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Preface

"Open Learner Models: Future Research Directions" Special Issue of the IJAIED (Part 2)

PAPERS IN PART 2 OF THE SPECIAL ISSUE ON OPEN LEARNER MODELS

The special issue of the International Journal of Artificial Intelligence in Education on Open Learner Models, is in two parts. The first issue introduced some of the key research questions. This issue (part 2) focuses on future research directions. It includes four papers which can be grouped in two categories.

The first two papers address issues surrounding learner inspection of peer models, and the availability of learner models to course instructors. Bull, Mabbott and Abu Issa present the UMPTEEN system which allows students to open their learner models to others in named and/or anonymous form. The CosyQTI system presented by Lazarinis and Retalis provides anonymous access to models of peers and restricted named access to friend peers. Both approaches use simple presentations of the learner model, and both are domain-independent, requiring instructors to input the necessary information. Both show individual and combined group data. The main differences between the two approaches include the following: Bull, Mabbott and Abu Issa's UMPTEEN aims to promote learner autonomy, to help students identify areas of difficulty so they may consult appropriate materials (or other users) – i.e. take the responsibility for directing their learning; while Lazarinis and Retalis's CosyQTI opens the learner model in the context of an adaptive hypermedia testing system.

In CosyQTI instructors need to provide more detailed information: question type, difficulty level, number of attempts, maximum/minimum scores, hints, penalty for consulting hints, definition of learning objectives, criteria for satisfying learning objectives, and associating concepts with sections. This allows more detailed learner models to be constructed to guide an interaction. In contrast, UMPTEEN's underlying learner models are quite simple: a weighted numerical indication of knowledge level. In this case the aim is to encourage widespread deployment by minimising the instructor effort required. Since it is primarily an assessment system, CosyQTI releases an aggregate group model and encourages competition by allowing students to release their named learner model to their friends. UMPTEEN encourages both collaboration and competition, permitting students to release a named or anonymous individual model to other users, in addition to the aggregate group model. Initial evaluations of the two systems suggest that learner models accessible to peers may be a useful approach in different learning contexts.

The remaining two papers in this special issue present argument-based approaches for maintaining the interaction with open learner models. Zapata-Rivera, Hansen, Shute, Underwood and Bauer describe an evidence-based open learner model EI-OSM that enables the integration and inspection of a variety of student assessment claims coming from different sources. The xOLM approach presented by Van Labeke, Brna and Morales addresses the problem of opening the learner model in a manner that enables the learner to create meaningful interpretations of the learner model and to understand the process of obtaining the model. Both approaches use probabilistic learner models derived by analysing pieces of evidence from different sources, and are exemplified in the

domain of Mathematics. Both utilise Toulmin's argumentation structure to organise the interaction with the learner model, and use graphical representations to give views of the student's knowledge. The main difference between the two approaches is that EI-OSM is aimed at supporting teachers in inspecting and interacting with models of students, while xOLM supports students to interact with their learner models.

EI-OSM follows a method of Evidence-Centred Design of assessments combined with Schum's model for evidence analysis to derive a learner model from various pieces of assessment evidence. It uses the notion of active reports which are integrated in an assessment-based learning environment to enable teachers, students and parents to provide assessment information and to guide the learning process. The challenge of making the assessment process overt is also addressed in xOLM, but in a different way. In addition to Toulmin's argument structure, the xOLM approach utilises the Dempster-Shafer Theory of data fusion. xOLM makes an explicit distinction between different layers in the learner model, including metacognition, motivation and affect, competency, conceptual and procedural errors, and the domain upon which the four layers are based. The student can examine the model by engaging in a structured dialogue asking for explanation and justification of how the beliefs in the model are derived. The two approaches point out the need to enable learners and teachers to inspect not just the learner model but also the process of how the model is derived; and illustrate that argumentation models can be helpful for this purpose.

The eight papers in both volumes of this special issue address a spectrum of open learner modelling issues. In the following sections, we will revisit the research questions outlined in the preface of part 1 of this double special issue, and will summarise how and to what extent they have been addressed in the eight papers. For a systematic analysis of research on open learner models prior to the special issue the reader is directed to the paper by Bull and Kay (2007), which includes an overview of earlier work. We will sketch out our speculative look forward into the research on open learner models by outlining some remaining challenges and open issues, based on the papers in this special issue and research presented at the most recent major conferences in the field, such as Adaptive Hypermedia and Adaptive Web-Based Systems (AH06), Intelligent Tutoring Systems (ITS06), User Modeling (UM07), and Artificial Intelligence in Education (AIED07).

