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Mining e-Learning domain concept map from academic articles

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Abstract

Recent researches have demonstrated the importance of concept map and its versatile applications especially in e-Learning. For example, while designing adaptive learning materials, designers need to refer to the concept map of a subject domain. Moreover, concept maps can show the whole picture and core knowledge about a subject domain. Research from literature also suggests that graphical representation of domain knowledge can reduce the problems of information overload and learning disorientation for learners. However, construction of concept maps typically relied upon domain experts in the past; it is a time consuming and high cost task. Concept maps creation for emerging new domains such as e-Learning is even more challenging due to its ongoing development nature. The aim of this paper is to construct e-Learning domain concept maps from academic articles. We adopt some relevant journal articles and conference papers in e-Learning domain as data sources, and apply text-mining techniques to automatically construct concept maps for e-Learning domain. The constructed concept maps can provide a useful reference for researchers, who are new to the e-Leaning field, to study related issues, for teachers to design adaptive learning materials, and for learners to understand the whole picture of e-Learning domain knowledge.

Keywords: Concept map; Knowledge building; e-Learning domain; Adaptive learning; Text mining

1. Introduction

In recent years, web-based learning has become a new means for learners to learn without time and distance barriers. Although information technologies enable learners to access large amounts of learning materials across geographical boundaries, this proliferation has led to a serious problem, called information overload (Berghel, 1997; Borchers, Herlocker, Konstanand, & Riedl, 1998; Eppler & Mengis, 2004). Information overload refers to a state of confronting with too much information to make a decision or remain informed

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about a topic. In the state of information overload, learners can feel anxiety, stress and alienation (Edmunds & Morris, 2000). In a hypertext and hypermedia environment, if the learners come across scrappy and fragmentary data, they can easily experience learning disorientation and find themselves being unable to construct complete and systematic domain knowledge (Lin & Davidson-Shivers, 1996; Calvi, 1997; Dias & Sousa, 1997; Stanton, Correia, & Dias, 2000).

Researchers have pointed out that appropriate navigation support can be a solution to information overload (Stanton et al., 2000; Papanikolaou, Grigoriadou, Magoulas, & Kornilakis, 2002). Maps can help learners to refer and then facilitate information research in a domain (Beasley & Waugh, 1995). A concept map, which represents the relationships of concepts for a certain domain using graph, is one such navigation tool. With the guided help of concept map, learners can then handle the whole picture of domain knowledge; hence information overload and learning disorientation problems can be reduced.

Usually, a concept map for a certain domain is constructed by a group of domain experts. This can be seen as a process of knowledge building. Scardamalia and Bereiter (2002) defined the term "Knowledge Building" as "creative work with ideas that really matter to the people doing the work". The definition can be applied to creative knowledge works of all kinds. We can view the whole process of academic paper publications as a knowledge building process as there are many domain experts/researchers involved in this publication process. And through literature survey and peer reviews, knowledge can be reused, refined and innovated. However, it is hard to get a whole picture for readers from just one academic publication source because articles addressing the same topic might appear in different volumes of the same journal or even across different journals. Therefore, a novel approach of ICT-based knowledge building is proposed in this study.

The reason why we select e-Learning as our domain for creating concept maps to demonstrate the idea of ICT-based knowledge building is because e-Learning is a newly growing field. In such a new domain, concept maps would be out of date if domain experts try to construct it manually in traditional manner over months if not years. To cope with the changing nature of e-Learning domain, we have developed a mining technique to construct e-Learning concept maps automatically. The constructed concept maps can provide a useful reference for researchers to study e-Leaning field, to support teachers in designing adaptive learning materials and to provide learners with a complete picture of e-Learning domain knowledge.

2. Concept map

Initial efforts in concept mapping can be found in the works by Novak (1993) in the 1960s. His work was based on the assimilation theory of Ausubel (1968) who emphasized that the new concept is related to the existing relevant knowledge of learners. These concepts may be represented visually by concept maps. Because of the advantage of visualization, concept maps are more suitable to represent domain ontology. Novak (1993) defined concept maps as "tools for organizing and representing knowledge". Moreover, according to Plotnick (1997), a concept map is a "graphical representation where nodes represent concepts and links represent the relationships between concepts". Concept mapping can be seen as a first step in ontology building and can also be used flexibly to represent knowledge structure for meaningful learning.

