Supporting Collaborative Interaction with Open Learner Models: Existing Approaches and Open Questions

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Abstract: In this paper we explore possibilities for open learner models to facilitate collaborative interaction and learning. We provide examples of the main approaches that use open learner models to support collaboration, and discuss some of the key issues that need to be considered for future work uniting research in the fields of computer-supported collaborative learning and open learner modelling.

Introduction

Computer-Supported Collaborative Learning (CSCL) predominantly subscribes to an intersubjective epistemology (Suthers, 2006) where the central focus is on designing artifacts for, and understanding practices of joint meaning-making (Koschmann, 2002). As such, from a human-computer interaction (HCI) perspective, usability, sociability, and learnability are three interdependent design challenges in CSCL (Vatrapu et al., 2008). Of these three design challenges, sociability has received significant attention in CSCL research (Buder & Bodemer, 2008; Kimmerle & Cress, 2008; Kreijns et al., 2002; Kreijns et al., 2007). In this paper we present Open Learner Models (OLM) as a new direction to the existing CSCL research on group awareness in particular, and sociability in general. A primary benefit of OLMs is to integrate both sociability and learnability aspects of the learning process.

The paper is organised as follows. First, we introduce and discuss OLMs. We then present the potential and promise of OLMs to foster collaborative interaction, and introduce some emerging trends. We conclude with a set of open research questions and future work directions.

Open Learner Models

OLMs have been available in adaptive educational systems for some time now. The underlying learner model (representation of learner knowledge, understanding, skills, etc.) is inferred by a system based on what has happened during an interaction with a learner or a group of learners (e.g. problem-solving tasks, specific questions, to more open-ended interaction). This allows a system to further adapt the interaction to suit individual learners, collaborating pairs or groups. OLMs have been deployed using a range of modelling techniques (e.g. constraint-based models – Mitrovic & Martin, 2007; Bayesian networks – Zapata-Rivera & Greer, 2004; fuzzy models – Mohanarajah et al., 2005; simpler weighted algorithms – Bull & Gardner, 2009).

The OLM is a human-understandable externalisation of the underlying learner model. This means that the representations used by the system to select or generate suitable tutorial interventions must (usually) be altered in some way before they are made accessible to learners. For example, as suggested by the above, the underlying system representation may be quite complex, such as in the form of programming code and/or factual statements relating to mathematical rules, scientific principles, or language rules, according to the subject being studied. More recently, interest has increased in adaptation in ill-defined domains (Mitrovic & Weerasinghe, 2009; Fournier-Viger et al., 2010), and so there may be yet more challenges for OLMs to face if such systems open a learner model for user inspection.

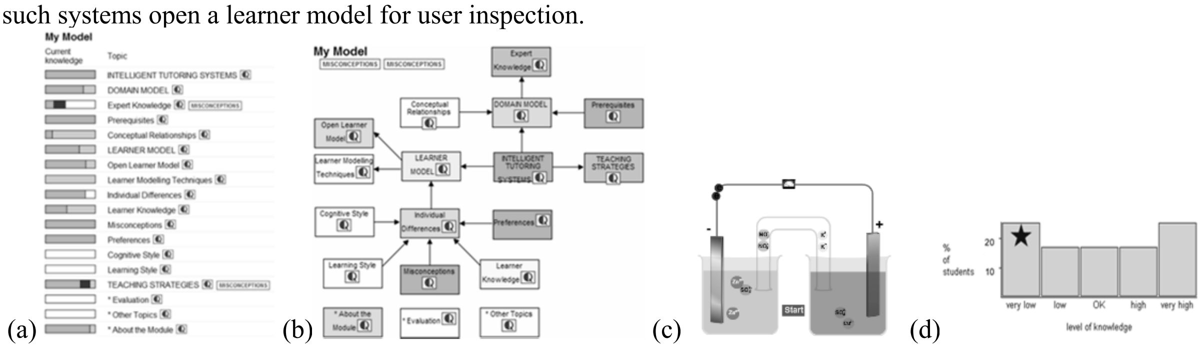

Figure 1. (a) Simple & (b) structured OLM (Ahmad et al., 2010); (c) snapshot of OLM animation (Johan & Bull, 2010); (d) simple comparison of individual to group (Bull & Britland, 2007).

