Using Language Technologies to support individual formative feedback.

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Abstract
In modern educational environments for group learning it is often challenging for tutors to provide timely individual formative feedback to learners. Taking the case of undergraduate Medicine, we have found that formative feedback is generally provided to learners on an ad-hoc basis, usually at the group, rather than individual, level. Consequently, conceptual issues for individuals often remain undetected until summative assessment. In many subject domains, learners will typically produce written materials to record their study activities. One way for tutors to diagnose conceptual development issues for an individual learner would be to analyse the contents of the learning materials they produce, which would be a significant undertaking.

CONSPECT is one of six core web-based services of the Language Technologies for Lifelong Learning (LTfLL) project. This European Union Framework 7-funded project seeks to make use of Language Technologies to provide semi-automated analysis of the large quantities of text generated by learners through the course of their learning. CONSPECT aims to provide formative feedback and monitoring of learners' conceptual development. It uses a Natural Language Processing method, based on Latent Semantic Analysis, to compare learner materials to reference models generated from reference or learning materials.

This paper provides a summary of the service development alongside results from validation of Version 1.0 of the service.

Introduction

'Lifelong Learning' is a mix of formal and informal learning opportunities, both of which place emphasis on development of independent self-directed learning. This is typified by workplace learning environments where learning trajectories involve interactions between learners and their peers alongside professionals from their own domain, as well as with "clients" (e.g. patients or customers). In such complex situations, it is frequently difficult to establish the extent to which a specific individual covers the key topics necessary for attainment of competence and expertise through the course of their learning.

In order to address misinterpretations and gaps in learning, learners require both pedagogic and affective support, through formative feedback from tutors and peers. Formative feedback is an opportunity to correct any misconceptions and suggest remedial actions to address gaps in an individual's knowledge and skills. Therefore, to be useful, formative feedback needs to be contextualised and provided to students in a timely manner (Shute, 2008). Shute advocates that a specific aim of formative feedback is to communicate information that will engender accurate, targeted conceptualisations of a particular topic for the purpose of improving learners' understanding of it.

1. The problem – the need for timely, meaningful formative feedback without incurring massive workloads for tutors

Learner support can place a heavy load on staff time and resources. Stakeholder analysis has identified four types of activity that constitute this burden: assessment of student contributions, answering students' questions, community and group support and monitoring and assessing the progress of students' studies (Van Rosmalen et al., 2008). Monitoring and recognising a learner's level of expertise has to take into account their knowledge, the level of cognitive processing required by the task, and the instructional strategy (learning context) used (Ertmer & Newby, 1993; Jonassen et al., 1993). Enabling learners to understand how they are structuring their knowledge, in a manner that is appropriate both to their level of expertise and to the social context of their learning, is an essential feature of the service reported here. In order to become self-directed, learners need to monitor the progress of their own understanding in a specific area or problem, so that they may recognise the limitations of their current level of expertise.

2. Approach to developing a solution - the application of language technologies to learner support issues.

Learners in most domains will produce written materials to document and evidence their learning. We assume here that an individual's collection of text materials represent the conceptual knowledge of the person and we seek to use language technologies to assess individual's knowledge in a (semi) automatic way.

Goldsmith *et al.* (1991) propose that a structural approach may be applied to assess an individual's knowledge of a domain, by analysing how he or she organises the concepts. This approach involves three steps: knowledge elicitation, knowledge representation, and evaluation of an individual's knowledge representation.

Knowledge elicitation is defined as the process of describing domain-specific knowledge underlying human performance (Cooke, 1999). In short, knowledge elicitation techniques measure the learner's understanding of the relationships amongst a set of concepts (Jonassen *et al*, 1993). Methods that support this activity include categorisation (e.g., card sorting, word association), graphical reporting (e.g., concept maps, semantic networking) and verbal or textual reporting methods (e.g., think aloud, essay questions).

The second step of the process is to define representations of the elicited knowledge that reflect the way in which the underlying data is organised (Goldsmith *et al.,*1991). Advanced statistical methods (e.g., cluster analysis, tree constructions, dimensional representations, pathfinder nets) may be applied to identify the structural framework underlying the set of domain concepts.