In the past, most concept maps were built by domain experts, and scholars used them in related researches (Khalifa & Kwok, 1999; Chularut & DeBacker, 2004). The process of building concept maps has been largely manual. Even at present, although various computer-based tools are available that can help the concept map building process by providing various visual editing functions, the actual data input still relies solely on human experts' contribution. Literature lacks any automatic mechanism to build concept maps. Our research has resulted in an automatic system with embedded text mining techniques to build concept maps.

3. Research assumptions

In order to construct the concept map for e-Learning domain, we use the "keywords" listed in journal articles as the "nodes" to represent concepts and the "relation strengths" between any two keywords appeared in the articles as the "links" to represent concept relationships. The "relation strength" between two keywords is measured by the distance of the two keywords appeared in the articles. The following four essential assumptions are drawn for this research.

Assumption 1. Each keyword listed in a research article represents one essential concept.

Keywords are usually used for representing key topics included in a research article and are useful for researchers to locate documents of interest (Barki, Rivard, & Talbot, 1988). Authors normally choose a few appropriate keywords to represent concept, methodology, theory, model, method, topic or any other significant issues about their research articles. We use these keywords as fundamental entities to construct concept map in e-Learning domain.

Assumption 2. If two keywords appear in one research article, it implies that certain relation exists between these two keywords.

A research article is typically aimed to solve a particular problem and the keywords listed in the article are supposed to be articulated together to solve the problem. This implies the existence of relationships among keywords. For example, if an article has three keywords, say, math problems solving, multimedia whiteboard and oral explanations, then there are three pairs of relationships among these keywords as shown in Fig. 1.

Assumption 3. The higher the frequency of occurrences of two keywords appeared in one sentence, the higher the relation would be between them.

When authors elaborate important descriptions in the article, they typically use keywords to compose sentences. Luhn (1958) suggested that the frequency of word occurrence is a useful measurement of word significance. Therefore, the term frequency of keywords is applied in this research. A pair of research keywords that appear more frequently in sentences implies that their relationship is closer. The frequency is calculated as a part of the formulation for "relation strength".

Assumption 4. The shorter the "distance" between two keywords in one sentence, the higher the relation would be between them.

Letters between two keywords are counted as "distance" to measure their relation. For example in Fig. 2, the relationship between "multimedia whiteboard" and "oral explanations" is stronger than between "multimedia whiteboard" and "math problems solving".

This research validated this assumption through questionnaire surveys. Thirty sentences that contained keywords were selected randomly from the articles database. Fifteen subjects were asked to rank the "relation strength" for every pair of two research keywords. The results of this survey were found to be consistent with this assumption. Based on these four assumptions, the process of constructing the concept map is designed, as explained in the Section 4.

4. System design and methodology

There are four main steps in the procedure: information retrieval from articles, concept item extraction, research keyword indexing and calculation of "relation strength". Finally, users can use query parameters to obtain concept maps through a friendly user interface. Fig. 3 illustrates the procedure for constructing the concept map.

Author Keywords: math problems solving, multimedia whiteboard, oral explanations.
Relationship 1: math problems solving ⇔ multimedia whiteboard
Relationship 2: multimedia whiteboard ⇔ oral explanations
Relationship 3: oral explanations ⇔ math problems solving

Fig. 1. The relationships among keywords in a paper (Hwang et al., 2006).

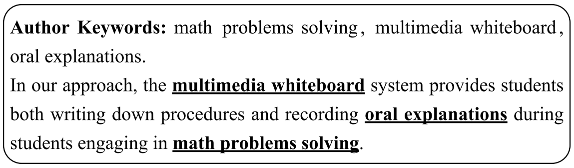

Fig. 2. The "distance" between two keywords (Hwang et al., 2006).