Learner models can be presented to learners in a variety of ways, ranging from quite simple representations, the most common of which are a skill meter for each topic, (sub)topic or concept in the domain (e.g. Ahmad et al., 2010; Corbett & Bhatnagar, 1997; Mitrovic & Martin, 2007; Weber & Brusilovsky, 2001), illustrated on the left of Figure 1(a); to more complex structured representations of understanding such as hierarchical trees (Kay, 1997; Mabbott & Bull, 2006); Bayesian networks (Zapata-Rivera & Greer, 2004); and concept maps (Kumar & Maries, 2007; Mabbott & Bull, 2006; Perez-Marin et al., 2007a). Figure 1(b) shows a structured map view of the learner model. Other methods of OLM presentation include simulation (Morales et al., 2000); and animations (Johan & Bull, 2010), shown for chemistry in Figure 1(c). The method of presentation of the learner model does not have to relate directly (in some way) to the underlying system representation or the modelling technique, though limitations will exist. For example, a simple underlying model of knowledge *level* as a subset or overlay of domain acquisition will not enable an OLM to display specific *beliefs* such as concepts and misconceptions.

While standards exist for learner profiling (IEEE LTSC PAPI; IMS LIP, 2001), the pedagogical characteristics included (e.g. preferences, interests, performance, competencies, amongst others), do not provide detail for how this data might be externalised to a learner in a manner consistent with many of the educational benefits aimed for by OLMs. The increased interest in opening the learner model to the user requires a means to help researchers to compare their OLMs, and learn from the developments and deployments of others. The SMILI☺ Open Learner Modelling Framework was developed for this purpose (Bull & Kay, 2007). In the following section we discuss some of the reasons for opening the model, based on this framework, but with a particular focus on the role OLMs can play in collaborative learning.

Open Learner Models to Promote Collaborative Interaction

Primary aims of OLMs include prompting metacognitive activities such as reflection, planning and self-assessment; supporting navigation; and facilitating collaboration (Bull & Kay, 2007). OLMs have achieved significant positive learning results when used by individual learners (e.g. Kerly & Bull, 2008; Mitrovic & Martin, 2007; Shahrour & Bull, 2009). We aim to foster this ability of OLMs to support learning in the collaborative context. OLMs have already been made available to allow learners to compare their progress to that of other users, or support or prompt peer interaction (e.g. Bull & McKay, 2004; Chen et al., 2007; Lazarinis & Retalis, 2007). However, work in this area is less advanced than in learner models open to the model owners (the modellees). Nevertheless, this is becoming increasingly important and relevant with widening use of social systems and students' familiarity with online social interactions, and Vassileva (2007) emphasises the integration of work in the fields of open learner modelling, interaction analysis and social visualisation.

We have identified three main current approaches to using OLMs to support collaborative interaction and learning, though systems often involve a combination of these:

i. individual learner models that are available for peers to view;
ii. a group model comprising data from individual team members;
iii. a combined group model which is available to group members.

The first approach using OLMs in collaborative learning is illustrated by OLMlets, used by university students (Bull & Britland, 2007). When simple individual models (Figure 1(a)) have been released (optionally) to peers by their owners, students are able to seek out suitable collaborators for areas where they have common difficulties; or seek help from people who have stronger knowledge in areas in which they have problems (Bull & Britland, 2007). Any (or all) of these released peer models can be presented to the learner alongside his or her own model, for easy comparison. The following shows the type of interaction that has been found to occur spontaneously amongst students using OLMlets alongside their courses, as described by one of the students:

> When several people were using OLMlets at the same time, most notably in one of the small computer rooms, there came to be almost a community feel. Students were comparing their model against those of people in the room, and discussions were occurring spontaneously all the time. (Bull & Britland, 2007)

