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Author(s): Adriana J. Berlanga, Marco Kalz, Slavi Stoyanov, Peter van Rosmalen, Alisdair Smithies and Isobel Braidman

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Language Technologies to Support Formative Feedback

Adriana J. Berlanga[1], Marco Kalz[1], Slavi Stoyanov[1], Peter van Rosmalen[1], Alisdair Smithies[2] and Isobel Braidman[2]

[1]Centre for Learning Sciences and Technologies (CELSTEC), Open University of the Netherlands, Heerlen, The Netherlands // [2]University of Manchester Medical School, Manchester, United Kingdom // adriana.berlanga@ou.nl // marco.kalz.ou.nl // slavi.stoyanov@ou.nl // peter.vanrosmalen@ou.nl // alisdair.smithies@manchester.ac.uk // isobel.braidman@manchester.ac.uk

ABSTRACT

Formative feedback enables comparison to be made between a learner's current understanding and a desired learning goal. Obtaining this information is a time consuming task that most tutors cannot afford. We therefore wished to develop a support software tool, which provides tutors and learners with information that identifies a learner's progress, and requires only limited human intervention. The central idea is to use language technologies to create concepts maps automatically from texts, such as students' essays or Blogs. By comparing maps from students over time, or with maps created from tutor's materials, or by other students, it should be possible to ascertain learners' progress and identify remedial actions. We review existing tools for automatic construction of concepts maps and describe our initial explorations of one of these tools. This paper then introduces the theoretical background of the proposed tool, design considerations and requirements. An initial validation, which explored tutors' perceptions of the tool showed that tutors found the approach relevant, but its implementation in practice requires to consider teachers' practices, the tools already in use, as well as institutional policies.

Keywords

Formative feedback, Conceptual development, Concept maps, Language Technologies

Introduction

According to Hattie and Temperley (2007) effective feedback should provide information that helps students to see where they are going (learning goals); feedback information that tells students "how they are going", and feed forward information that points out to students "where to go next". From the tutor's perspective, providing this feedback requires several tasks, for example considering the learner's position regarding the curriculum (i.e., his/her current stage of learning), assessing his/her level of understanding, identifying possible gaps in knowledge, and suggesting remedial actions. These are time consuming tasks, especially as learners may have different learning goals and backgrounds, and may follow divergent learning paths.

We believe that providing this feedback should be part of the next generation of support and advice services needed to enhance individual and collaborative building of competences and knowledge creation. The premise is that language technologies, and particularly Latent Semantic Analysis (LSA) (Landauer, McNamara, Dennis, & Kintsch, 2007), could be used for this. LSA creates a mathematical model in which both the domain knowledge and the knowledge of the learner can be projected thereby enabling the progress of the learner to be analysed (Clariana & Wallace, 2007).

Our aim is to design a tool that provides learners and tutors information about a learner's conceptual development set side by side with the intended learning outcomes of the curriculum and of others in their learning group. The tool would use language technologies to extract such information automatically, enabling tutors to provide students with formative feedback in an efficient and time effective manner. This paper presents the design considerations and initial validation of such a tool. The first section presents the theoretical background, followed by design considerations and requirements. After this, the paper presents a review of existing technological solutions. We discuss the use of one of them when applied in a "mock-up" to explore the feasibility of our approach. Thereafter, the paper describes the initial validation of a first prototype of the anticipated service. It investigates the tutors' perceived relevance and satisfaction of the approach. Finally, the paper presents conclusions and future work.

Theoretical background

Feedback, is a key element in formative assessment, can be defined as information provided by an agent (e.g., teacher, peer, book, parent, tool) regarding aspects of performance or understanding (Hattie & Temperley, 2007) with the aim of modifying thinking in order to improve learning (Shute, 2008).