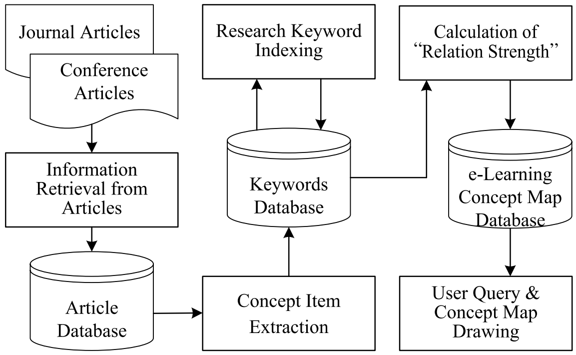

Fig. 3. Procedure for constructing e-Learning domain concept map.

A system is developed to realize the whole process of automatic concept map construction for e-Learning domain. We use Perl, a text manipulation programming language, to program software for information retrieval from articles, research topic extraction, term frequency count and calculation of "relation strength". SPSS statistics software is employed to do the principal component analysis. These processes are needed only once for constructing concept map database. Users can then use the database to query e-Learning domain concept maps by giving interested keywords and parameters. Query's output is drawn automatically using the WebDot graphical software (WebDot, 2006).

4.1. Information retrieval from articles

In order to construct the concept map in the e-Learning domain, it is essential to obtain appropriate content for analysis. Because the peer review process for journal articles is typically more rigid compared to conference review processes, the keywords listed in journal articles are more suitable for representing e-Learning domain concepts. However, the time lag problem of journal articles (typically quite long duration between when the article was submitted to the journal and when it was published) would potentially result in less timely effect of the constructed concept maps. This problem can be compensated using conference papers for those new emerging concepts that have not yet appeared in journal articles. We selected two representative Social Sciences Citation Index (SSCI) journals and proceedings of one well-known conference in e-Learning domain as our data sources. The names of these publications are not mentioned because of ethical considerations. This research collected journal articles from 1999 to 2004 and conference articles from 2001 to 2004. The system was populated with the full texts of all articles from the web sites of these publications and it extracted various relevant pieces of information to store them into the article database. Those relevant pieces of information include publication title, year, volume, issue, article title, authors and keywords.

4.2. Concept item extraction

According to the first assumption in this research, a keyword is a research concept in e-Learning domain. However, the terms chosen as keywords by different authors are not always consistent. Authors may describe the same concepts using similar terms but not exactly the same terms. Therefore, these keywords are classified into appropriate groups during the following three steps. This process significantly reduces the total number of terms. A thesaurus is created to store these grouped terms in topic database. The highest frequency term is used to name each group.

4.2.1. Step 1. Keyword clearing

The keywords were obtained from the article database and the synonymous terms were identified, such as "web-based" and "web based"; "eLearning", "e-Learning" and "E Learning"; "co-operative" and "cooperative", and so on. After getting rid of the surplus symbols such as dash, hyphen and space, they were treated as the same keywords.

4.2.2. Step 2. Acronym mapping

An acronym is a specific form of an abbreviation created from the capitalized initial letters or parts of a series of words (Rowe, 2003). Acronyms are frequently used to represent a special term in academic articles. Because some acronyms may have dual meanings, authors must declare it when an acronym appears at the first time. An acronym is usually put in brackets following a specific term. For example, Fig. 4 shows an example of two acronyms (SLMS and NSYSU-CU). An acronym mapping table is therefore established to store these acronym mapping terms for each article.

4.2.3. Step 3. Suffix stripping

Terms with a common stem usually have similar meanings, for example, "learned", "learnt" and "learning". To avoid these similar terms being used as different keywords, suffix stripping algorithm (Porter, 1980) was adopted to remove various suffixes, such as -ed, -ing, -ion, and -ions. The accuracy of keywords classification improves if term groups such as these are conflated into a single term (Porter, 1980).