This illustrates that, even when students have no specific pair or group task, they can instinctively engage in discussion with peers as a result of viewing each others' OLMs. Furthermore, this becomes a normal part of learning over time. Thus, a learning interaction that is initially used by individuals, becomes a source of information to support collaboration and peer help sessions without any (system or human tutor) intervention. Indeed, in a later experimental study it was also found that students will spontaneously discuss their learner models by viewing other users' screens, even when the option to release their models was not available (Johan & Bull, 2010). This occurred despite there being no instruction or even suggestion that they should or could do so. This further supports the possibilities for OLMs to facilitate spontaneous collaborative activities; and may also have a similar motivational role in contexts where specific pair or group interactions/tasks are defined.

Another method of supporting collaboration with OLMs is to provide a model of group interaction over time, and individuals'contributions to a joint project or task. This is illustrated by Narcissus, where the primary goal is to facilitate effective group functioning, using evidence gathered from university students' use of group work tools (Upton & Kay, 2009). Enabling group members to view the extent and type of individual participation in a group learning context allowed team members to better identify any difficulties in the group, and work out solutions to overcome them. A major contrast to OLMlets is that all group members' participation is included in the display, reflecting that this is a group project, though a user can focus on just those peers who are relevant to them at the time. Results from Narcissus suggest that, as well as supporting learner reflection and understanding of the group interaction, the system has potential to support navigation through large and complex groupware sites (Upton & Kay, 2009). Further, examples specifically related to learner model visualisations to support team work are given in Kay et al. (2006).

A final example is a group model comprising aggregated group data (i.e. where, unlike in the previous examples, the individual peer models are not necessarily available). Such a model can allow a student to compare their own progress against the group as a whole. One method of doing this is shown (for one topic) in Figure 1(d). This also comes from OLMlets (Bull & Britland, 2007): the star shows the learner's own position against that of other group members, on a five-point scale from very low knowledge to very high knowledge. A related approach is used by Linton and Schaefer (2000), who show a user's level of knowledge against the combined knowledge of other user groups; and Tongchai and Brna (2005), who propose initially providing only a group model, before allowing users to make more direct comparisons between their own, and peer knowledge. There are many uses to which such an approach could be put, ranging from information simply for the individual, to information which a group can use together, to allow learners to *actively* consider how group members might be able to help each other and achieve their shared goal(s). This therefore also provides opportunities for the kind of metacognitive activities prompted by the first two methods.

The above suggests that there are strong roles for OLMs to help support collaborating learners, even without system or human tutor guidance. From a CSCL perspective, OLMs can empower the students to recognize and realize opportunities for learning with a more capable peer in the Zone of Proximal Development (Vygotsky, 1930/1980). The conceptual representations of OLMs can help facilitate artifact-centered discussion and engender a shared sense of a community of inquiry. Moreover, OLMs open up the possibilities for inter-group collaborative learning as an extension to the current intra-group collaborative learning emphasis of CSCL.

Open Research Questions and Future Work Directions

While there are now many examples of learner models open to individuals and increasingly also to instructors, with this trend spreading to group and peer models new issues need to be considered. For example:

Role of OLMs and OLM use

- To what extent can individual OLMs be used to support collaborative learning, and in what contexts? (E.g. voluntary sharing of models for independent spontaneous use; individual OLMs and their contribution to group knowledge, achievement, and group interaction.)
- To what extent will the sexpected OLMs differ according to individual roles in the group, and how might this be used to better understand group functioning?

Possible differences in OLMs for individuals

- To what extent will OLMs differ according to type of task a user is completing at the time, to a project?
- To what extent will OLMs differ according to level of input expected of (and obtained from) each participant (or subset of participants), at various points in time?
- Should all participants have the same attributes made available in a group model, or set of individual models? (Should this depend on their role within the group?)
- Should all group members receive the same learner model information at the same time? (Will this depend on their own progress or level of contribution?)