USABILITY ISSUES RELATED TO OPEN LEARNER MODELS

The usability of open learner models is generally concerned with the presentation of the models, the access to the models, and the interaction with the models. We will examine how these issues have been addressed by the papers in the special issue and will suggest what future research on usability of open learner models may involve.

Presentation of Open Learner Models

The special issue illustrates several forms of presenting open learner models, including simple presentation modes to facilitate model inspection, such as numerical values (Chen et al., 2007) and skillmeters (Bull, Mabbott, & Abu Issa, 2007; Lazarinis & Retalis, 2007; Mitrovic & Martin 2007); a variety of textual and graphical representations for inspection and editing of the model (Bull & Kay, 2007); multiple linked external representations to help students gain a better understanding of their model (Van Labeke, Brna, & Morales, 2007); and argumentation structures to show how different

pieces of assessment evidence are used to derive the student model (Van Labeke, Brna, & Morales, 2007; Zapata-Rivera et al., 2007). Mitrovic and Martin (2007) have shown that simple open learner models like skillmeters can have a positive effect on the students' learning and metacognition, while studies conducted by Bull, Mabbott and Abu Issa (2007) and by Lazarinis and Retalis (2007) show that skillmeters are an adequate representation for sharing learner models with peers and instructors. In all cases, skillmeters were used for presenting an overview of the student's knowledge level, and were combined with textual representation to give additional information about the student's possible misconceptions.

Apart from cognitive aspects, other dimensions of the learner model have been examined in this special issue. Chen et al. (2007) consider several dimensions, including cognitive (remembering, understanding, and applying), affective (confidence, interest level), and social (reminding, helping); and show that a simple numerical approach can be helpful for opening these dimensions to children when combined with appropriate game-like scenarios. Although an experimental study has confirmed the effectiveness of this simple way of representing the learner model, more careful examination would be required to decide what other dimensions may be needed and how to help students become aware of these dimensions and their dependencies. This would require additional strategies for guiding the students through the model and helping them see how their behaviour affects the model. A step in this direction, as well as an example of using a more comprehensive open learner model by taking into account cognition, meta-cognition and motivation, is presented by Van Labeke, Brna and Morales (2007). They experiment with interactive maps that can allow students to not only analyse the various aspects of their models but to also initiate dialogues with the system to get explanations and justifications of how the model has been derived. While interactive maps can offer a powerful form for inspecting and interacting with open learner models, future experimental studies would be required to examine the pedagogical benefits of this complex form of interaction with the learner model. Furthermore, studies are required to investigate under what circumstances it might be useful to show learners data about their emotions and affective state.

Although some notable progress with regard to using different forms of representation has been illustrated in this special issue, we still lack comparative studies and conclusive evidence of which external representations are good for which purposes. Questions such as "When are some structures better suited to specific purposes for accessing the learner model?" and "Is the 'right' open learner model format more dependent on the structure of the domain, or the nature of the task?" still require careful investigation. An interesting direction is given by recent empirical studies that compare the use of different representations of the learner model (Bull & Mabbott, 2006; Mabbott & Bull, 2006) and provide an analysis of which parts of the model the students focus on (Bull, Cooke, & Mabbott, 2007). Future work can build on these experimental studies, as well as on research which identifies features of effective diagrammatic representations (Brna, Cox, & Good, 2001), or which exploits a variety of information visualisation techniques for comparison, contrast, and navigation (Mazza & Dimitrova, 2007). Finally, as pointed out by Van Labeke, Brna, and Morales (2007), implementing rich graphical representations is computationally challenging. This is partially addressed with the use of existing open source libraries, but significant effort is still required to implement powerful and effective graphical representations. Future advances can be brought by collaboration among open learner modelling researchers who may share not only their experiences and findings, but also their development procedures and code.