In our study, initially, there were total 2311 keywords in our content database. Through the three steps mentioned above, we finally obtained 1170 keyword groups as concept items, hence reducing the original keywords to nearly 50%.

4.3. Research keyword indexing

Principal component analysis (PCA) is a powerful multivariate data analysis method. Its main purpose is to summarize large datasets by removing any redundancy in the data for finding the key features (Jolliffe, 2002). In this research, PCA was used to find out the comprehensive index for indexing and choosing representative research keywords. There are three variables that can be used to evaluate the research topic importance, which are the "related counts", "appeared times" and "sustained periods".

We counted the number of other keywords that appeared in the same sentence with the research topic as "related counts". The "related counts" shows that a particular keyword was usually studied with other research keywords. "Appeared times" is the number of times a keyword appeared in an article. When "appeared times" of a keyword is higher than others, it typically shows that this keyword is more important than others in this article. The "sustained periods" is the period during which the keyword appeared from the first time to the last time. When the "sustained periods" of a keyword is longer than others, it typically shows that the researchers have active interest in that research topic.

> **Synchronous learning management systems (SLMS)** such as the **National Sun Yat-sen Cyber University (NSYSU-CU)** and K12 Digital School are now available.

Fig. 4. An example for acronym mapping (Chen et al., 2005).

Table 1
The result of principal component analysis

Periods	Related counts	Appeared times	Sustained periods	Eigenvalues	Explained variance (%)
1999	0.805	0.828	0.663	1.773	59.097
2000	0.836	0.826	0.614	1.758	58.589
2001	0.762	0.758	0.674	1.610	53.667
2002	0.784	0.772	0.647	1.629	54.308
2003	0.692	0.681	0.750	1.505	50.182
2004	0.669	0.694	0.736	1.471	49.032
1999–2000	0.862	0.841	0.604	1.815	60.494
2001–2002	0.810	0.773	0.638	1.660	55.323
2003–2004	0.709	0.670	0.724	1.476	49.207
1999–2002	0.872	0.838	0.568	1.784	59.482
2001–2004	0.799	0.749	0.634	1.602	53.399
1999–2004	0.858	0.819	0.592	1.758	58.600

The weight of each independent variable, eigenvalues and "explained variance" of first principal component for various periods of time are shown in Table 1. These independent variables would explain about 50% of the total variation in the predictor variables.

4.4. Calculation of "relation strength"

According to the third and fourth assumptions (mentioned in Section 3), a novel formula is proposed to calculate the "relation strength" between two research keywords as follows:

$$\mathrm{RS}(K_i, K_j) = \log_{10}\left(\frac{n_{ij}/\max(n)}{\mathrm{avg\_}d_{ij}^2/\max(\mathrm{avg\_}d^2)}\right), \quad i \neq j \tag{1}$$

where $\mathrm{RS}(K_i, K_j)$ is the degree of correlation between the keyword i and j. The variable n_{ij} is the number of times keywords i and j appeared in the same sentence. The concept of squared Euclidean distance (Johnson & Wichern, 2002) is used to calculate average distance which is represented as variable $\mathrm{avg\_}d_{ij}^2$. $\mathrm{avg\_}d_{ij}^2$ is the sum of the distance of two keywords divided by the number of times two keywords appeared in the same sentence. The equation is as follows:

$$\mathrm{avg\_}d_{ij}^2 = \frac{\sum_{m=1}^{n_{ij}} d_m^2}{n_{ij}}, \quad i \neq j \tag{2}$$

Because frequency and square of distance are in different scales, we divided them by their corresponding maximum value and multiplied by $\log_{10}$ to reduce the variance. If the "relation strength" of two keywords is higher than the others, this implies that their relationship is also stronger than the others. It is worth to note that the formula we proposed here takes only the extrinsic meaning into consideration; this opens an interesting research issue for improving relation strength calculation by considering both extrinsic and intrinsic meaning.