Access to OLM data

- What are the privacy issues that need consideration in peer or group models?
- How will learners feel about the availability of their learner model to other users? (Will users feel differently about data relating to their knowledge, cognitive abilities, contributions, motivation, or other social or affective states?)
- Will all group members (have to) see the same information in the same way, to facilitate collaboration? (Will this depend on their role in the group? Or on preferences for how to use learner model data?)
- What differences might there be between co-located and distributed group members?

These are only a sample of questions related to OLMs for groups. Questions are likely to differ according to the approaches most suitable in a particular collaborative learning context. For example where individuals' models are available to others, students could be allowed to choose whether to release their model data, meaning that the privacy issues relating to other users seeing their data, are in the hands of the owner of that data. This is the case in OLMlets: learners can release their model with their name, anonymously, or keep it hidden from others. Sufficient numbers of students select to release their model to encourage spontaneous collaboration amongst those who wish to work with peers (Bull & Britland, 2007). The situation becomes more complicated, however, when a user's data contributes individually to a group model, where other users can identify who that contributor is. In a group task, the purpose of a group OLM is often to facilitate discussion, planning, production, etc. If only some users offer their model for group access, an overall (aggregated) model may be distorted; or a model containing only information about some group members (identifiably or not), may be less useful. In this case, should the group decide that all data be available? Can a group expect this, without taking away some of the rights of the model owner (i.e. control over an individual's own data)?

How will collaborations that occur spontaneously amongst users when individuals release their models to (selected or all) peers, influence group interaction if only some group members are engaging in such discussions spontaneously? Similar to the above, is it the role of a group leader (or the group collectively) to require all participants relevant to a particular issue, to be involved, thus potentially dampening any spontaneous discussion that can lead to sudden insights and advances? This may be advantageous for the group as a whole, but might an individual feel 'left out', or find it harder to catch up because others have already moved on?

An important issue related to the above question of whether a user has control over their own model data, is the situation where other users might be able to contribute information to a person's model. Peer contributions to learner models have been used in cases such as evaluating a partner after a help session in a decentralised learner model (Vassileva et al., 2003). A crucial question is the requirements if such a learner model were externalised to the learner in sufficient detail for them to recognise where the model evidence came from. What if a learner disagrees with the peer's assessment? Will this disrupt group activity?

What happens if learners are collaborating around a learner model, but prefer to access the model data in different ways? Figure 1 gives examples of different methods of presenting learner model data, and learners can have quite different individual preferences about how to view learner model information (Bull et al., 2010). To what extent will individuals be able to adapt to others' ways of viewing a learner model, when in face-to-face and distributed collaborative contexts?

How important is the timing of release of learner model information to learners? What happens if one learner becomes aware that another has access to group or individual data that they cannot see themselves? This could be possible, for example, if a threshold had to be reached before a user could access certain information; of if a team member's role does not require the information. The latter might be easier for a learner to accept, but is there a reason to restrict their access if they are interested?

Many questions have been raised here, and we do not yet attempt to answer them. But the benefits of prompting metacognitive activities for individuals using OLMs, and the positive learning gains achieved, suggest the potential of also using this approach in CSCL. A range of collaborative interaction types can be (and have been) supported by OLMs, including individual models released to peers, aggregated group models, and individual models contributing to a group model (and combinations thereof). This can help not only in structured activities, where a system may or may not have a managing role over group interaction, but also in encouraging spontaneous peer interaction. These interaction types can clearly address issues of joint meaning-making (Koschmann, 2002), as raised in the Introduction; and also encompass usability, sociability, and learnability - suggested as interdependent design challenges in CSCL (Vatrapu et al., 2008). Furthermore, they are in line with approaches to encourage work in the Zone of Proximal Development (Vygotsky 1930/1980).

Future research in CSCL should help towards resolving some of the issues, and further exploration of others; and research in open learner modelling can reciprocate, sharing findings of research into facilitating collaborative interaction around individual shared, and various kinds of group OLMs.

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