Alternative Views on Knowledge: Presentation of Open Learner Models

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Abstract. This paper describes a study in which individual learner models were built for students and presented to them with a choice of view. Students found it useful, and not confusing to be shown multiple representations of their knowledge, and individuals exhibited different preferences for which view they favoured. No link was established between these preferences and the students' learning styles. We describe the implications of these results for intelligent tutoring systems where interaction with the open learner model is individualised.

1 Introduction

Many researchers argue that open learner modelling in intelligent tutoring systems may enhance learner reflection (e.g. [1], [2], [3], [4]), and a range of externalisations for learner models have been explored. In Mr Collins [1], learner and system negotiate over the system's representation of the learner's understanding. Vismod [4] provides a learner with a graphical view of their Bayesian learner model. STyLE-OLM [2] works with the learner to generate a conceptual representation of their knowledge. ELM-ART's [5] learner model is viewed via a topic list annotated with proficiency indicators. These examples demonstrate quite varied interaction and presentation mechanisms, but in any specific system, the interaction style remains constant.

It is accepted that individuals learn in different ways and much research into learning styles has been carried out (e.g. [6], [7]). This suggests not all learners may benefit equally from all types of interaction with an open learner model. Ideally, the learner's model may be presented in whatever form suits them best and they may interact with it using the mechanism most appropriate to them. In discussion of learner reflection, Collins and Brown [8] state: "Students should be able to inspect their performance in different ways", concluding that multiple representations are helpful. However, there has been little research on offering a learner model with a choice of representations or interaction methods. Some studies [9], [10], suggest benefit in tailoring a learning environment to suit an individuals learning style, so it

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may be worth considering learning style as a basis for adapting interaction with an open learner model.

This paper describes a study in which we use a short web-based test to construct simple learner models, representing students' understanding of control of flow in C programming. Students are offered a choice of representations of the information in their model. We aim to assess whether this is beneficial, or if it causes information overload. We investigate whether there is an overall preference for a particular view, or whether individuals have particular preferences, and if so, whether it is possible to predict these from information about their learning style. We also consider other ways of individualising the interaction with an open learner model, such as negotiation between learner and system, and comparing individual learner models with those of peers or for the group as a whole. The system employed is not intended to be a complete intelligent tutoring system, and consists of only those aspects associated with presenting the learner model. Such an arrangement would not normally be used in isolation, but is useful for the purpose of investigating the issues described above.

2 The Learner Model

The system's domain is control of flow in C Programming, and is based on an MSc module for Electronic, Electrical, and Computer Engineering students entitled "Introduction to Procedural Programming and Software Design".

2.1 Building the Learner Model

The domain is divided into nine basic concepts plus some higher-level concepts formed by aggregating these. A thirty-question multiple-choice test provides data for the learner model. Each question offers up to nine alternatives, plus an "unsure" option, and is associated with one or more concepts. Choosing the correct answer adds points to the scores for these concepts. In some cases, points may be deducted from concepts not related to the question, if a student's response demonstrates a lack of understanding of this area too. Sufficient time was allowed to answer all of the questions, so unanswered questions are assumed to show a lack of understanding. The overall knowledge for a concept is calculated as a fraction of the possible score.

The model also includes information about six possible misconceptions a learner may hold. Some questions were designed such that they included incorrect answers that would be likely to be chosen by a student who has a given misconception.

2.2 Presenting the Learner Model

Learners are offered four representations of their model's contents. If they favour different views from each other then they may each have a potentially different experience interacting with their model. Thus it is important that the learner can obtain relevant information about their knowledge using any view in isolation, so while the views differ structurally, the same information is available. Kay [3] identifies four questions learners may seek to answer when viewing their model: "*What do I know?*", "*How well do I know topic X?*", "*What do I want to know?*", and "*How can I best learn X?*". For effective reflection on knowledge, the learner must be able to answer these questions easily, particularly the first two. Thus a simple and intuitive system was used where the learner's knowledge on a topic is represented by a single coloured node on a scale from grey, through yellow to green, with bright green indicating complete knowledge and grey indicating none. Where a misconception is detected, this overrides and the topic is coloured red. This simplicity means that learners should require little time to familiarise themselves with the environment.