Opening Parts of the Model and Restricting Access

The effective presentation of open learner models depends upon important decisions about which parts of the model can be shown to the students, their peers, instructors or parents. The papers in the special issue examine several relevant issues. Bull, Mabbott and Abu Issa (2007) show that there is sufficient interest in viewing peer models and willingness to open the model to peers and instructors, and that further studies in the area are worthwhile. They found that in small groups students were willing to share their models with everybody, while in larger groups a more restricted access was required and anonymous release of the model was likely to be selected. These results were echoed in the work of Lazarinis and Retalis (2007) who also offer anonymous access. With regard to deciding what can be opened, all the papers in this special issue consider mostly cognitive aspects. Initial attempts have been made by Chen et al. (2007) and Van Labeke, Brna and Morales (2007) to include other aspects, such as motivation, affect and social aspects, but further studies are required to find out how students would interact with these parts of the model, and what benefits or drawbacks this may bring. One area of very high potential here is motivating students, as Webster and Vassileva (2006) show. Using a variant of the Comtella system they have been experimenting with how visualizations capturing various aspects of learner interactions in a discussion forum can motivate enhanced participation by learners.

A key issue has arisen from the analysis of open learner models conducted by Bull and Kay (2007). They found that an explicit distinction has to be made between a learner model that can be edited and one which allows students (and other stakeholders such as teachers, parents or peers) to add evidence that can be used alongside existing evidence. The special issue contributes with approaches illustrating the latter, while examples of the former are presented in Bull and Kay's review. A systematic approach to handle evidence coming from different sources is described by Zapata-Rivera and his colleagues (2007). Although the approach enables structured interaction with learner models, it requires substantial effort from teachers and may not be applicable in complex domains when a large number of students are involved. Along the same lines, Van Labeke, Brna and Morales (2007) illustrate an approach to provide structured, in-depth interaction to examine how pieces of evidence have been used to derive the beliefs in the learner model.

Future research is required to further examine the extent to which the decision to allow different levels of control over the open learner model is determined by the domain, the purpose and level of interactivity with the learner model, or the user's task, individual preferences and cognitive/meta-cognitive abilities. In line with this, the papers in the special issue point at promising research directions. For example, Mitrovic and Martin (2007) have found that less able students can significantly improve their performance when interacting with their learner models, and predict that the benefits will be even more prominent if the students are also engaged in dialogues about their models. In contrast, Bull, Mabbott and Abu Issa (2007) report that some weak students did not want their model to be shown to others, as they felt embarrassed and ashamed; some students were concerned that everybody would know how they were performing; comparison with others might reduce the student's confidence. (It should be noted, however, that positive attitudes to opening the model to peers and instructors greatly exceeded negative attitudes, with some of the weaker students being very keen to share their model). The results of these studies can inform future work to examine which attributes should be shown to the learner and when, as well as when a learner can be offered more interactive approaches to using their open learner model. Furthermore, as pointed out by Kay (2006), sharing the learner model with others brings another crucial aspect which will be an inevitable

part of future work in open learner models – how trust and privacy issues should be taken into account when opening the model to others. Interestingly, the learning modelling techniques that may undermine privacy may also actually help to preserve it, as shown for example by Kettel, Brooks and Greer (2004) who examined learner attitudes to sharing information about themselves, and explored how various learner modelling filtering techniques could help to maintain each person's desired level of privacy. This work is on-going, see Anwar, Greer and Brooks (2006).

Interaction with Open Learner Models

The interaction with open learner models was examined in several papers in this special issue. Two papers show how motivational and metacognitive aspects can be taken into account when planning the students' interaction with their models. Chen et al. (2007) present an approach where pedagogical goals, such as motivation, awareness, reflection and positive group interactions, determine the strategies employed to enable children to interact with their learner models. A more descriptive model of structuring the interaction with the student model is proposed by Tchetagni, Nkambou and Bourdeau (2007), where the system engages the student in dialogue games aimed to encourage the student's reflection on his/her knowledge. Initial studies with both systems show promising results. Building on these results, future studies can further examine how to integrate pedagogical strategies when designing the interaction with open learner models. In line with this, we can expect that future work will investigate how to exploit conversational models to define interaction scripts tailored to the specific needs of interacting with an open learner model.

