Learner Models to Promote Reflection in Combined Desktop PC / Mobile Intelligent Learning Environments

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Abstract. This paper considers the potential for the use of learner models to promote reflection in combined desktop PC / mobile intelligent learning environments. This is illustrated with reference to two such environments. The first is an adaptive tutoring system that has two versions (for the desktop PC and handheld computer), each of which has the same interaction options. In the second, the main tutorial interaction takes place on the desktop PC, after which tailored revision material based on the learner model is synchronised to the handheld computer for later consultation. Each system has an open learner model to promote learner reflection, but the differences in the two systems dictate the use of different kinds of open learner model.

1 Introduction

This paper considers two relatively new areas in computer assisted learning: open learner models and mobile learning, and the educational potential of combining these fields.

Over the last few years, interest has grown in the possibility of employing open learner models as a learning resource to promote an individual's reflection on their evolving knowledge and on the learning process. This is one way of using "the computer as a tool for learning through reflection" [1]. An open learner model allows the student to see information about their knowledge state held by the tutoring system, that they would not usually obtain through standard system feedback on their input. Because students may automatically compare any such information to their own beliefs about their knowledge, this can be a powerful method of fostering reflection - particularly if the system's beliefs and the student's own beliefs about the student's understanding differ. A range of methods of externalising the learner model have been investigated, from text and tables [2] to various graphical formats such as a concept map [3] or hierarchical structure [4], or a simple skill meter [5]. Presentation methods can also be combined [6].

Some approaches to open learner modelling are quite complex, requiring the user to negotiate the contents of their model with the system, providing justifications for changes they wish to make to their model. This not only allows the creation of a more accurate learner model, but discussion and argumentation over the representations in the model also focus the student's attention on their developing knowledge. Negotiated models have been implemented textually for a belief model [2] and graphically as a concept map [3].

Other approaches to open learner modelling encourage students to contribute information directly to their learner model, or allow them to edit the model, with no argument from the system. As with negotiated learner models, editable models can also serve to encourage reflection, as students must focus on their understanding if they wish to make changes in their learner model. These models have also been implemented in both textual form [7] and structured graphical form [4,8].

In some approaches students are presented with a simple overview of their knowledge level in the various topics of the environment, to encourage them to recognise their strengths, weaknesses and areas requiring further effort, but they do not interact with the model. The latter are often presented graphically, as a skill meter with the student's knowledge level depicted as a subset of the expert knowledge [5,9,10]; or with the student's knowledge as a subset of the material covered which is, in turn, a subset of the expert knowledge [11]; or with the user's knowledge displayed against the combined knowledge level of other user groups [12]. Alternatively, this kind of skill level model may be represented in graph form [6]. These simple graphical overviews are not usually structured.

In addition to increased attention from researchers to the application of open learner models, recently interest has also grown in the field of mobile learning, with technological advances making mobile interaction feasible in educational systems. This growing interest is evidenced by the emergence of new workshops in the area [13,14]. The term 'mobile learning' encompasses educational use of a variety of mobile technologies. In this paper we focus specifically on the use of handheld computers.

Much of the interest so far in mobile learning with handheld computers has been in tools for teacher administration, classroom management, quizzes and note taking - especially in secondary schools. However, to date, less attention has been directed towards the potential for intelligent mobile learning environments. One example is the Adaptive Geometry Game [15], which has versions for laptops and handheld computers. The system models the user's accuracy and speed of response to adapt questions presented, to their skill level. However, as with most intelligent learning environments, it does not explicitly aim to promote learner reflection by giving learners access to the contents of their learner model.

As long as a mobile learning environment is not intended for use only in a specific situation (e.g. in relation to museum exhibits or particular features of field trips), there is no reason why a mobile environment should not be designed for use across both the standard PC and handheld computer. This paper investigates the possibilities for learner modelling to promote reflection on a student's knowledge and misconceptions, and to increase the student's understanding of the learning process more generally, in a combined desktop PC and mobile context. This is illustrated by two such combined environments which use their learner models to help encourage students to reflect on their learning, by making the learner model contents explicit to the user. This use of two devices parallels the movement towards the creation of mobile versions of computer-based learning environments, including the Adaptive Geometry Game introduced above. However, the different versions of the Adaptive Geometry Game are independent of each other. In the systems described in this paper, it is expected that the system will be used both on a desktop PC (or laptop) and on a handheld computer, as suits the learner at the time. The initial versions of the two environments have been implemented, but have not yet been evaluated in use.