Figures 1 to 4 illustrate the four views available to the learner. Tabs above the model allow navigation between views, with misconceptions listed above this.

The *lectures* view (Fig. 1) lists topics according to the order they were presented in the lecture course. This may aid integration of knowledge gained from using the system with knowledge learned from the course, and help students who wish to locate areas of poor understanding to revise from the lecture slides. Factors such as conceptual difficulty and time constraints may affect decisions on the ordering of lecture material, such that related topics are not always covered together. The *related concepts* view (Fig. 2) shows a logical, hierarchically structured grouping of subject matter. This allows a topic to be easily located and may correspond better to a stu-

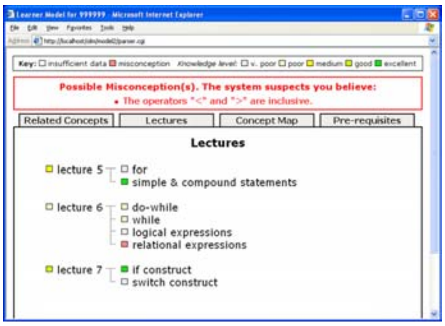

Fig. 1. Lectures view

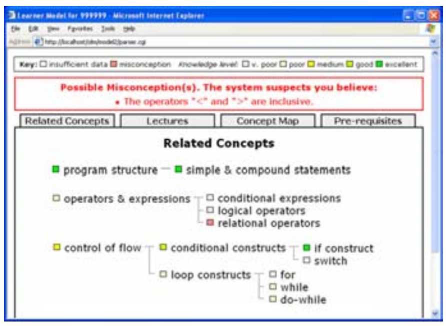

Fig. 2. Related concepts view

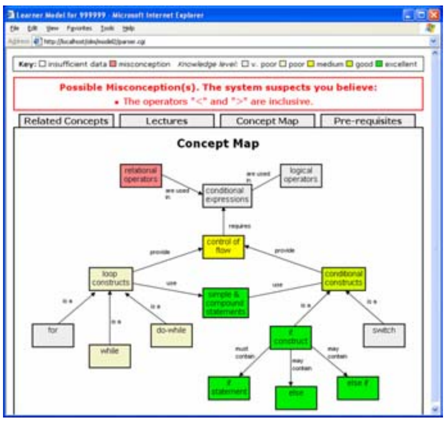

Fig. 3. Concept map view

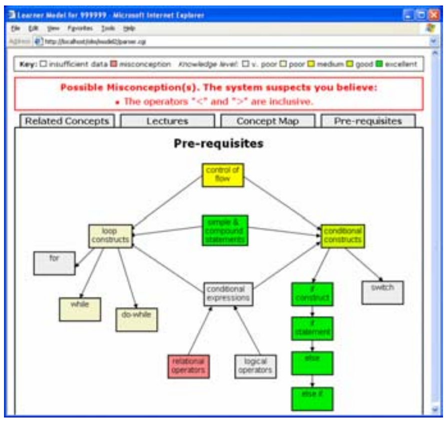

Fig. 4. Pre-requisites view

dent's mental representation of the course. The *concept map* view (Fig. 3) presents the conceptual relationship between the topics. To date, research combining concept maps (or similar) with open learner models has focused on learner constructed maps [2], [11], but in the wider context of information presentation, arguments have been made for the use of pre-constructed concept maps, or the similar *knowledge maps* [12], [13]. Finally, the *pre-requisites* view (Fig. 4) shows a suggested order for studying topics, similar to Shang et al's [14] annotated dependency graph.

A student's choice of view may not be based purely on task, but also preference. If differences in learning style contribute to these preferences, the Kolb [6] and Felder-Silverman [7] learning style models may have relevance in the design of the views. According to these models, learning involves two stages: reception, and subsequent processing, of information. In terms of reception, Felder and Silverman's use of the terms *sensing* and *intuitive* is similar to Kolb's use of *concrete* and *abstract*. Sensing learners prefer information taken in through the senses, while intuitive learners prefer information arising introspectively. Both models label learners' preferences for processing using the terms *active* or *reflective*. Active learners like to do something active with the information while reflective learners prefer to think it over.