In contrast with summative assessment, formative assessment does not have the intention of summarizing or grading the achievement of a student for certification purposes (Sadler, 1989); it occurs typically after instruction and seeks to impact on learning, by providing knowledge and skills or to develop particular attitudes or to advise the student on learning strategies (Hattie & Temperley, 2007; Sadler, 1989). It could be used both by teachers and students. Formative feedback provides teachers with useful information for making decisions regarding delivery of a programme on the basis of students' progress diagnosis of any shortcomings in students' learning and its remediation (Shute, 2008). Students and teachers use formative feedback to monitor the strengths and weaknesses of students' performances, the former could be recognized and reinforced, whereas the latter modified or improved (Sadler, 1989). According to Shute (2008) formative feedback can reduce learners' uncertainty on how well they are performing, can reduce their cognitive load (particularly with novice or struggling learners), can potentially promote learning, and provide useful information for correcting misconceptions. Formative feedback strategies include providing learners with information that moves them forward in their conceptual development, empowering them as owners of their own learning as well as "instructional resources" for individuals (Black & Wiliam, 2009).

Our ambition is to design a formative feedback tool that, with minimal human intervention, provides tutors and learners with information about learners' conceptual development. The design considerations of the tool we envisage are grounded on three aspects: developing expertise, knowledge creation, and the process of measuring conceptual development. A full description is provided by Berlanga, Van Rosmalen, Boshuijzen, and Sloep (in press).

Briefly, it has been observed that in the development of expertise, novices and experts differ in the way they structure their utterances and knowledge. Novices do so in networks that are incomplete, loosely linked and solve problems in long chains of detailed reasoning steps throughout these networks. In contrast, experts have well structured and organized mental frameworks. They structure knowledge so problems may be solved by omitting reasoning steps rather than by proceeding one step at the time. Differences between novices and experts are closely reflected in the textual utterances expressed by novices in their evolving domain knowledge. Thus the way novices and experts express their use of concepts and how they relate them to one another's changes through time. This occurs in a systematically way and is based on learning experiences (Boshuizen & Schmidt, 1992; Arts et al., 2006; Boshuizen et al., 2004).

Second, theories of knowledge creation focus on how individuals and groups develop knowledge that is new to them. They stress that it is not transmitted untouched and unchanged from one knowledgeable person to another individual who is unknowing. In contrast, they emphasize that knowledge is constructed in a dialectical and social process. Not only explicitly stated knowledge and information is a source or result of this process but it also depends on a much bigger reservoir of tacit knowledge. Examples of knowledge creation theories include Stahl's knowledge building cycle (Stahl, 2006), and the "SECI" process of Nonaka et al. (2000). Stahl proposes a model in which individuals build their knowledge in a cycle which comprises personal understanding and collaborative knowledge, and assumes that the construction of knowledge is a social process. The SECI process describes the interplay between the individual and group learning as four connected and interacting processes of knowledge conversion: socialization, externalization, combination and internalization. These processes can take place in different levels of sophistication, depending on how people create and employ a context for implicit and explicit communication, the quality of the input in the process, etc.

The third consideration is related to the process of measuring conceptual development. If we aim to develop a tool that provides formative feedback, learners should be able to judge the quality of their work. To this end they need to (a) possess a concept of the standard (or goal or reference level) for which they are aiming; (b) compare their actual (or current) level of performance with the standard; and (c) engage in appropriate action which leads to some closure of the gap between them (Sadler, 1989).

A well-known example of the use of computer modelling techniques to approximate the structure of a metacognitive theory (Schraw & Moshman, 1995) is the structural approach proposed by Goldsmith et al. (1991) which analyzes how an individual student organizes the concepts of a domain. This involves three steps: (1) eliciting the student's' knowledge, (2) representing his/her elicited knowledge, and (3) evaluating this representation relative to some standard (e.g., reference model, an expert's organisation of the concepts in the domain, reference).

Design considerations and requirements

Based on the theoretical foundations discussed above, the design of the proposed tool is grounded in the idea that providing formative feedback should consider that:

- A learner's level of expertise is reflected in the way they use and relate concepts, when they express their knowledge;
- Learners develop their expertise in a knowledge building process, which encompasses cognitive and social perspectives; and,
- Learners should be provided with diverse ways of comparing their level of performance.