5. Results

Holsapple (2002) pointed out that concept maps can help users in understanding knowledge and in using knowledge effectively. E-Learning is a new and evolving domain, and constructing e-Learning domain concept maps would be very useful for a number of stakeholders. The designed system (ConceptMap, 2006) can automatically construct concept maps to present the relationships among concepts in e-Learning domain. Users can use two different types of queries to construct concept maps, holistic-based or center-based, as per their own requirements. Fig. 5 shows the holistic-based query interface for concept maps. Users can choose data sources, time period, number of nodes and keyword lengths to construct concept maps. Table 2 shows the top fifteen research keywords from 1999 to 2004. The weights shown in Table 2 are ‘‘comprehensive index values’’ which were calculated using research keyword indexing method. A keyword with a higher weight than the others implies that it is a more important keyword.

Fig. 6 shows the corresponding concept map of the top fifteen research keywords from the above query. The values in the figure are ‘‘relation strength’’. Q1 is the first quartile and Q3 is the third quartile of ‘‘relation strength’’. Some keywords that are presented in Table 2 do not appear in Fig. 6 because these topics do not have enough ‘‘relation strength’’ compared to others. Researchers can use this feature to explore the whole concept map of e-learning domain to facilitate their study.

Fig. 7 shows the central-based query interface of the system. Users can choose appropriate time period, keyword of interest and number of nodes to construct the concept map. Table 3 shows the top five research

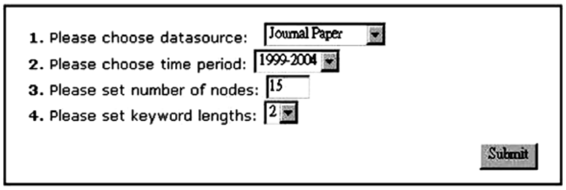

Fig. 5. The holistic-based query user interface of the system.

Table 2
The top 15 research keywords in e-Learning domain from 1999 to 2004

Rank	Keyword	Weight	Rank	Keyword	Weight
1	Information Technology (IT)	27238.50	9	Learning Technologies (LT)	2557.93
2	Intelligent Tutoring Systems (ITS)	6200.92	10	Higher Education	1649.58
3	World Wide Web (WWW)	4541.00	11	Computer Mediated Communications (CMC)	1625.32
4	Information and Communication Technologies (ICT)	3107.74	12	Distance Learning (DL)	1561.40
5	Web Based	3011.72	13	Learning Object Systems (LOS)	1428.60
6	On Line	2836.39	14	Problem Solving	1369.68
7	Collaborative Learning (CL)	2694.93	15	Learning Process	1107.98
8	Distance Education (DE)	2636.04			

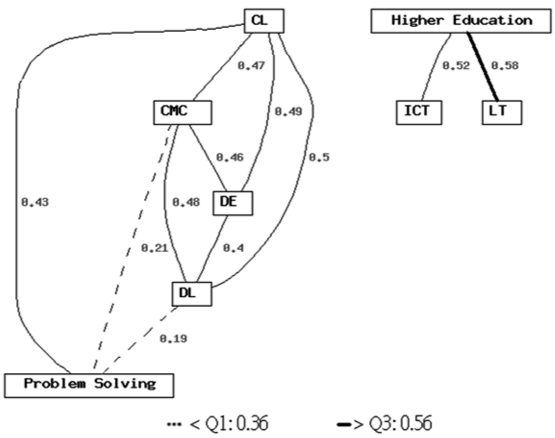

Fig. 6. The Concept map represented from the top 15 research keywords in e-Learning domain.

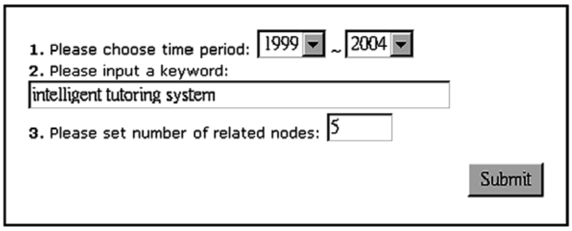

Fig. 7. The center-based query user interface of the system.