The Felder-Silverman model has two further dimensions, sometimes referred to as dimensions of cognitive style, and defined by Riding & Rayner [15] as "an individual's preferred and habitual approach to organising and representing information". The *sequential-global* dimension incorporates Witkin et al.'s [16] notion of field-dependence/field-independence and Pask's [17] serialist/holist theory. It describes whether an individual understands new material through a series of linear steps or by relating it to other material. The *visual-verbal* dimension describes which type of information the individual finds easier to process: text or images.

In a multiple-view system, reflective learners may appreciate the opportunity to view their knowledge from multiple perspectives while active learners may like to compare different views to see how they are related. Intuitive learners may use the concept map and pre-requisites view to focus on conceptual interrelationships, while sensing learners may favour the simpler lecture-oriented presentation as a link with the real world. The lectures and related concepts views are more sequentially organised while the concept map and pre-requisites view may more suit the global learner.

3. The Study

A group of students were given the 30-question test and presented with the four views on their open learner model. They completed questionnaires indicating their opinions on the usefulness of the different views, and the experience in general.

3.1 Subjects

Subjects were 23 Electronic, Electrical, and Computer Engineering students studying a module entitled "Educational Technology". Eighteen of these, on a one-year MSc programme, had undertaken the course called "Introduction to Procedural Programming and Software Design”. The remainder, finalists on a four-year MEng programme, had previously covered the similar “Introduction to Computing Systems and C Programming”. The subjects had yet to be introduced to the idea of open learner modelling or indeed intelligent tutoring systems more generally.

3.2 Materials and methods

Subjects received the test simultaneously online. On completion, a web page was generated showing alternative views of their learner model. Students then completed a six-item questionnaire, indicating choices on a five-point Likert scale and providing additional comments where necessary. They were asked how useful they found each view of the learner model, how easily the model enabled them to assess their knowledge, how useful they found multiple views, and how accurate they believed their model to be. They were also asked about the usefulness of comparing one’s model with that of a peer or the whole group. As the subjects took the test in the same location they could examine each other’s models but were never explicitly asked to do so.

Next, subjects compared correct solutions to the test with their own solutions, and completed a second questionnaire concerning how accurate they now believed their model to be and how important it is for a system to give the reasoning behind its representation. Suggestions were sought for additional information that the system should provide as part of its feedback. On a separate occasion, subjects completed the self-scoring Index of Learning Styles (ILS) [18] online. Though used extensively, the ILS has not been validated [19] so in an attempt to assess its usefulness for our purposes, students were asked to rate their agreement with their diagnosed style on a five-point scale (strongly agree, agree, partly agree, disagree, strongly disagree).

3.3 Results

Students spent between 8 and 30 minutes on the test, scoring from 8 to 29 out of 30. All but two students were identified as holding at least one misconception. None had more than four. Seven students discovered that they could send multiple test submissions. The maximum number of submissions from an individual was seven.

Table 1. Preference for individual views

	degree of usefulness						preference	
	<- very useful.............not very useful ->					Avg. score	favourite	least favoured
	(5)	(4)	(3)	(2)	(1)			
Lecture	6	11	5	1	0	4.0	6	5
Related concepts	3	12	5	3	0	3.7	6	10
Concept map	9	9	2	1	2	4.0	10	5
Pre-requisites	6	7	9	1	0	3.8	4	6

In the first questionnaire, students rated, on a five-point scale, how useful they found each view. The number selecting each option is shown in Table 1. For comparative purposes, assigning a value from 1 to 5 to each option allows averages to be calculated. The penultimate column lists, for each view, the number of people that rate it more highly than the other views. The seven students favouring three or four views equally are excluded from this total, as this does not suggest real preference. Similarly, the final column shows, for each view, the number of people that give it a lower rating than the other views.

With similar average scores, no view is considered better than the others overall. The results show that each view has a number of students that consider it to be the most useful and a number of students who consider it to be the least useful.