2 Combined Desktop PC and Mobile Intelligent Learning Environments

As stated above, a mobile learning environment does not necessarily need to be restricted to the mobile device only. There are times when it might be useful to use an intelligent learning environment on a handheld computer, for example when travelling or when the user has only a few minutes to spare and would like to use the time productively. Mobile technologies enable individualised learning opportunities at times when this would not normally be possible. However, when the learner has sufficient time and when there is a desktop PC or laptop available, they might find these more convenient to use for an educational interaction. Hence the division across two devices of the learning environments described in this paper. Two approaches are being investigated initially:

- an intelligent learning environment that can be used either on the desktop PC or the handheld computer, where the interaction types available are identical for each version of the system;
- a system in which the main tutorial interaction takes place on the desktop PC, and individualised revision materials are recommended for synchronisation to the handheld device for later consultation.

As will be seen in this paper, in some kinds of combined desktop PC / mobile environment, an open learner model may be useful, though not essential. In others it will be a crucial component of the system. The attributes modelled will depend, as always, on the domain, system aims, educational philosophy, etc. The two systems described here model knowledge level, specific concepts known, problematic concepts and misconceptions. The open learner models are based on the findings of an initial questionnaire study of students' perceptions of what they might find generally useful in a mobile open learner model [16]. The results suggested presentation of the following to be of likely importance to users: an indication of known topics; an indication of problematic topics; a suggestion of probable reasons for difficulties (e.g. misconceptions); a comparison of student beliefs and domain information. Based on the above, students would also like: suggestions of areas to revise[1]; tailored revision materials.

While it is not possible to obtain reliable results about the potential utility of software based only on descriptions of the software, this does provide a starting point for further investigation. The two systems presented in this paper are the first implementations based on these findings. Planned evaluations of the systems in use will further investigate the utility of modelling these attributes, and presenting them to the user in a mobile and desktop PC-based open learner model.

In the desktop PC context some studies have found that learners may not view their learner model even though they are aware of the feature [17,18]. Such systems do not generally have as a main aim, the possibility of promoting reflection through opening the learner model to the individual being modelled. Other work has suggested users may find an open learner model beneficial [2,3,11]. The extent to which learners find an open learner model useful is likely to depend in part, on how the model is integrated with the aims and interactions of the system. In the two systems presented in this paper, the learner model clearly has a role in supporting reflection while the student learns across two devices.

Issues for consideration with reference to the desktop PC / mobile open learner model include, as in other systems with open learner models, the most appropriate method of displaying the learner model data. As stated in the Introduction, there are various methods of externalisation of the student model, and that chosen for a system may depend on the domain, the attributes modelled, the purpose of opening the model and the general system aims. In the combined desktop PC / mobile environment, differences in the size of the screen must also be taken into account. Should a single method capable of being displayed in both environments be used to maintain consistency, or should the chosen presentation be that which best suits the particular device? Is there any difference in the degree to which reflection can be successfully supported on the different devices? Also important to consider is the kind of open learner model. Should the model be negotiable, editable or simply presented for viewing? Is it important that the same method is used for each device?

The above are important questions. The first steps are being investigated with systems that use the same learner modelling techniques and similar presentation across devices, to

[1] For clarification: the term 'revise' is used in this paper in the sense of 'review', not 'edit' or 'change'.

maintain a small set of variables for later empirical study. Because of the small screen of the handheld computer, this limits the presentation to quite simple graphical representations enhanced with more detailed text. Many issues remain for future investigation.

3 C-POLMILE: An Intelligent Learning Environment for the Desktop PC and Handheld Computer

C-POLMILE is an intelligent learning environment with an open learner model for C programming. There are two versions of the system - the desktop PC version, and a version for use on a handheld computer. The student can use whichever is most convenient at the time, and can take part in the kind of interaction which is most appropriate for their current location, the device being used, the time they have available, the likelihood of distraction in that location, etc. Interaction types include browsing information; individualised tutoring sessions; multiple choice test questions; interacting with the learner model. The possibility of interacting with the learner model, in particular the ability to modify its contents, is essential in C-POLMILE because the student could plausibly use different versions of the system without having first synchronised their student model.