Table 3
Related concepts list with "intelligent tutoring system"

No	Keyword	Related Strength
1	Evaluation	0.60
2	Algebra	0.53
3	Get Bits	0.49
4	Intelligent Learning Environment	0.44
5	Language Learning	0.43

keywords which are strongly related to "intelligent tutoring system" from 1999 to 2004. Its corresponding concept map is shown in Fig. 8. Learners who are interested in learning intelligent tutoring system can then get a complete picture of important knowledge related to intelligent tutoring system.

Let's explain the idea of how instructors can use the constructed concept map to design adaptive learning materials for learners. Firstly, concept map can be used as a diagnostic tool to assess student's misconception by comparing the concept map constructed by the system with the concept map created by the student. Secondly, instructors can then provide the student with adaptive learning material, which was designed for remedying the specific misconception.

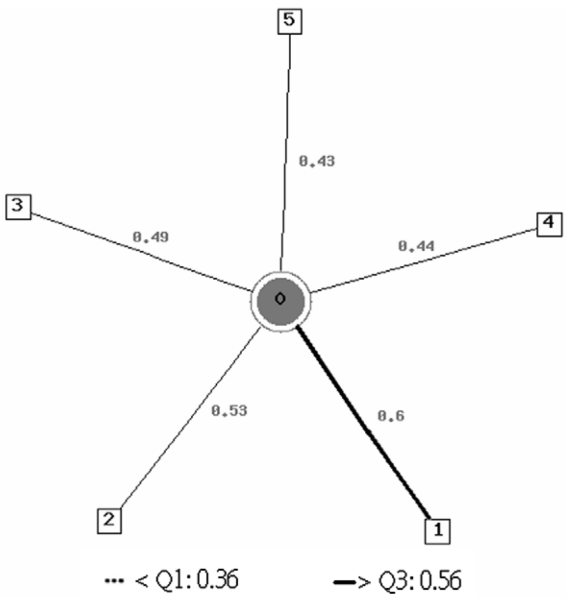

Fig. 8. Concept map of intelligent tutoring system.

Table 4
Result of concept maps assessment

Time periods	Assessment items		
	1999–2004	2003–2004	Overall
The ranking of concepts	7	7	8
The relationship among concepts	8	8	

6. Evaluation

Two top 30 concepts ranking tables with different periods, one for 1999–2004 and another for 2003–2004 (see Appendix A), and two associated concept maps (see Appendix B) have been constructed for the evaluation of the developed system. A 10-point Likert scale questionnaire (see Appendix C) was used in the assessment. The questions covered two different perspectives: the ranking of importance concepts and the relationship among concepts. Because there is no existing e-Learning domain concept map for doing a comparison with ours, therefore, expert opinions are used for the evaluation. Cooper and Schindler (2003) suggested that survey from experienced experts can be applied in an exploratory study. Two e-Learning domain experts were invited to fill out the questionnaire. The result is shown in Table 4. These experts agreed with the facts that the relationship among concepts and the overall fitness in the constructed concept map reached up to 80% of their professional knowledge and that the ranking of concepts was 70% compliant with their professional knowledge.

7. Conclusions

Along with the advances in technology, the chances of learner disorientation due to massive information availability are increasing. In order to assist the learners in learning effectively, it is necessary to provide an appropriate learning environment and suitable content. Learners can use concept maps, created by domain experts, to reduce information overload and learning disorientation. Instructors can also use concept maps to provide adaptive learning materials and design adaptive learning paths to guide learners (Noy & Hafner, 1997). However, construction of concept maps requires consensus among domain experts (Hsu & Hsieh, 2005). Therefore, it is a rather tough and time consuming task. The purpose of this study was to develop a mechanism using data mining technique to construct e-Learning domain concepts automatically.

Our approach used journal and conference articles as source data to analyze the relationships among concepts in e-Learning domain. It enables learners to see the whole structure of the domain in order to understand what is important in that domain. Additionally, the concept maps created by this approach display the "relation strength" of concepts to the learners when they learn a topic, and guide them what other topics they can learn which have high "relation strength" with the current topic.