The third step is to evaluate the individual's knowledge representation relative to a defined standard (e.g., expert's organisation of the concepts in the domain, reference model, etc.). Normally, researchers follow one of the three following approaches (Goldsmith *et al,* 1991): qualitative assessment of derived representations; quantifying the similarities between a student representation and a derived structure of the content of the domain; or comparing the cognitive structures of experts and novices. Research on expertise has shown differences in the knowledge base development between novice to expert (Boshuizen & Schmidt, 1992). Experts and novices differ in their knowledge usage, information processing, and in how their knowledge structures are organised (Arts *et al.*, 2006). Findings in Law (Nievelstein *et al.*, 2008), Physics (Dufresne *et al.*, 1992), Management (Arts *et al.*, 2006), and Medicine (van de Wiel *et al.*, 2000) have shown that knowledge, with increasing expertise, is more hierarchically structured, while novices' knowledge appears to be highly fragmented with concepts loosely connected. Interestingly, semantic networks have been used to represent knowledge and compare cognitive structures of experts and novices (van de Wiel *et al*, 2000; Bude, 2007).

The design of the service we present here is underpinned by a theory synthesis that considers the processes on which learners build their knowledge, as well as the effects this has on their knowledge structures in their transition from novice to expert.

Learners develop their expertise through participation in a knowledge building cycle, which comprises cognitive and social processes. A cognitive process focuses on perception, memory and meaning; it assumes the memory is an active processor of information, and knowledge, as a commodity plays an important role in learning. A social process assumes that learning is a social activity, which occurs in interaction with others. It takes into account both the learner and the environment, where learners are pro-active producers of the environment in which they operate.

Our work is informed by Stahl's knowledge building cycle (Stahl, 2006). Following a social epistemological perspective (Brown & Duguid, 1991; Lave & Wenger, 1991), Stahl models the learning process as a mutual construction of the individual and the social knowledge building. In his view, knowledge is a socially mediated product. Individuals generate personal beliefs from their own perspectives, but they do so on the basis of socio-cultural knowledge, shared language and external representations. These beliefs become knowledge through social interaction, communication, discussion, clarification and negotiation. Learners, therefore, build knowledge both personally and collaboratively.

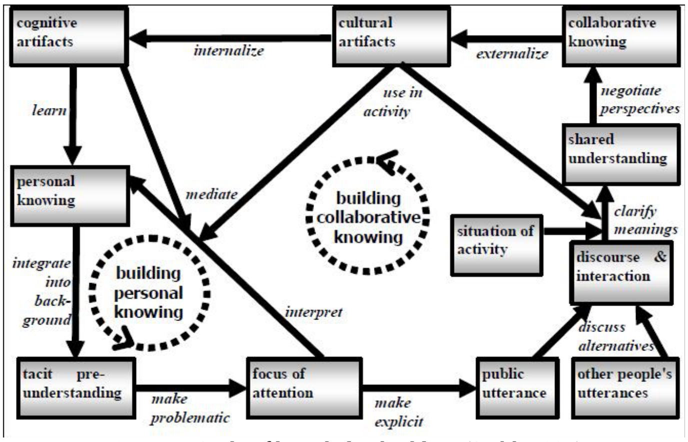

Figure 1. Cycle of knowledge building (Stahl, 2006).

Figure 1 shows Stahl's (2006) cycle of knowledge building. The diagram depicts how the personal and the collaborative knowing building cycles interact.

Building personal knowing begins with tacit pre-understanding, informed by personal knowing. Our understanding changes as our conceptual knowledge becomes more informed; we reinterpret our own knowledge as we address conflicts and clarify misconceptions to arrive at a new state of personal knowing. This typically involves some feedback, for example, from our experience with artefacts such as our tools and symbolic representations. New comprehension gradually settles in to become our new tacit understanding and provides the starting point for future understanding and further learning. If it is not possible to arrive at a new state of personal understanding individually, we may enter into public discourse in order to develop shared understanding, collaboratively. To do this, we typically articulate our initial belief in words and express ourselves in public statements, and we enter into the cycle of social knowledge building.

The right hand part of the diagram depicts how the social process of interaction with people and with our shared culture, influences the individual's understanding. This process is an interchange of arguments that provide rationales for different points of view, which eventually may converge on a shared understanding, resulting from a clarification of differences in interpretation and terminology. Although in the diagram personal cognition and social activity are depicted separately, this is only a matter of representation; they are intertwined and can only be separated artificially.