To this end, the service should provide learners with diverse ways of comparing their understanding against different reference models (Berlanga et al., 2009):

- Predefined reference model which considers intended learning outcomes described in, for instance, course material, tutor notes, curriculum information, etc.
- Group reference model, which considers the concepts and the relations that a relevant group of people (e.g., peers, participants, co-workers, etc.) used the most.

The idea is that the tool is used by a learner or a teacher to process text materials automatically (such as student input, learning materials, etc.), and in return obtain the most relevant concepts included in the input text and the relation between these concepts. The tool could then represent them visually as a concept map or as a list of concepts. If the text input consists of intended learning outcomes (such as course materials, books, etc.), then the result of the automatic process is the so-called predefined reference. If the text input consists of written output from a group of students (aggregated in a single text), then the tool produces the so-called group reference model.

The tool should also offer the possibility of generating comparisons between different texts inputs. For example, if a tutor decides to generate one concept map from a predefined reference model and another using text input from a student, they may be compared to identify which concepts the student is omitting from his/her text but are present in the learning materials. These comparisons could also be obtained from a group model and a predefined reference model. In this case the comparison will enable the tutor to identify those concepts that are not mentioned by the group as a whole and make it easier to identify outliers, diagnose causes of relevant problems, and take prompt remedial actions.

Based on our requirements and earlier work we decided to use language technologies as the underlying technology for the feedback tool. In order to decide how it could be implemented, next we review existing technologies that could support the analysis of conceptual development and serve as a foundation for this tool.

Existing tools for automatic construction of concept maps

In the previous section we have already referred to the use of concept maps. This means of eliciting and representing a learner's knowledge, is one of the most common ways of representing cognitive structures (Novak, 1998). Research evidence demonstrates that concept maps are well-suited for eliciting knowledge (Nesbit & Adesope, 2006), and are better for evaluating learners of different ages than classical assessment methods such as tests and essays (Jonassen, Reeves, Hong, Harvey, & Peter, 1997; Novak, 1998). The creation of concept maps, however, is a complex and time consuming task. It requires training and practice to understand how the relevant concepts should be identified and to make relationships between them. Therefore we analysed existing tools and tool sets that are able to support the creation of concept maps. We have not included purely algorithmic methods which have been tested for concept map construction (Bai & Chen, 2008, 2010) but we have focused on integrated solutions that allowed us to work with text input directly.

There are already a number of tools for the automatic construction and support of concept maps: Knowledge Network and Orientation (KNOT, PFNET) (Clariana, Koul, & Salehi, 2006); Surface, Matching and Deep Structure (SMD) (Ifenhaler & Seel, 2005); Model Inspection Trace of Concepts and Relations (MITOCAR) (Pirnay-Dummer, 2006); Dynamic Evaluation of Enhanced Problem Solving (DEEP) (Spector & Koszalka, 2004); jMap (Jeong, 2008) and Leximancer (Smith & Humphreys, 2006), Table 1 summarises these tools in terms of the data collection they require and the analysis and comparison they perform.

Table 1: Existing tools for construction of concept maps (adapted from Shute, Jeong, Spector, Seel, and Johnson, (2009))

	Data Collection	Analysis	Comparison
KNOT	Concept pairs/Propositions	Quantitative Analysis	Direct comparison of networks with some statistical results
SMD	Concept map or natural language	Quantitative analysis is calculated using tools	Unlimited comparison
MITOCAR	Natural language	Quantitative analysis included multiple calculations using tools	Paired comparisons for semantic and structural model distance measure
DEEP	Annotated causal maps	Quantitative/qualitative analysis is done mostly by hand	Unlimited comparisons, showing details relative to concepts
JMap	Concept maps, causal maps, or belief networks	Quantitative analysis (calculated using tools)	Superimposes maps of individual (n=1) and group of learners (n = 2+) over a specified target map
Leximancer	Concept maps	Content analysis and relational analysis (proximity, cognitive mapping)	Imposes tags in a single map over user-defined tags (names, concepts, files, etc.)

