Epistemic Beliefs and Open Learner Models

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Abstract. Information on epistemic beliefs has the potential to enrich feedback to students and teachers, through open learner modelling (OLM). We outline existing OLM applications with epistemic content and ways in which more holistic aspects of learning and development (epistemic beliefs, values, identity cognition etc.) may extend OLM for 21st Century learning. We propose three steps to extend epistemic network analysis to provide an OLM which contains epistemic beliefs.

Keywords: Open Learner Modelling. Epistemic Beliefs.

1 Introduction

In adaptive learning environments (ALEs), a learner model (LM) represents student knowledge, allowing for personalisation and adaptation towards learners and their current needs [1]. Traditionally the information in the LM may be read only by the ALE (i.e. it is *closed* to the learner it represents.) An *open* learner model (OLM) allows learner access to the LM's content in a meaningful way, for example through a visual representation of its content, during interaction. OLMs may be presented in a variety of forms from skill meters and coloured nodes (Fig 1, a,b), through to concept maps (Fig 1, d), animations and domain specific representations (Fig 1, c) [2]. Learner responsibility, awareness and independence in learning are benefits of viewing an OLM, and metacognitive activities such as self-assessment, planning and reflection may be promoted [2,3,4].

Traditionally the content of the LM may range from core competencies (knowledge, misconceptions etc. [5]) to measures of affect (e.g. motivation [3]). Information less commonly modelled includes epistemic activities such as argument construction [6]. Such activities are highly relevant to learning and may potentially enrich the learning-based feedback OLMs provide. In this paper we look at the suitability of including epistemic beliefs in OLMs, and consider methods to capture and display epistemic information in the OLM context and conclude with a method for doing this.

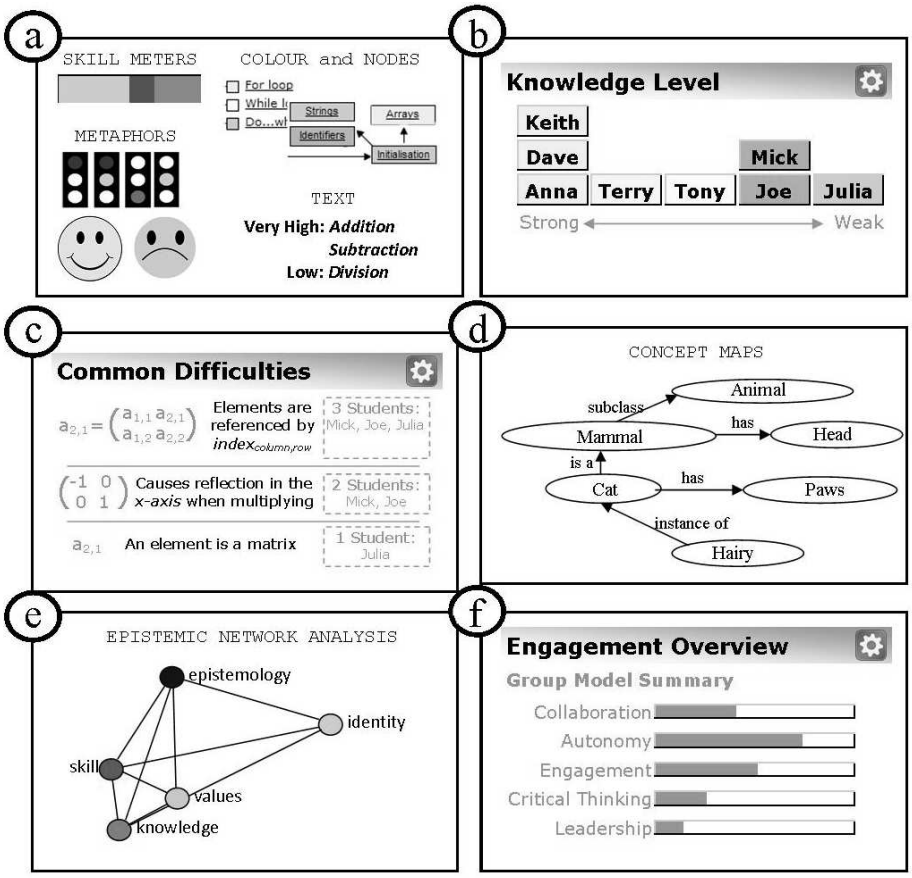

Fig. 1. Example methods for presenting OLM information. The top two rows show existing ways of presenting the information through: (a) knowledge level skill meters, metaphors coloured nodes and text etc.; (b) group model information; (c) detailed or domain specific presentations; (d) concept maps. The bottom row shows potential ways further epistemic information may be presented using existing means: (e) epistemic network analysis (adapted from [11]); (f) overviews of 21st Century skill mastery.