The display of the two versions of the system is consistent as far as this is possible, but there are differences as the desktop PC version uses the full screen space available, while the version for the handheld computer is obviously restricted. This is illustrated with the C-POLMILE multiple choice questions, the responses to which provide the data to update the learner model. The learner modelling itself is quite straightforward, occurring through comparison of the student's knowledge as revealed in their responses, to the domain model and a predefined misconceptions library, with weightings applied in the learner model to (correct and incorrect) rules according to the likelihood that a given rule represents the student's understanding. Figure 1 shows the multiple choice questions in the desktop PC version of the system; Figure 2 shows the presentation for the mobile version.[2]

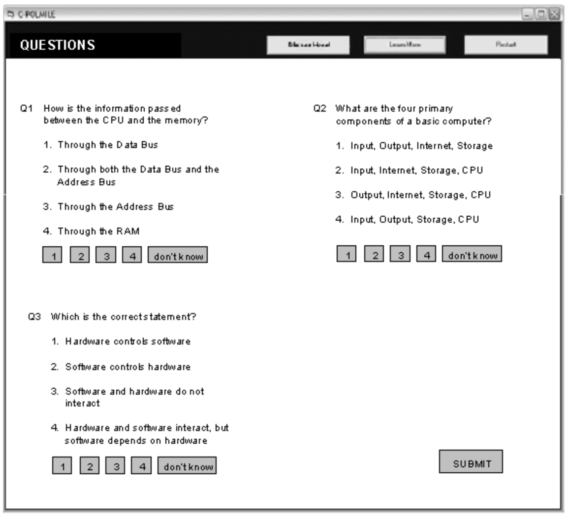

Figure 1: The C-POLMILE desktop PC questions

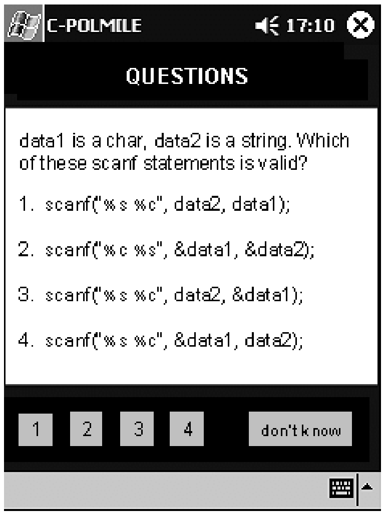

Figure 2: The C-POLMILE mobile questions

As stated above, the facility to edit the learner model is essential in an intelligent learning environment divided across two devices. The C-POLMILE open learner model uses skill meters to portray an overview of the proportion of each topic learnt, the problematic areas and likely misconceptions, based on the weighted rules in the learner

[2] Screen shots have been edited to render them legible in black and white reproduction.

model. This is an extension of previous uses of skill meters, which did not indicate the difference between material not covered and problematic areas or misconceptions (see [19] for further details). This distinction is important when one of the aims is to help users to reflect on their understanding, because even when they are aware of having difficulties, students may often not attribute these to the existence of misconceptions. Accepting that they may hold a misconception is an important step towards working to overcome it.