These tools have some common characteristics: (a) they can (semi-)automatically construct concept maps from a text; (b) they use a type of distance matrix; (c) they propose a quantitative analysis of the maps; and (d) most of them are concerned with conceptual development of learners. Among their differences, we have found that, even though they all use a language technology, not all of them refer to it explicitly. These tools also differ on the scoring schemas they use to perform the quantitative analysis: DEEP uses the number of nodes and links; SMD uses propositions or the number of the links of the shortest path between the most distant nodes.

Most of these concept mapping tools provide opportunities to identify the conceptual gap between a learner's concept map and a criterion map (which could be a predefined reference model or group model), or to compare a learner's concept maps over different periods of time. However, only SMD, jMap and, in some extent DEEP, purposely provide a visualisation of this progression with reference to the standard criterion. Most of these mapping approaches construct and analyse individual maps. jMap visualises and assesses changes observed in either individual or collective maps. However, jMap is restricted to producing causal maps. KNOT, SMD, MITOCAR and Leximancer report on reliability and the correlation of validity criteria. Typically, they consist of the automatic scores generated by these tools, human concept mapping scores and human essay scores.

Each of the tools discussed can be used, at least to some extent, to provide formative feedback. Leximancer is the only tool that does not require specific input to start and/or a specific way of working. Therefore, based on our requirements we have focused on using Leximancer for an initial, empirical validation of our approach.

Initial explorations

In view of the theoretical considerations discussed above, we designed and prepared two experiments with functional mock-ups of the service to check the validity of our ideas. Each of the mock-ups was based on a combination of manual interventions and existing tools. The mock-ups were used to explore the following questions:

A. Is it possible to build a concept map of a text on a selected topic that, according to the writer, covers the *core* concepts of the text?
B. Similarly, is it possible to build a 'group' concept map which represents a set of selected texts on a specific topic that, according to the authors, covers the *core* concepts of the aggregated text?
C. Do the writers of the input texts perceive the representations of A and B as useful input when they want to compare and contrast the individual versus the group perspective of the selected topic?

In the first experiment (Berlanga et al., 2009), users were only indirectly involved i.e., as providers of materials, as the actual outcomes were assessed by an expert. In the first test we transcribed a student's spoken description of a medical case and used Leximancer to create a concept map (A) of this text and of the tutor materials for the corresponding topic (B). The results indicated that the student's concept map used much more detailed concepts compared to that derived from the tutor materials. The study illustrated that a model based on comparing concept maps from tutor materials with those from students, must be used with care, since the interpretations of such maps may require more expertise than is possessed by a student in C, who is at a novice level.

In the second test of the first experiment, we used Leximancer to create concept maps (A) of each of 10 interviews with researchers in our group on how they understood the concept of a Learning Network (Sloep, 2008) and one emerging concept map based on integrated summary of all transcripts (B). Results indicated that by using Leximancer we identified the 10 most commonly used concepts and their importance. Moreover, an initial analysis showed that a comparison of an individual's map and the group map could be used to indicate differences and similarities (C).

In the second experiment (Berlanga et al., in press), we explored the same questions. This time, however, the users were directly involved. We asked six researcher of our research group to provide us with one of their articles (average size 5000 words) on their research on Learning Networks. Each of the articles and the summary of all of them were represented as a concept map by Leximancer and, alternatively, as a word cloud by using Wordle (http://www.wordle.net) to check the possibilities of more commonly used tools. A questionnaire, based on the questions A, B and C, stated above, was used to assess the users' perceptions of the concept map and the word cloud. The results indicated that there was a fair coverage of concepts included in the articles by both representations, in answer to question A. Likewise, in answer to B, the representations of the summary of all articles covered by the Learning Network were, as a whole, satisfactory. The answer to question C was more ambiguous; five of the six users, found the concept map was useful for detecting similar and missing concepts when their article was compared with the summary article, whereas three out of the six users obtained this results with the word cloud.

The results of the two experiments indicated that there were sufficient grounds to start developing a dedicated prototype.