This special issue includes two approaches that illustrate how models of argumentation can provide a structured way for interacting with open learner models. Van Labeke, Brna and Morales (2007) use argumentation structure to design dialogue games that lead the students through the model. This guides the students' interaction with the open learner model and helps them see the right parts of the model. Zapata-Rivera and colleagues (2007) illustrate that argumentation structures can be used to help teachers inspect and change the models of their students. These studies provide strong evidence for the feasibility of negotiation and argumentation interactions with the learner model, and draw attention to their potential to facilitate meaningful interactions with open learner models. We can expect future work to build on these studies, and to develop richer argumentation models that explore different perspectives on the learner model. In this vein, dialectic approaches that explore discrepancies in viewpoints of learners and teachers (e.g. Panayiotou & Dimitrova, 2007) can be followed. Future interaction modes with open learner models may adopt more human-like means for discussing the model in free text, which can build on recent work on using chatbots (Kerly & Bull, 2006) or exploiting advanced natural language processing techniques (Peres-Marin, 2007).

DEPLOYMENT AND EVALUATION OF OPEN LEARNER MODELS

The papers from this special issue provide several interesting examples of integrating open learner models in learning environments, as well as experimental evaluations of open learner models. Based on the findings of the special issue, we will draw future research directions concerning deployment and evaluation of open learner models.

Integrating Open Learner Models in Learning Environments

The use of open learner models for formative and self-assessment is a predominant theme in papers in the special issue. Some papers discussed specifically designed adaptive assessment tools (Lazarinis & Retalis, 2007; Zapata-Rivera et al., 2007) while others discussed assessment as part of existing interactive learning environments (Mitrovic & Martin, 2007; Tchetagni, Nkambou, & Bourdeau, 2007; Van Labeke, Brna, & Morales, 2007). As stressed by Mitrovic and Martin (2007), self-assessment requires knowledge awareness and ability to reflect on one's knowledge and learning skills. This justifies the suitability of open learner models in such cases. Hence, one can expect that future successful deployments of open learner models will be integrated with appropriate means for formative and self-assessment.

Chen and colleagues (2007) draw attention to searching for creative and engaging ways to integrate learner models with classroom practices, and to motivate the students to interact with their models. The paper points at the potential of game-like scenarios to interact with open learner models. Ongoing work (Girard, 2007; Storey 2007) shows that linking games and open learner models is a promising research direction to make the interaction with open learner models more exciting, engaging, and enjoyable. We also expect that human-computer interaction approaches can play an important role when designing open learner models, and deciding how they can be integrated with teaching practices. A step in this direction is made by Girard and Johnson (2006) who utilise participatory design to involve teachers and learners in the design of emotive personas for interacting with open learner models. However, this research points at potential drawbacks because the expectations of teachers and children often differ and user suggestions may sometimes violate usability principles. Future research may develop systematic approaches for designing usable open learner models, effectively embedded in learning environments.

Evaluation of Open Learner Models

With open learner models becoming increasingly popular, it is critical to conduct appropriate evaluation studies that examine the kind of learning gains that can be achieved, and the extent to which these gains may be attributed to interaction with open learner models. Bull, Mabbott and Abu Issa (2007) report the results from several studies that examined under what circumstances students were willing to open their learner models to peers and instructors. The students' feedback suggests potential benefits of open learner models to improve students' motivation, facilitate goal setting, promote knowledge awareness, enhance confidence, stimulate competitiveness, and encourage collaboration. Large scale studies in realistic settings reported by Mitrovic and Martin (2007) also indicate that interaction with open learner models can improve the motivation of more able students to spend more time in problem solving and extend their knowledge. Furthermore, Mitrovic and Martin found that interaction with open learner models can lead to better selection of problems and improved performance (which was significant for less able students). Learning gains are also identified in a classroom study with children conducted by Chen et al. (2007) examining both cognitive and affective aspects of interacting with learner models. The children's test scores increased, and evidence of improved motivation and reflection was found.

It can be noted that large scale studies in real settings have been performed only with simple open learner models where the students could inspect but not change the model. The papers in the special issue which present studies with more sophisticated external representations and/or interaction means

(e.g. Tchetagni, Nkambou and Bourdeau (2007), Van Labeke, Brna and Morales (2007), and Zapata-Rivera et al. (2007)) outline experimental studies, at a formative level, concerned with examining what students and instructors feel about their interaction with open learner models. These evaluation studies give insufficient evidence at this stage, to justify that the extensive computational effort required for implementing complex open learner models can lead to improved pedagogical benefits. Enhancing the robustness of the existing prototypes will enable deeper evaluation studies that examine compound criteria and involve a large number of students. In addition, recent advances in monitoring students' interaction with the learner model, e.g. eye tracking approaches (Bull, Cooke, & Mabbott, 2007), as well as robust techniques for analysing log data, e.g. data mining approaches (Baker et al., 2007; Heiner, Heffernan, & Barnes, 2007), can empower future evaluation studies with open learner models. We also expect ecological approaches (McCalla, 2004), which monitor the use of open learner models to enhance the presentation and interaction with the models, to play an important part of future work in open learner models.