Our service aims to support both knowledge building cycles. On the left hand side of the cycle, it provides a cognitive artefact (i.e., a graph representing learner's topic representation which can be visualised in various ways) that can help learners to understand and resolve conflicts or fill in gaps in their knowledge. If this is not possible, learners enter into the cycle of social knowledge building. In this cycle, the service provides a 'cultural artefact' (i.e. a graph visualisation that contains the intended learning outcomes or a single graph visualisation that is based on peers' graphs) that can help to foster understanding.

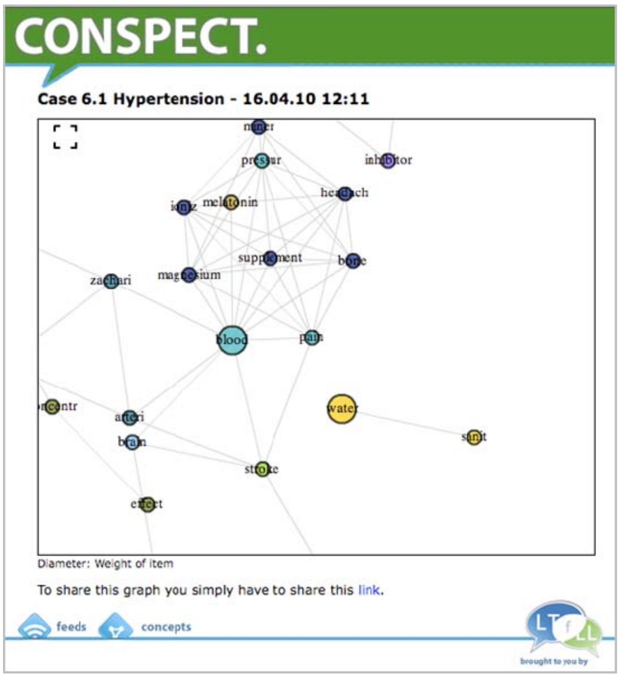

Figure 2. CONSPECT output – a Conceptogram showing concepts identified from a blog.

CONSPECT provides learners with diverse ways of comparing their understanding against different models, principally (Berlanga *et al.*, 2009):

(1) *Predefined reference model*, considering intended learning outcomes described in, for instance, course material, tutor notes, relevant papers.

(2) *Group reference model*, considering the concepts and the relations a group of people (e.g., peers, participants, co-workers, etc.) used the most.

The result of using these particular models is that, from a cognitive point of view, the service provides learners with information that contrasts their understanding of the topic against the intended learning outcomes. From a social point of view, the service provides information to learners so they recognise the differences in how they conceptualise a topic with respect to the way in which their peers do.

From early validation activities, it is clear that the pre-defined reference model is too complex for comparison with a novice learner and may not be suited to early stages in a curriculum. The emerging reference model was a better indicator of the appropriate level of abstraction and relationship between concepts attainable by individual learners (Berlanga et al., 2009).

3. Type of tool being developed - its underpinning mechanism and types of user interactions

By using Latent Semantic Analysis, a natural language processing method, larger collections of texts from a specific domain area can be used to identify key terms for that domain and the conceptual relationships between these constituting terms, thus creating a latent semantic space. Associative closeness thereby serves as an approximation of semantic relatedness of concepts in the domain of interest, which is calculated from the contextual neighbourhood of the terms.

Landauer and Dumais, (1997) describe Latent Semantic Analysis (LSA) as “a theory and method for extracting and representing the contextual-usage meaning of words by statistical computations applied to a large corpus of text”. LSA “induces global knowledge indirectly from local co-occurrence data in a large body of representative text”. The LSA technique is a method for solving a huge set of simultaneous equations that represent terms in documents (Landauer, 2007 pp. 13-14). LSA takes no account of word order, using what is known as a “bag of words” approach, which removes any word order information. In the often cited example, “Mary loves John” is not the same as “John loves Mary”. This limitation of the method does not translate into a weakness for the CONSPECT service, however, as extraction of meaning is concerned simply with the identification of key concepts and not making explicit the nature of the semantic relationships between them. A novel extension of LSA in this project has been its combination with Network Analysis to form what we’ve termed ‘Meaningful Interaction Analysis (MIA)’ which furnishes further detail regarding the closeness of concepts in the results of LSA analyses. This is described in detail in the D4.2 project deliverable.

The application of LSA in the CONSPECT application involves projecting (converting to the same semantic space of the training corpus) an individual’s writings into the dimensional system provided in a latent semantic space. As mentioned above, this space is created by analysing a larger number of texts that are representative of the target domain. To keep the workload for administrators in creating a discipline specific latent semantic space to a minimum, the deployed method has been optimised to work with texts taken from a literature database (such as Medline for medicine).