Validation of the approach

Following the results from the partly manual explorations described above, the proposed design was used to develop a first prototype of an automated tool called CONSPECT (Wild, Haley, & Bülow, 2010). This tool enables a user to extract the core concepts from their own text and a reference text automatically. The comparison can be shown both as a list and a concept map (as shown in Fig. 2).

As a first step, the CONSPECT service was validated from the perspective of tutors at the University of Manchester (UK), who were involved in year 2 of a 5 year undergraduate medical degree. Five tutors were recruited for this purpose, four of whom had more than five years experience in this role and one was less experienced, but had been tutoring for over one year; all but one were women. The software was explained to all participants, who were given an overview and demonstration of CONSPECT and shown how to input materials and access outputs. The text output used were blogs, written by students and tutors on the weekly clinical case studied in that part of the programme. They were trained to interpret results and asked to produce a 'model answer' blog. The concepts from the blogs were extracted by CONSPECT and were compared with those produced by the students, using either a student group reference model or blogs produced by individuals, which were also compared with each other. These comparisons were then shown to the tutors. A mixed methods approach was used to record and analyse their responses. They completed a questionnaire, comprised of forty three questions each with a five-point Likert scale, which covered aspects of time management, usability and efficacy of CONSPECT, and its role in augmenting teaching. Tutors then completed free text comments which were thematically analysed. The main findings were that tutors gave highest ratings to their knowledge and skills in using the software and to their efficient completion of tasks. Analysis of free text comments indicated that tutors appreciated the fundamental basis for CONSPECT and that it could provide rapid comparisons of students' understanding of the particular subject area with a "model" answer. It had the potential to identify those students who engaged at a more superficial level and others who might be delving more deeply into the subject matter, which might enable tutors to confirm those individuals who were outliers in their groups (Smithies, Braidman, Berlanga, Wild, & Haley, 2010).

A further validation was then conducted in the Open University of The Netherlands in the context of distance education by obtaining feedback from tutors about the relevance of using CONSPECT for their practice. The rest of this section describes this validation.

Method and data

Five tutors of the Open University of The Netherlands, Faculty of Psychology attended a workshop session, which included a demonstration, an individual hands-on session, a focus group discussion and completing a questionnaire.

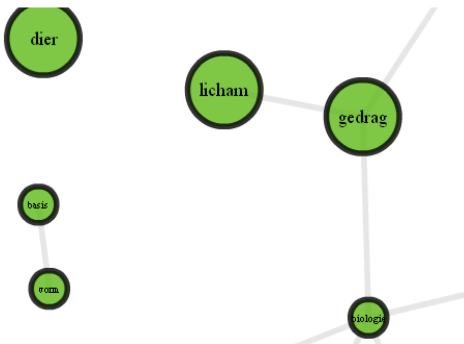


Figure 1a: Concept map from learning materials (predefined reference model; zoom view)

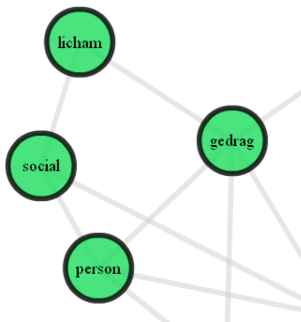


Figure 1b: Group concept map (zoom view)

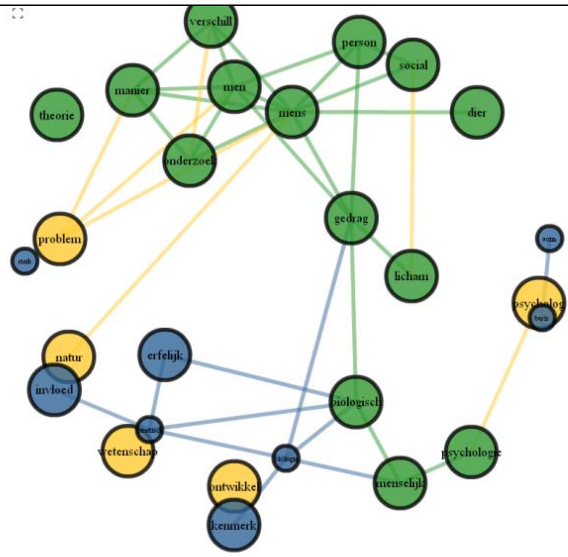
In preparation for the workshop, we collected learning materials from two Psychology courses namely a digitalized book of the course, and a tutor's model answer for a specific assignment, which answered specific questions that covered the main course topics. We used CONSPECT to create a predefined reference model of the main concepts that the students should cover (see Fig.1a for an example). We also used examples from the students' answers to create a group reference model (Fig.1b). Finally, a comparison between these models was created alongside a list of similar and dissimilar concepts (Fig. 2), to identify concepts that are not covered well by the students.