2 Epistemic Beliefs in the Context of Open Learner Models

Learning is not restricted to mastering concepts, procedures or specific skills, but includes the "*ability to think, act and interact with others in productive ways to solve complex tasks*" [7]. Epistemic beliefs help address this point and can be considered as those an individual holds about the nature of knowledge, and 'knowing information'. Epistemic beliefs focus on the systematic linking of knowledge and the justification of understanding using evidence or prior understanding [8].

In the case of the epistemic activity of *argument construction* this can be summarised formally by Toulmin's [9] argumentation structure. OLMs such as xOLM [3]

use this structure to formally reason about student understanding, although these beliefs belong to the system rather than being the epistemic beliefs of the student. The OLM presentation is highly visual, presents links between evidence and makes predictions about student ability. Warrants that justify claims are important to establish their legitimacy. OLMs such as STyLE-OLM [5] allow joint construction of the LM, requiring learners to justify beliefs, and in doing so the OLM may foster reflective thinking in students, through negotiation. Again, representations are highly visual and links are forged between beliefs. Relationships modelled are epistemic in nature and show the systematic linking of low-level information. This is similar in concept mapping. In Flexi-OLM [4] learners constructed their own OLM presentations by linking concepts. Relationships specified included formal relationships, information related to planning learning, and information to aid future knowledge acquisition. In such activities, labels on links between information are important for developing epistemological understanding. These examples show that existing OLMs have the potential to capture and model epistemic information. Future challenges include scaling up the domain content, increasing the epistemic information quality, visualising greater volumes of epistemic beliefs, and inferring epistemic beliefs not explicitly stated by the learner.

Stoeger [10] highlights the potential for creating a LM composed of epistemic beliefs and proposes a non-computer based learner model, constructed from fixed questionnaire items (e.g. "The manner in which I learn [maths] will never change"). Using the model, composed of three principal facets (epistemic inclination, epistemic acquisition and knowledge characteristics), he demonstrates epistemic beliefs are effective predictors of ability and more accurate than IQ tests. Extending OLMs to include these facets provides a starting point for more formally modelling epistemic beliefs.

In the context of 21st Century learning, epistemic beliefs may not be solely about knowledge and its acquisition, but of wider social/cultural experience, values and practices [7] – potentially, a community of practice. For example, epistemic games encourage learners to use concepts/ procedures in activities to learn what it is to *think* and *act* as a member of a specific profession (e.g., journalist) [7]. The professional competence is modelled as an epistemic frame containing inter-related *skills*, *knowledge*, *identity conceptions*, *values* and *epistemological beliefs* [11]. The classroom/home setting constitutes itself a community of practice, albeit a 'non-professionally based' one; arguably OLMs could also model student identity conceptions, values and epistemic beliefs – by being extended to encompass rich, contextual 'epistemic frame' inferences. Epistemic network analysis (ENA) [11] is used to model and display epistemic frame information, and the extent to which students internalise its attributes. Using graphs and network diagrams the model is visualised (in ways similar to Fig 1e), and changes over time may be discerned. OLMs could be extended to include ENA-type information, and so give feedback to students and teachers in real time regarding how they resemble epistemic frames of experienced members of the community of practice. The LM incorporates process and product data, and the OLM reveals this information to the student. This makes explicit, normally tacit metacognitive processes that experts participate in to engage students in 21st century learning. In alignment with the initial aims of OLMs, this may help with short and long term planning, in addition to being a source to promote reflection. This extends the benefits of OLMs to permit the acquisition of 21st Century skills (e.g. collaboration [6], leadership [7], critical thinking [11]), through inspection of episte-

mologically based information. These skills, often labelled “soft skills”, are recognised as key to innovation. They make the process of knowledge building accessible to all, permitting the development of new ideas that are of value to others in a community. Students can build knowledge relative to their current level of understanding through acculturation to the wider social/cultural practices of a community and experience more meaningful learning.