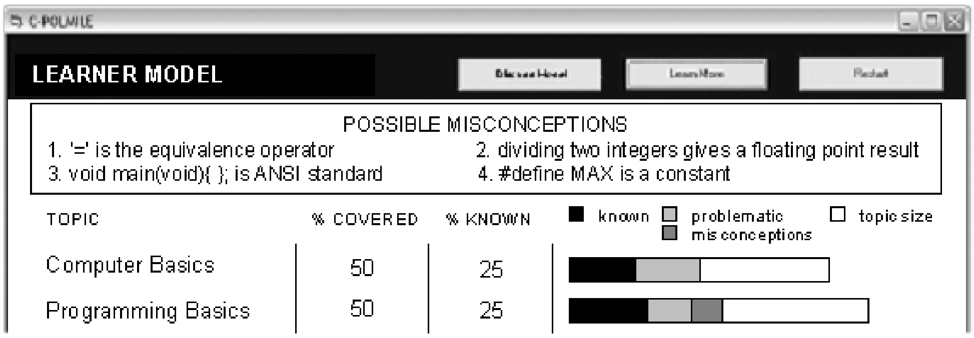

Figure 3: The desktop PC version of the C-POLMILE open learner model

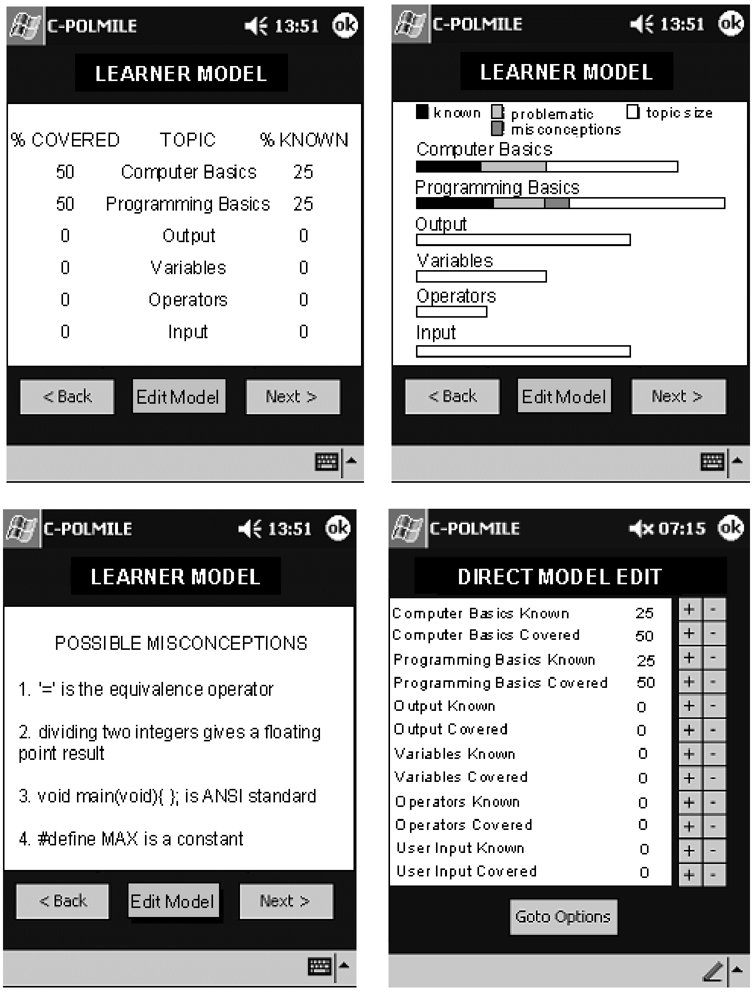

Figure 4: The mobile version of the C-POLMILE open learner model

Through the use of skill meters of different lengths, the learner model also allows the relative sizes of the various topics to be displayed - another unusual feature of skill meters. However, because the use of skill meters of different lengths also has the disadvantage that direct comparison of knowledge level of different topics is more difficult, it is necessary also to display this information. This is shown textually in C-POLMILE. In addition to this general overview, the learner model explicitly states likely misconceptions to extend the general information, to enable the learner to investigate these specific problems further (either through the system or by other methods). The learner model can be displayed in either the desktop PC version of the system (Figure 3), or the mobile version (Figure 4).

In this example, for the first topic (computer basics) the student has viewed and attempted 50% of the content, but has actually understood only 25%. For the second topic (programming basics) they have also covered 50% and understood 25%, but their answers to the multiple choice questions suggest that as well as having difficulties understanding material, they probably also hold some misconceptions. In addition to the graphical overview of knowledge level, extent of problematic areas and misconceptions, a statement of specific misconceptions is provided.

As stated previously, because C-POLMILE is intended for use across two contexts, it may sometimes be the case that the two learner models are inconsistent. This will occur if the student uses the two versions of the system independently, without the opportunity to first synchronise their learner model. The learner therefore needs a mechanism to update their model whenever this occurs, in order that their session will be adapted appropriately for their current understanding. Students can directly edit the contents of their overview model by increasing or decreasing the proportion of a topic that they have covered and understood, using the plus and minus buttons (the display on the desktop PC is identical to that of the mobile version shown in Figure 4). They can delete misconceptions that no longer apply by clicking on the description of the misconception.