Through the projection of the learner’s writings into the latent-semantic space, a representation is created of the learner text in the ‘language’ of the space. The resulting representation is then presented to the user in the form of a visualisation (See Figure 2) and with other forms of user interfaces (for example a list of the core concepts they have covered, derived from the analyses). This re-representation of the meaning expressed in the texts allows the learner (or tutor) to view simply, in summary, the concepts that they have presented evidence for in their learning materials.

4. Functions of the tool - ways of using it for student and tutor

CONSPECT has been designed to provide a means by which a learner’s conceptual development can be monitored and formative feedback opportunities may be promptly exploited.

The intended purpose of the service is to:

- Provide timely formative feedback to students, based on the text-based materials they develop in their learning.
- Encourage self-directed learning based on the feedback offered by the system

- Provide diagnostic information to tutors, to inform and guide the feedback they provide

The main stakeholders of CONSPECT service are learners and tutors. CONSPECT uses text materials such as essays or blogs to establish a visual model, a ‘conceptogram’, of how learners relate concepts to one another. Conceptograms are simple representations, similar to concept maps, of topics based on an automated analysis of textual evidence produced by learners. In a conceptogram, the concept node size and colour are used to communicate information about the analysis to the viewer, with lines and distances between nodes representative of relationships between concepts and the ‘associative closeness’ of terms.

By interacting with the interface, a user can discover new and previously non-obvious aspects in the latent semantic representations. One form of interaction is, for example, to rearrange the layout of the conceptograms to discover whether certain clusters are connected. Visualisation interactions help to review the underlying complex data (the graph representing the latent semantics of the learner’s textual evidence). By comparing (re-)representations against peer models and other forms of provided reference models, differences in coverage and organisation become salient. Inspecting the conceptual, latent semantic representation with the help of this user interface mediated re-representation helps to reflect on the conceptual coverage and conceptual gaps. This supports the learner in making decisions about which area to focus on next or about which area needs more evidence (assuming that it is just a lack of evidence, not a lack of competence).

We investigated the utility of reference models against which learner texts can be compared, as a basis for feedback. Feedback from users in validation of the first version of the service indicated that they found the tool’s ability to conduct comparisons valuable:

> *“I find it useful as well, especially the comparing part... You can see what’s been missed out on, ... I think it’s more useful to see what you’ve missed out on that to see overlap – it’s always good to know if you’ve covered extra.”*

Two types of reference models were investigated: a pre-defined Intended Learning Outcomes model based on materials from the curriculum and an ‘emerging reference model’, drawn from the concepts and inter relations between them generated by a peer learning group. The Intended Learning Outcomes model was too complex for comparison with a novice learner and may not be suited to early stages in a curriculum. The emerging reference model was a better indicator of the appropriate level of abstraction and relationship between concepts attainable by individual learners.

Once the learner has compared their conceptograms with an Intended Learning Outcomes model conceptogram or an emerging group reference model, they can then take self-directed actions to address a knowledge area that is identified as deficient, for example by contributing further materials, or they may choose to share their concept map with peers or their tutor. When learners choose to share concept maps with their tutors, the tutors are able to see under-represented areas of knowledge, for which they can identify a course of remedial action that combines suitable resources and learning activities.

The analysis of an individual’s evidence can be compared with outputs from other students or a tutor-generated model, to identify shortcomings, misconceptions, and emerging learning opportunities within the learner’s zone of proximal development (Vygotsky, 1978). Tutors are able to view the conceptograms of individuals and groups who have shared it on a one-to-one basis or who have chosen to make their outputs public and comparisons can be made of the learners’ conceptograms with conceptograms generated from texts of the standards required to meet specified outcomes. The tutor may also choose to alter his or her learning activities for the group of learners, based on a conceptogram that represents a group reference model.

5. Evaluation

During the early stages of the project, the outputs from a number of concept mapping tools were compared, providing a means of determining how learners relate basic concepts, to establish which could meet the requirements identified in a learning scenario. We investigated the utility of reference models against which learner texts can be compared, as a basis for feedback. Trials were undertaken using existing software tools to produce concept maps manually from selected texts; Leximancer (www.leximancer.com) and Pathfinder (Schvaneveldt, 1990) were used to conduct a showcase validation of the service. Although Leximancer and Pathfinder were selected for initial experiments, their functionality and flexibility was insufficient for the requirements of the project. These tools provided manual processing of text sources, and also use language technologies. Using these concept mapping tools, a clear distinction could be made between the ability to integrate concepts demonstrated by individual learners with that of reference material.