Thus: existing OLMs have the potential to encompass epistemic information within current technologies; techniques exist as a starting point for modelling learners’ epistemic beliefs; and through considering the wider context provided by an epistemic frame, OLMs can be extended to support the acquisition of 21st Century skills.

3 Realising Epistemic Open Learner Model Content

Epistemic information may typically originate from two sources: *process data* (people interaction, whether between learners, a teacher or a non-learner) and *product data* (tangible outcomes/artefacts, e.g. from learning activities) [7]. For OLMs, epistemic beliefs could explicitly result from educational activities (e.g. writing reflective prose [11], concept mapping [4] or negotiation [5]), or OLMs may be extended to encompass other, more informal, sources (e.g. teacher observation, chat logs etc.). It is important to acknowledge that epistemic information may be latent and affected by other measurable attributes [7] as a result of learners systematically linking information [11], and that strong relations exist between epistemological facets. Information is often modelled to a course level of granularity for precisely this reason [11].

OLM based epistemic information, originating in the classroom or home, has practical benefits for students, teachers and parents alike. Independent from technology, teachers and parents can use the information to scaffold students’ learning and further 21st Century skills that mainstream classroom technologies do not necessarily promote. Teachers and parents may draw on their own personal experience to support students in developing aspects of these skills, using the epistemic OLM information. Furthermore, teachers’ feedback to students often draws on in-depth knowledge of local circumstances and general context [13]. Epistemic OLM information could specify the context in which to interpret core abilities (knowledge, misconceptions etc.) and visualise pedagogically-based information. This may allow the prediction of future behaviour, its evolution over time and inter-student relationships or belief networks that exist; these are useful tools for designing educational interaction.

Our research project makes advances in three steps to realise the vision that OLMs for 21st Century learning may include more holistic aspects of learning and development. These include epistemic beliefs, values, and identity cognitions, in addition to 'classic' KSAs (knowledge, skills and aptitudes).

The first step is towards automating ENA [11], which has so far been realised by employing human coders. The construction of the basic data table, required to analyse inter-frame development, will be automated by graph-theoretical means: the list of time slices together with the frequencies of frame elements. In our approach we will apply natural language processing techniques to extract concepts, relationships and sentiments, and will use machine learning techniques to build classifiers (e.g. Support Vector Machines). These techniques rely heavily on corpus data that is obtained when

human ‘raters’ perform content analysis in order to code student-produced materials (mainly students’ writing documents) in terms of the epistemic frame dimensions. This content analysis (valuable in its own right to answer research questions) will then yield the data required to train the automatic classification method.

In the second step we will automate the analysis of the adjacency matrices that can be built from the basic data table. This will require respective software to be written and/or to reuse existing implementations of graph algorithms, such as the ones used for social network analysis.

Our third step will visualise the information contained in adjacency matrices as well as plotting graph theoretical parameters (such as centrality, density, etc.) over time. In addition to writing the respective software, this requires research into the graphical interface provided to the users. As stated above, existing OLM presentations containing epistemic information are highly visual (links between information, coloured nodes etc.) and network diagrams/graphs are appropriate methods for representing epistemic information, with an emphasis on clarity. This is our starting point for visualisation, and the OLM may be extended to include more emerging techniques (e.g. tag clouds, timelines or sparklines [12]), which also allow collaborative activity content to be represented.

In summary: appropriate information sources exist to build on the capabilities of OLMs highlighted in Section 2, and extend epistemic information in alignment with current student and teacher practices; secondly, we have highlighted that epistemic OLM information may have the potential to support human-based scaffolding of students’ 21st Century skill development; finally, we have outlined three steps towards an OLM for 21st Century learning that can include more holistic aspects of learning development.

4 Summary

Existing OLMs include activities that are appropriate to formally model epistemic beliefs. By capturing aspects of process (people interaction) and product (learning artefact) data, epistemic OLM information may be modelled and presented in a highly visual manner. This has the potential to extend the state-of-the art to allow OLMs to support students, teachers and parents in their respective roles, and to further students’ development of epistemic practices and 21st Century skills (e.g. collaboration, critical thinking). In our work, we will extend approaches developed in former OLM research to model and visualise epistemic activities and beliefs, and we will extend ENA in three steps so that it can be applied to the assessment of school-relevant 21st century learning.

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