Table 2 summarises responses to the other questionnaire items. Students reacted positively to the idea of multiple views, with an average response of 4.2 out of 5 and only one neutral reaction. They were also positive about how easily they could assess the strength of their knowledge on various domain aspects using their model. This received an average response of 4.0, with just two students giving 2 out of 5.

The high scores for perceived accuracy of the model show that there was little disagreement from students about the system's representation of them, either before or after they had seen the correct solutions. Despite agreeing with the system, students were keen for the system to offer some explanation and reasoning for its representation of them. This issue received an average score of 4.2 in the questionnaire. There were comments asking for more detailed feedback, such as "[the system should] give the possible reason why you make these mistakes" and for the system to identify which answers indicate which misconceptions: "I would like to see my misconceptions with examples [of my mistakes added] when the user clicks on red boxes".

Table 2. Summary of questionnaire responses and average scores. A scale from 1 to 5 is used, with 5 representing a postive response, 3 neutral, and 1 a negative response.

	(5)	(4)	(3)	(2)	(1)	Avg
Usefulness of multiple views	5	16	1	0	0	4.2
Ease of understanding strength of knowledge on various aspects	9	8	4	2	0	4.0
Perceived accuracy of model before seeing solutions	7	13	3	0	0	4.2
Perceived accuracy of model after seeing solutions	7	14	1	0	0	4.3
Importance of system giving reasons for its feedback	12	5	4	2	0	4.2
Usefulness of comparing own model with peer's model	4	8	5	3	3	3.3
Usefulness of comparing own model with a group model	5	8	6	3	1	3.6

Responses appear more neutral regarding comparisons with peer or group models. More detailed analysis of the individual responses shows a number of students are very interested in comparing models, but this is offset by a number of students who have very little interest. During the study, many students were seen viewing each other's models for comparison purposes, without any prompting to do so. One student remarked that he would like to see "the distribution of other participant's answers", another said: "Feedback in comparison to other students would be useful".

Nineteen students completed the ILS questionnaire [18]. Table 3 shows the average learning style scores (in each of the four dimensions) for the group as a whole compared to the average scores for the students who favour each view. The similarity between the overall figures and the figures for each view indicates no obvious link between any of the style dimensions and preferences for presentation form. The results also show that in most style categories the distribution is biased towards one end of the scale. In the poll regarding accuracy of the ILS, seventeen students voted that they "agreed" with their results, while two abstained.

Table 3. Average learning style scores for students favouring each view, compared to average learning style scores for the whole group. Scores from 0-11 describe each dimension.

	Active / Reflective (11 – 0 – 11)	Sensing / Intuitive (11 – 0 – 11)	Visual / Verbal (11 – 0 – 11)	Sequential / Global (11 – 0 – 11)
Overall scores	3.3	3.0	6.7	0.5
Lectures	3.5	5.0	8.0	0.5
Related concepts	2.5	3.5	7.5	3.0
Concept map	2.8	2.6	5.9	0.6
Pre-requisites	3.5	2.5	5.5	3.0

3.4 Discussion

The important question is whether providing multiple views of an open learner model may enhance learning. It is argued that an open learner model may help the learner to become aware of their current understanding and reflect upon what they know, by raising issues that they may not otherwise have considered [20]. A motivation for providing multiple views of the learner model is that this reflection may be enhanced, if the learner may view their model in a form they are most comfortable with. As each representation was found to have several students regarding it the most useful, then if any view were removed, some students would be left using a form they consider less useful, and their quality of reflection may reduce. Providing a representation students find more useful may help to counter problems discussed by Kay [21] or Barnard and Sandberg [22], where few or no students viewed their model.

In addition to having knowledge represented in the most useful form, results show that having multiple representations is considered useful. Students are not confused by the extra information, as indicated by the fact that only two gave a negative response to how easily they could tell the strength of their knowledge from the model.

It is important to remember that the information for the study comes from students' self-reports on an open learner model in isolation. It does not necessarily follow that a multiple-view system helps provide better reflection or increased learning, only that students *believe* it may help. Nor can we assume students know which representation is best for them. Such a system needs evaluating within an intelligent tutoring system. Positive results here suggest this may be a worthwhile next step.