As well as the possibility of easily editing the model being essential in a combined desktop PC / mobile intelligent learning environment to ensure that the learner model is up to date, an additional educational advantage is that the learner will have to think about their knowledge before effecting any changes in their model. For example, before they delete a misconception, they will need to consider carefully whether they are sure that this misconception no longer holds true, and that they no longer wish to receive help in this area. A disadvantage of this approach must be acknowledged: it allows the possibility for greater inaccuracy in the model if the learner does not appropriately assess their level of understanding. A negotiated learner model overcomes this difficulty as far as possible, as each party (student or system) has to justify any changes they wish to make in the model, and modifications will only be accepted if the other party accepts the argument for the change [2,3]. In a combined desktop PC / mobile system, however, this is less appropriate as such negotiation could occur quite frequently in an environment regularly in use across two versions, and the learner may be less likely to want to repeatedly argue about their understanding. Hence the choice of an editable model for C-POLMILE. If a student's responses to questions suggest that their previous amendments to their model are inaccurate, the model will be updated accordingly in the usual manner.

4 MoreMaths: Individualised Revision Material for the Handheld Computer

MoreMaths (Mobile Revision for Maths) differs from C-POLMILE in that the main interaction is intended for the desktop PC component of the system only. The user receives individualised tutorial material consisting of content and quizzes (Figure 5), and provides information to further update their learner model through their responses to a series of test questions upon completion of a tutorial (Figure 6). As in C-POLMILE, inferences about the learner's knowledge based on their answers to these questions are compared to the system's domain knowledge and a predefined misconceptions library, and represented as rules in the learner model.