During the first part of the workshop the design of the CONSPECT service and its aim were presented. Examples of concept maps were also introduced to show the type of information the service could provide. The participants then had a hands-on session in which they were asked to use the service with the existing materials to generate a concept map for a student, a concept map for a group model and a concept map for a predefined reference model. They were then required to compare these concept maps and see the results provided by the service. The respondents were asked to work alone, and take notes about their experience with the tool. If necessary, support was provided. Finally, we conducted a focus group, which was recorded both electronically and by notes taken at the time. Data was also collected as follows:

- Background questionnaire, to summarise tutor's teaching experience and age;

- Post activity questionnaire using a five-point Likert scale, with questions about relevance of the tool and user satisfaction:
  - Relevance: Four questions explored how tutors perceived the tool (see Table 2).
  - Satisfaction: Based on the UTAUT questionnaire (Venkatesh, Morris, Davis, & Davis, 2003), six questions were posed to explore the perceived satisfaction (see Table 3).
- Observer and participants' notes made during the validation session;
- Notes and audio recording from the focus group.

Participants (n=5) were tutors from different Psychology areas, with more than 5 years of experience in teaching. Three of them were between 30-40 years old; and the rest were older. Four of them were male.



Concept map from Learning Material (see Fig. 1a)	Overlapping concepts: learning material and group map	Group concept map (see Fig. 1b)
erfelijk (hereditary) invloed (influence) kenmerk (characteristic) basis (basis) biologie (Biology) genetisch (genetic) sterk (strong) vorm (form, manner)	biologisch (biological) dier (animal, creature) gedrag (behaviour) licham (body) manier (way) men (people, one) mens (people) menselijk (human) onderzoek (study) person (person) psychologie (Psychology) social (social) theorie (theory) verschill (difference)	natur (nature) ontwikkel (development) problem (problem) psycholog (psychology) wetenschap (science)

Figure 2: Comparison between concept maps

Results

The results summarised in Table 2 show that all tutors considered the information provided by the tool is useful in identifying the progress of a group of learners (Q2), and that only 20% of them considered it was not useful for identifying the progress of individual learners (Q1). Not all tutors (40%) considered that the approach is relevant for addressing "burning" problems of their institution (Q3), whereas most (80%) of the tutors indicated that they could identify new potential uses of the tool (Q4).

Table 2: Perceived Relevance of the approach

Question	**Negative (<3)**	**Neutral (=3)**	**Positive (>3)**
Q1. The way CONSPECT provides information (list concepts, graphical representation) is useful to identify learners progress	20%	60%	20%
Q2. The way CONSPECT provides information (list concepts, graphical representation) is useful to identify the progress of a group of learners	-	60%	40%
Q3. I think CONSPECT addresses one of the burning problems of the institution	40%	20%	40%
Q4. I can identify new potential uses of CONSPECT, which will address problems of the institution	20%	40%	40%

The results for tutor satisfaction are summarised in Table 3. Most tutors (80%) considered that the tool increases their curiosity about the topic (Q6), whereas only 40% indicated that the tool makes teaching more interesting (Q7); Half the tutors indicated that the tool motivates them to explore the teaching topic (Q8); and 40% considered themselves eager to explore the tool further (Q10). However, 60% of the tutors were negative regarding the way the tool would help them in their teaching (Q1), and on recommending the tool to other teachers (Q9).