High levels of agreement with the system's representation validate the modelling technique used. However, they raise questions about the possibility of including a negotiation mechanism, the intention of which would be to improve the accuracy of the model and provide more dynamic interaction for active learners. While Bull & Pain [1] conclude that students will negotiate their model with the system in cases of disagreement, this disagreement would appear to be lacking in our case. Nevertheless, in a complete system used in parallel with a course, rather than after students completed the course, there may be more disagreement and scope for negotiation.

The asymmetric distribution of learning styles is expected as "many or most engineering students are visual, sensing and active" [7]. With an unbalanced distribution, and a small number of subjects, it is difficult to draw firm conclusions, although clear differences in preference of view observed between learners of the same style corroborate recent findings [23] of only weak linkages between learning style and learning preference. With no obvious link between preferred view and learning style, it seems unwise to use style to make decisions about which view to present to a user. As students were not confused by being presented with multiple views, it is easiest to let them choose their own view. There may be other uses for learning style, as the idea of how to present the model is just one aspect of an adaptive open learner model system. There are other areas of interaction that may be style dependent: for example, how much negotiation is sought from the learner when arguing over their model, or the degree of interpretation of the model the system provides.

The interest from some students in comparing models show there may be benefit in compiling a group model (such as the OWL [24] skill meters) and in providing a mechanism for students to view each other's individual models (such as in [25]). Which types of learner may benefit from this and how such a comparison is presented could form the subject of a study in its own right.

Students' comments expressing a desire for feedback about why they have chosen an incorrect answer highlight the need in a complete system for a much larger misconception library and better justification on the part of the system.

Incremental increases in proficiency shown by students sending repeated test submissions, indicate that they did so after viewing their model, but before seeing the correct solutions. This shows that some learners like to watch their model update as they answer questions. Thus the process of viewing the model must be heavily integrated with the process of building the model and not carried out as separate tasks.

The "unsure" option on the test was provided to reduce the amount of guessing and avoid misdiagnosis of misconceptions, yet only 8 students used it and 90% of failed questions were answered incorrectly rather than with an "unsure" response. The system's diagnosis may be improved if students guessed fewer answers, but only attempting a question if you are "sure" represents too negative an attitude to be encouraged. A method is required where students can attempt a question, but state that they are unsure about it. The practice of soliciting such confidence measures has been found to be valuable in informing construction of the learner model [1], [26].

As students believe an open learner model with multiple views may be beneficial, investigation in the context of a full intelligent tutoring system seems worthwhile.

4. Summary

This paper has described a study where students were presented with their open learner models and offered a choice of how to view them. The aim was to investigate whether this may be beneficial, and how it might integrate into an intelligent tutoring system where the interaction with the open learner model is individualised.

Results suggest students can use a simple open learner model offering multiple views on their knowledge without difficulty. Students show a range of preferences for presentation so such a system can help them view their knowledge in a form they are comfortable with, possibly increasing quality of reflection. Results show no clear link with learning styles, but students were capable of selecting a view for themselves, so intelligent adaptation of presentation to learning style does not seem beneficial.

A colour-based display of topic proficiency proved effective in conveying knowledge levels, but to improve the quality of the experience, a much greater library of misconceptions must be built with more detailed feedback available in the form of evidence from incorrectly answered questions. Allowing the student to state confidence in answers may be investigated as a means of improving the diagnosis. The student should have the facility to inspect their learner model whenever they choose.

The limitations of self-reports and using a small sample of computer-literate subjects necessitate further studies before drawing stronger conclusions. The educational impact of multiple presentations must be evaluated in an environment where increases in subjects' understanding may be observed over time, and using subjects with less computer aptitude. A learner model with several presentations is only the first part of an intelligent tutoring system where the interaction with the model is personalisable. Further studies may investigate individualising other aspects of the interaction, such as negotiation of the model. Students like the idea of comparing models with others and investigation may show which learners find this most useful.

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