-288 (2007)
32. Kay, J.: Learner Know Thyself: Student Models to Give Learner Control and Responsibility. In: Halim, Z., Ottomann, T., Razak, Z. (eds.), *Int. Conference on Computers in Education*, AACE, pp. 17-24 (1997)
33. Tchétagni, J., Nkambou, R., Bourdeau, J. Explicit Reflection in Prolog-Tutor, *International Journal of Artificial Intelligence in Education* 17(2), 169-215 (2007)
34. Lloyd, T., Bull, S.: A Haptic Learner Model, *International Journal of Continuing Engineering Education and Lifelong Learning* 16(1/2), 137-149 (2006)
35. Morales, R., Pain, H., Conlan T.: Effects of Inspecting Learner Models on Learners' Abilities, in J.D. Moore, C. Luckhardt Redfield & W.L. Johnson (eds), *Artificial Intelligence in Education*, IOS Press, Amsterdam, 434-445 (2001)
36. Johan, R., Bull, S.: Consultation of Misconceptions Representations by Students in Education-Related Courses. In V. Dimitrova, R. Mizoguchi, B. du Boulay & A. Graesser (eds), *Artificial Intelligence in Education*, IOS Press, Amsterdam, 565-572 (2009)
37. Mazzola, L., Mazza, R. Toward Adaptive Presentations of Student Models in eLearning Environments, in V. Dimitrova, R. Mizoguchi, B. Du Boulay & A. Graesser (eds), *Artificial Intelligence in Education*, IOS Press, Amsterdam, 761-762 (2009)
38. Bull, S., Kay, J.: Metacognition and Open Learner Models. In I. Roll & V. Aleven (eds), *Proceedings of Workshop on Metacognition and Self-Regulated Learning in Educational Technologies, Intelligent Tutoring Systems*, 7-20 (2008)
39. Beck, J., Stern, M., Woolf, B.P. Cooperative Student Models, in B. du Boulay & R. Mizoguchi (eds), *Artificial Intelligence in Education*, IOS Press, Amsterdam, 127-134 (1997)
40. Kerly, A., Bull, S.: Children's Interactions with Inspectable and Negotiated Learner Models. In B.P. Woolf, E. Aimeur, R. Nkambou & S. Lajoie (eds), *Intelligent Tutoring Systems*, Springer-Verlag, Berlin Heidelberg, 132-141 (2008)
41. Ahmad, N., Bull, S.: Do Students Trust their Open Learner Models?, in W. Neijdl, J. Kay, P. Pu & E. Herder (eds), *Adaptive Hypermedia and Adaptive Web-Based Systems*, Springer-Verlag, Berlin Heidelberg, 255-258 (2008)
42. Gakhal, I. & Bull, S.: An Open Learner Model for Trainee Pilots, *ALT-J: Research in Learning Technology* 16(2), 123-135 (2008)
43. Shahrour, G., Bull, S.: Does 'Notice' Prompt Noticing? Raising Awareness in Language Learning with an Open Learner Model, in W. Neijdl, J. Kay, P. Pu & E. Herder (eds), *Adaptive Hypermedia and Adaptive Web-Based Systems*, Springer-Verlag, Berlin Heidelberg, 173-182 (2008)
44. Bull, S., Britland, M.: Group Interaction Prompted by a Simple Assessed Open Learner Model that can be Optionally Released to Peers, in P. Brusilovsky, K. Papanikolaou & M. Grigoriadou (eds), *Proceedings of Workshop on Personalisation in E-Learning Environments at Individual and Group Level (PING), User Modeling* (2007)
45. Perez-Marin, D., Alfonso, E., Rodriguez, P., Pascual-Neito, I.: Automatic Generation of Students' Conceptual Models from Answers in Plain Text, in C. Conati, K. McCoy & G. Paliouras (eds), *User Modeling*, Springer-Verlag, Berlin Heidelberg, 329-333 (2007b)
46. Eyssautier-Bavay, C., Jean-Daubias, S., Pernin, J-P.: A Model of Learners Profiles Management Process, in V. Dimitrova, R. Mizoguchi, B. Du Boulay & A. Graesser (eds), *Artificial Intelligence in Education*, IOS Press, Amsterdam, 265-272 (2009)
47. Lazarinis, F., Retalis, S. Analyze Me: Open Learner Model in an Adaptive Web Testing System, *International Journal of Artificial Intelligence in Education* 17(3), 255-271 (2007)

48. Papanikolaou, K.A., Grigoriadou, M. Sharing Knowledge and Promoting Reflection through the Learner Model, in S. Gutierrez-Santos & M. Mavrikis (eds), Proceedings of the Intelligent Support for Exploratory Environments Workshop, Third European Conference on Technology-Enhanced Learning (EC-TEL '08), <http://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-381/paper05.pdf> (2008)
49. Yacef, K.: The Logic-ITA in the Classroom: A Medium Scale Experiment, *International Journal of Artificial Intelligence in Education* 15(1), 41-62 (2005)
50. Zapata-Rivera, D., Hansen, E., Shute, V.J., Underwood, J.S., Bauer, M. Evidence-Based Approach to Interacting with open Student Models, *International Journal of Artificial Intelligence in Education* 17(3), 273-303 (2007)
51. Gaudioso, E., Montero, M., Talavera, L., Hernandez-del-Olmo, F.: Supporting Teachers in Collaborative Student modeling: A Framework and Implementation, *Expert Systems with Applications* 36(2), 2260-2265 (2009)
52. Upton, K., Kay, J.: Narcissus: Group and Individual Models to Support Small Group Work, in G.J. Houben, G. McCalla, F. Pianesi, M. Zancanaro (eds), *User Modeling, Adaptation and Personalization*, Springer-Verlag, Berlin Heidelberg, 54-65 (2009)
53. Kay, J., Reimann, P., Yacef, K.: Mirroring of Group Activity to Support Learning as Participation, in R. Luckin, K.R. Koedinger, J. Greer (eds), *Artificial Intelligence in Education*, IOS Press, Amsterdam, 584-586 (2007)