Finally, we want to point out the lack of studies that report negative aspects of using open learner models. Such studies can be invaluable for pointing to directions for future research in open learner models, as shown by studies of failures in learning environments (Duval, 2006). An initial step is made in this issue with the paper by Bull, Mabbott and Abu Issa (2007) who report negative aspects expressed by some students when opening their models to peers and instructors. In the future we expect to see more studies where researchers consider not only how beneficial open learner models are, but also what may go wrong and what drawbacks this can bring.

OPEN GROUP MODELS

Research in opening models of groups for inspection and interaction is still at an early stage. This new dimension of open leaner models is becoming increasingly important in social systems, as well as in collaboration and cooperation settings. This special issue includes three papers that consider issues related to open group models. Each of these examine simple group models composed by averaging the values of individual student models. Chen et al. (2007) explore the metaphor of team animal companions to open team models to children, while Bull, Mabbott and Abu Issa (2007) and Lazarinis and Retalis (2007) use group models to facilitate individual students' comparison with the average progression in the class. The group models stimulated students to improve their knowledge to help the team perform better, or to aim to outperform their peers.

Apart from the need to deal with privacy and trust, as already mentioned above, the papers show that future studies with open group models will be needed. This will require revisiting the usability issues discussed above to add the individual versus group dimension. Work in this direction has commenced. Notable successes adopt visualisation approaches to show various dimensions of group/team models. Parchoma, Brooks, and Daniel (2007) use sociograms to visualise social interactions in a group. In a series of studies, Vassileva (2007) and her colleagues show how data for representation in a group model can be chosen, and how appropriate visualisations can be designed to stimulate social comparison and reciprocation. Mazza and Dimitrova (2007) also experiment with a series of visualisations to open cognitive, behavioural, and social aspects of a whole class for inspection by teachers. Kay et al. (2006) present a more systematic approach for visualising team interactions, by following a well-established model of effective teamwork which considers five dimensions: team leadership, mutual performance monitoring, backup behaviour, adaptability, and

team orientation. They show a promising approach for capturing the long term, high level, graphic summary of individual activity within teams. All these approaches focus on asynchronous interactions over a long period of time. An important aspect of effective groups is active communication achieved via synchronous chat. Research in conversation visualisations (e.g. Erickson & Kellogg, 2000) can provide helpful insights for opening these aspects of group models.

We expect that there will be an increasing number of studies of open group, team, and community models in the future. Research can examine how group models differ from individual models, which characteristics should be used when modelling groups, which of these characteristics can be opened to the group members, and how this might be achieved. Evaluation studies will be required to examine what benefits or drawbacks the opening of group models can have on group performance, group efficacy, and effectiveness of group collaboration. It will also be important to investigate when a model should be opened to a group, what aspects of a model can and should be opened, and how the representations can be tailored to individuals' performance and roles.

BEYOND EDUCATIONAL DOMAINS

We would like to conclude the analysis of the findings of this special issue on open learner models with a look into future opportunities to deploy open learner modelling ideas in other domains. We endorse the view of Kay (2006) who advocates that scrutability is an issue crucial not just for learner models but to all components of adaptive systems. Furthermore, system transparency and explaining system rationale traditionally examined in open learner models are crucial characteristics of effective environments that adapt to their users (Jameson, 2006). Recent applications in assistive technology show a rather unusual application of open learner modelling techniques to visualise a patient's behaviour or treatment to a group of elder care givers (Pollack, 2007). Historically, many studies have shown that educational domains are highly useful for pioneering experiments on new techniques. Along these lines, we expect future work to show open learner or group modelling ideas taken beyond the educational domain to empower work in areas that one can barely imagine at present. We hope to see ideas reported in this double special issue developed and adapted to a variety of domains and in a wide range of settings in education and beyond.

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