Table 3: Satisfaction of the approach

Question	**Negative (<3)**	**Neutral (=3)**	**Positive (>3)**
Q5. Overall, I am satisfied with the way CONSPECT would help me in my teaching.	60%	40%	-
Q6. Using CONSPECT increases my curiosity about the teaching topic.	20%	-	80%
Q7. CONSPECT makes teaching more interesting.	60%	-	40%
Q8. Using the CONSPECT motivates me to explore the teaching topic more fully.	50%	-	50%
Q9. I would recommend CONSPECT to other teachers to help them in their teaching.	60%	40%	-
Q10. I am eager to explore different things with CONSPECT	60%	-	40%

The initial reaction of the tutors was positive, as they pointed out that indeed one of the problems they face is that they cannot easily identify students that are struggling with the course and that providing formative feedback promptly is a time consuming task. Tutors also feel students work only to get marks on assessments, instead of producing evidence of their actual learning. During the focus group, 4 out of 5 tutors commented that the approach has potential for their practice. They all stress, however, the importance of integrating the tool in their current learning environment, as essential for them to use the tool.

In their validation of the concept maps, tutors indicated that they could easily identify the most relevant concepts, as well as the similar and dissimilar concepts. They also mentioned that the maps had a fair coverage of the content and meaning of the text. Although tutors found it difficult to interpret the representation of the concept maps, they liked the idea of visualizing the links between the concepts, instead of simply a list of overlapping concepts.

The respondents felt that the user interface of the tool was still too complex for most people, but they acknowledged the added value of the approach. They suggested a variety of new forms in which the approach could be used in their teaching practice, for instance:

- Checking different resources (e.g., books, papers, articles), comparing them and deciding which is most relevant to the course learning objectives
- Checking if the learning materials produced by tutors contain the most relevant concepts
- Generating outlines (based on a set of input resources) to create study materials
- Initially checking the quality check of students texts, by asking them to write a text from which a concept map could be generated
- Using the tool in forums, to get a picture of what topics have been discussing
- Checking for plagiarism by comparing different student’s texts.

Conclusions

In this paper we argued that a tool to provide prompt formative feedback can be designed in such a way that, by means of language technologies, little tutor intervention is needed. We proposed that learners will benefit if a tool provides them with information regarding their coverage of key concepts in the study domain, and compares this information with that of their peers. From the tutor perspective this feedback provides evidence which can then help identify individual learners who have difficulty in recognising key concepts.

From the validation conducted it was evident that most tutors perceived the approach relevant and useful for them and their students. They also suggested several different ways of using the tool, which indicated that they appreciated the potential of the tool. Nevertheless, tutors identified several conditions that should be fulfilled in order to incorporate the tool in their current practice. This may also negatively influence the results regarding user satisfaction. There were strong arguments in favour of aligning the tool with existing practices, such as total integration to existing platforms (e.g., institutional virtual learning environment), using only specific types of text documents, or privacy issues in sharing information. These constraints, whether institutional or tutor- oriented, are difficult to avoid if the proposed service is to be implemented in real practice. At the same time, these might cause that stakeholders overlook the potential technology has for supporting learning and therefore limit the possibilities the service –or any other new technology solution– could provide in the learning practice.

We believe that our approach could be of use in other learning situations, where different pedagogical approaches are used. It could be valuable in collaborative writing, where it is important to recognise differences and similarities between the texts, in discussion forums, to identify which concepts have been discussed, in workplace learning to specify core concepts in different documents (for a trial case see Berlanga et al. (2009)) and in informal learning situations where a formative feedback tool, such as the one we propose, could be of use to a group of people who share the same interest on a particular topic and are willing to explore the domain further.

Finally, further research is needed to evaluate learner's perception of the proposed tool as well as evaluation that involves a wider range of stakeholders. It is also essential to verify the accuracy and reliability of the language technologies used to underpin the development of this tool. This is important as we must ascertain how tutors and learners understand the limits of this technology, the conditions under which it may be used to produce reliable results, and those in which some results may be inaccurate.

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