A Web-based service development, implementing the LSA natural language processing method (combining it with network analysis into MIA), was undertaken to produce CONSPECT, which sought to automate the submission and processing of text materials, the production of their semantic representations, and creation of plus the analysis against reference models.

The first version of the system has been evaluated with educational practitioners and learners in a qualitative evaluation. The methodology of the qualitative evaluation used focus groups and interviews with stakeholders to collect data about the effectiveness of the service. The data was thematically categorised in an open coding exercise. The findings were related back to a set of initial validation topic questions and used to revise the development roadmap for the service.

Learners in a pilot of version 1 of this service have kept a journal of their own learning in the form of a blog. A learner begins to use CONSPECT by adding an RSS feed from their blog. CONSPECT then analyses the content of the blog entries to identify the presence of words that indicate coverage of key concepts.

A respondent commented:

> *"It's quite a clever way to compare yourself to what other people have written down, that you've covered everything you need to cover, which is a problem in PBL at the moment."*

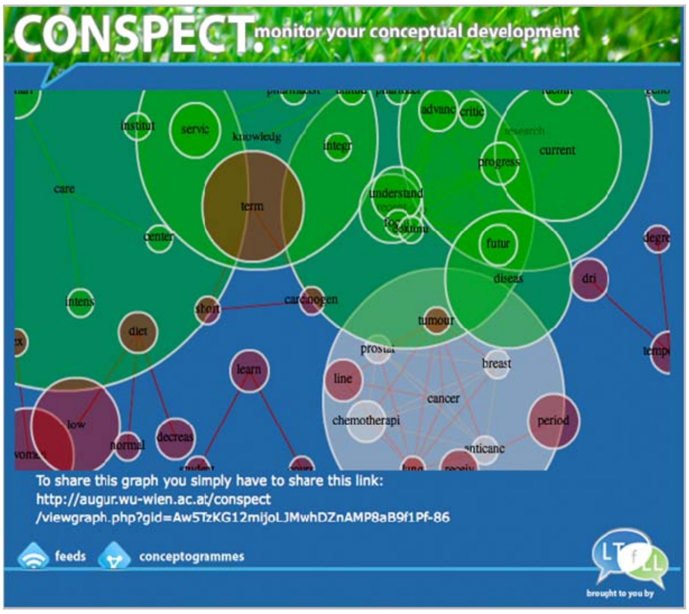

Figure 3. Comparing a student's conceptogram with a conceptogram of intended learning outcomes in Pharmacology (grey: overlap, green: missing concepts).

However, qualitative data from interviews with students indicates that although the service provides good support for their learning, it does not provide adequate substitution for feedback from a tutor.

6. Conclusion and Outlook

The work reported here has resulted in the development of Version 1 of a Web-based service, which is designed to help learners monitor their conceptual development. This service requires minimal human pre-configuration and automates, using Meaningful Interaction Analysis, the identification of concepts and extent of their coverage in text materials. We have explained the theoretical underpinnings and rationale for the design and use of the service. Specifically, we discussed how the design of the service is grounded in findings from the area of expertise development and is based on a knowledge building model. We have also explained how the service might be used in educational contexts.

Further research is required to establish how learners would benefit the most from comparing their conceptual development with the models described here (pre-defined reference model and group model): whether it is good strategy for learners to see comparisons with both models or, whether, depending on their level of expertise, comparisons with different models will be made available. The type of reference model learners find useful may depend on the level of learner development. The emerging reference model, which is based on concepts and their interrelationships, generated by peers, would most likely be of use for an individual learner at a novice level, as at this stage it would correspond to his/her Zone of Proximal Development (Vygotsky, 1978). As expertise develops, the emerging reference models may still be appropriate, depending on the development stage of the group as a whole, but pre-defined reference models may be more suited to a more advanced learner.

Further refinement of the CONSPECT service will be realised in the next version, informed by the validation results from Version 1. A further validation of the new software with stakeholders from the Manchester Medical School, and from a distance Psychology course at OUNL, will be conducted. Besides extending the test to a different domain (Psychology versus Medicine) we will also test in a new language (Dutch versus English). We believe these further experiments will serve to provide confidence in the broader applicability of our service.

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For further details of the project, see http://www.ltfll-project.org