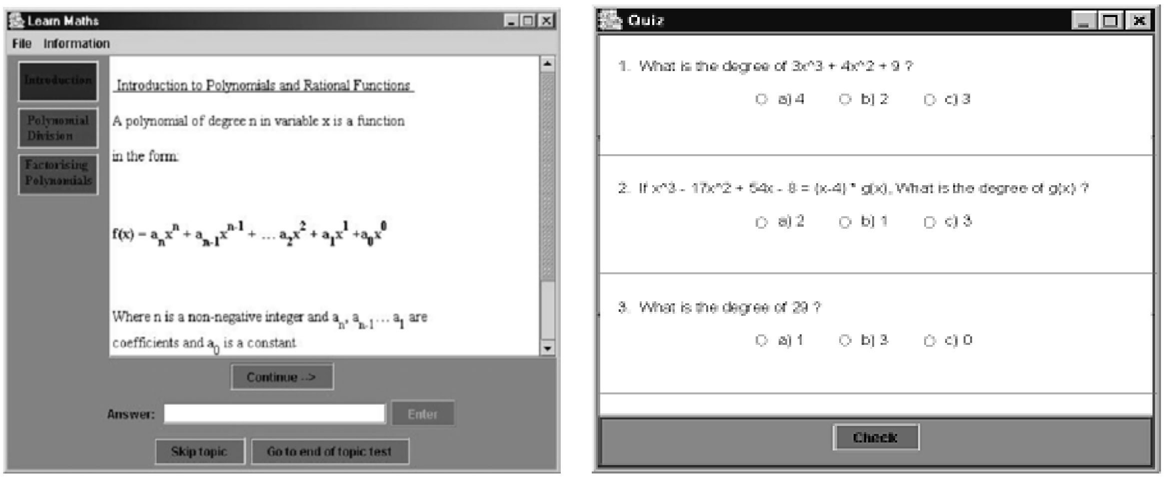

Figure 5: The MoreMaths desktop PC tutorial

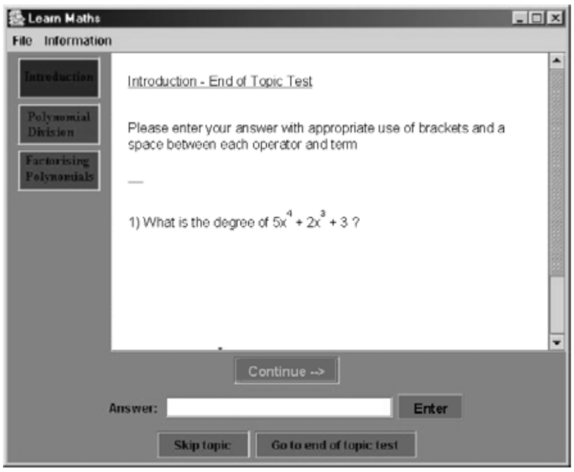

Figure 6: The MoreMaths desktop PC test

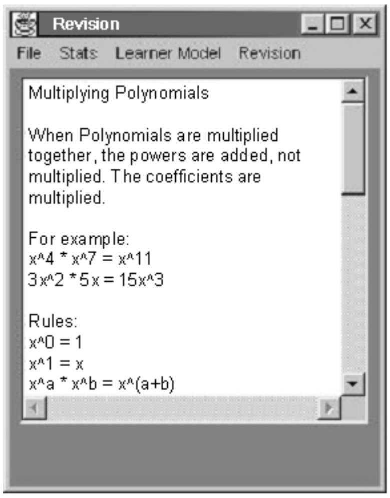

Figure 7: The MoreMaths mobile tailored revision material

As stated previously, the purpose of interactions with the two components of the MoreMaths system differ. As well as synchronising the learner model, after an interaction with the desktop MoreMaths tutoring system, the system recommends individualised revision materials to the user according to the contents of their learner model. These materials are synchronised to the handheld computer, intended for use in addition to the main computer interaction if the learner has a little time between sessions. The revision materials take as their starting point a learner's knowledge and misconceptions, and aim to help the learner overcome difficulties by explicitly pointing them out in the context of an explanation of the target concept (Figure 7).

Because the interactions on the desktop PC and mobile device are different in MoreMaths, the situation of the inconsistent learner model is much less crucial than in C-POLMILE. The revision materials are static, with individualisation occurring before the materials are recommended for synchronisation. When the student returns to the PC-based system after having received mobile revision materials, it gives them a brief test on the revision material (if they used this content), in order to update the learner model for the new interactive session. There is therefore a reduced need to allow the learner to be able to edit their model. Thus the open learner model in MoreMaths is for viewing only.

The MoreMaths open learner model uses a graph to show the overview of progress. This does not allow misconceptions to be differentiated from problematic areas, but as in C-POLMILE, misconceptions are listed explicitly in the learner model for consultation. Moreover, as mentioned above, treatment of misconceptions is explicit in the revision materials. The learner model may be viewed on either device. Figure 8 shows the mobile version. The desktop PC version is similar, with the graphical overview and more detailed textual information also appearing in separate windows, but these can be viewed simultaneously, unlike with the mobile device.

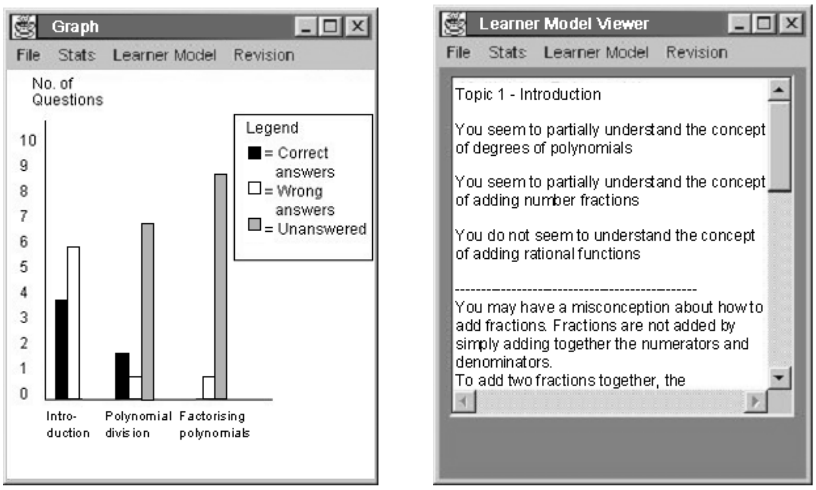

Figure 8: The mobile version of the MoreMaths open learner model

MoreMaths is designed to support an undergraduate maths course taught through lecture format. The desktop PC component of the system may be used quite heavily if the student has difficulties with the subject or misses lectures. Their use of this component will be lighter if they have a better general understanding. In either case, the mobile revision materials describe the target concepts in the level of detail appropriate to the student's existing knowledge (as identified in the desktop PC interaction), with reference to concepts known. Misconceptions are also contrasted with the target material in order to highlight to the learner the difference between their own understanding and the expert knowledge. Students can also view the more abstract descriptions of misconceptions in their learner model. A pre-evaluation questionnaire study where students were shown screen shots of the learner model and revision materials suggested that students would welcome such individualised materials [20]. The next stage, of course, is to test this in practice.

5 The Role of Open Learner Models in Combined Desktop PC / Mobile Intelligent Learning Environments

In environments that are used solely on a single device, negotiated learner models can be a powerful method of promoting learner reflection as they require the user to justify any changes they wish to make in their model. However, when an environment is divided across two versions, negotiating the model can become cumbersome if the user just needs to make some straightforward changes to update the contents of their model across devices. A negotiated model could, however, be available as an option in such an environment - to be used to further enhance reflection if appropriate. Direct editing should remain as an option for updating the model across the two versions of the system if the model has not been synchronised. There could also be a role for a negotiated learner model in a system where the interactions on each device are different. Where an adaptive interaction occurs on one device only, this would be the most suitable place for a negotiated learner model, as the result of the negotiations would feed into further adaptations. If both components of the system are adaptive, there could be a role for a negotiated model in both versions. Negotiated learner models would be an interesting area to investigate in the context of combined desktop PC / mobile learning environments. However, the first implementations have focused on the most essential features of an open learner model in those environments as described above: an editable model for C-POLMILE, and a viewable model in MoreMaths. As has been seen, these can also be used to prompt reflection.

It has already been argued that an open learner model can be used as a learning resource for the student, as it reflects to them a representation of their understanding. It was also suggested that the open learner model may need to be fully integrated into the interaction to be successful. In C-POLMILE, the option of viewing the learner model is given equal status to other components of the system, as indicated by the options available on the startup and main contents screen. This makes it clear to the learner that viewing their learner model is a normal part of the interaction. The same is true of MoreMaths, where in the mobile component of the system more detailed examination of the learner model is likely to take place, there is a learner model menu alongside the other system menus. (The learner model can also be accessed easily in the PC version.) The main focus of the mobile MoreMaths, however, is on the use of the revision materials which are based on the contents of the learner model. Explanations given in the revision content refer directly to the learner's existing knowledge and misconceptions, thus incorporating information from the learner model into the revision material. In MoreMaths, therefore, it is not so important that the learner view their model directly to encourage reflection, as the contents of their learner model are still presented to them explicitly in the revision material. This is, of course, not strictly an open learner model, but it is nevertheless a presentation of the learner model contents - but in a larger learning context. The open learner model is available in addition for learners who find the more abstract presentation of their understanding useful. In contrast, in C-POLMILE the existence of the open and editable learner model is crucial - it is essential for users who commonly use both versions of the system and who may not have the opportunity to synchronise their learner model between sessions on different devices. This central role for the learner model means that the learner is more likely to have a need to inspect their model. While this need relates to updating the model contents, this may also result in reflection particularly if the learner finds information about their knowledge that they did not expect. The next crucial step will be to investigate whether the learner modelling in the two systems described, really does encourage reflection in practice.

Further work also includes investigation of the questions raised in Section 2: to what extent should open learner models in the two components of the system be consistent?; to what extent can reflection be supported on each device?

6 Summary

This paper has considered the potential for learner models to promote reflection in combined desktop PC / mobile intelligent learning environments. Two systems were presented as illustrations. In the first, the same interaction options are available in each version of the system. In the second, the main interaction takes place on the desktop PC, with individualised static revision material offered for synchronisation to the handheld computer for later consultation. Each of these systems makes explicit the contents of the learner model to help encourage students to reflect on their learning. The differences in the two environments prescribe the use of different types of open learner model. In the first, an editable model is essential, as the same interaction options are available in each version, and the learner may not always have the opportunity to synchronise between devices. In the second, interactions in the two components of the system differ, and a viewable learner model is sufficient. Combined intelligent learning systems such as the above are still new, and much research therefore remains to be undertaken before we find out the extent of the potential for encouraging reflection through learner modelling in this context.

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