In effect, the automatic mechanism of this study to effectively construct the concept maps depicting the domain knowledge circumvents the problems that were experienced in the past, when concept maps were prepared manually by the domain experts in a time consuming and costly process. Users can view the concept maps in holistic representation or centralized representation to understand the relationship among concepts. Domain experts have verified that these concept maps highly accord with their cognition on e-Learning domain knowledge.

Finally, we propose three directions which are worth for future study: (1) expanding the range of data to construct a more robust concept map for the e-Learning domain; (2) in addition to the three parameters that were used in principal component analysis, other parameters, such as taxonomy of keywords and timing can be added for representing the importance of the research keywords; and (3) improving the formula of "relation strength" by considering intrinsic meaning.

Acknowledgement

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Appendix A. The top 30 concepts in e-Learning domain used for evaluation

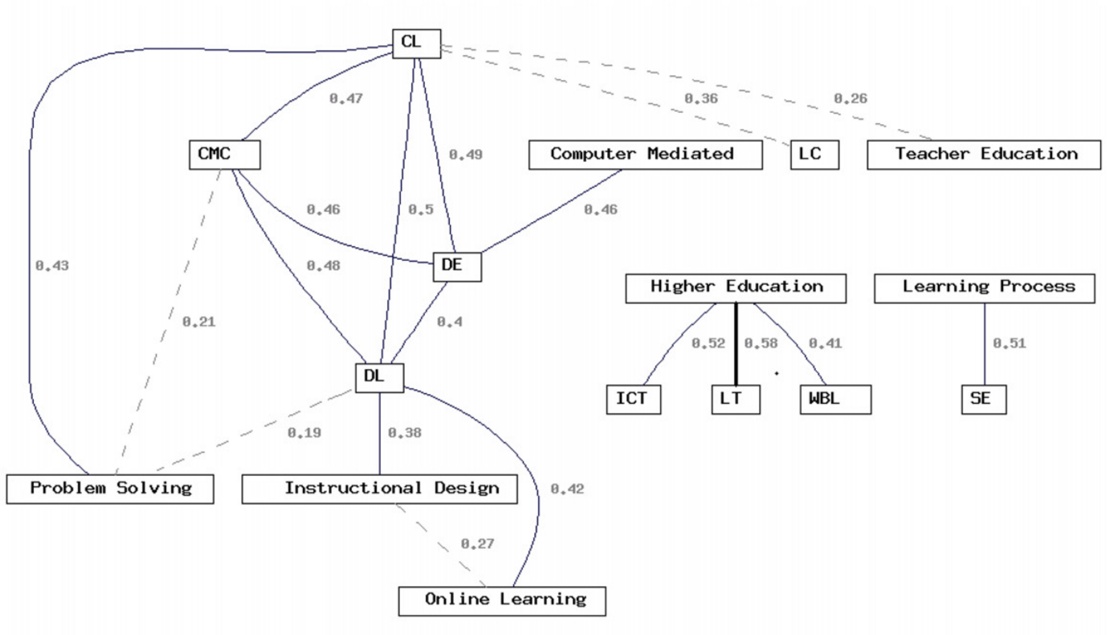
The top 30 concepts in e-Learning Domain from 1999 to 2004

1. Information Technology	16. Computer Mediated
2. Intelligent Tutoring Systems	17. Learning Community (LC)
3. World Wide Web	18. Online Learning
4. Information and Communication Technologies (ICT)	19. Computer Science
5. Web Based	20. Instructional Design
6. On Line	21. CD Rom
7. Collaborative Learning (CL)	22. Resource Description Framework
8. Distance Education (DE)	23. Virtual Learning Environments
9. Learning Technologies (LT)	24. Teacher Education
10. Higher Education	25. Learning Management System
11. Computer Mediated Communications (CMC)	26. Professional Development
12. Distance Learning (DL)	27. Self Efficacy (SE)
13. Learning Objects	28. Web Based Learning (WBL)
14. Problem Solving	29. Virtual Reality
15. Learning Process	30. User Interface

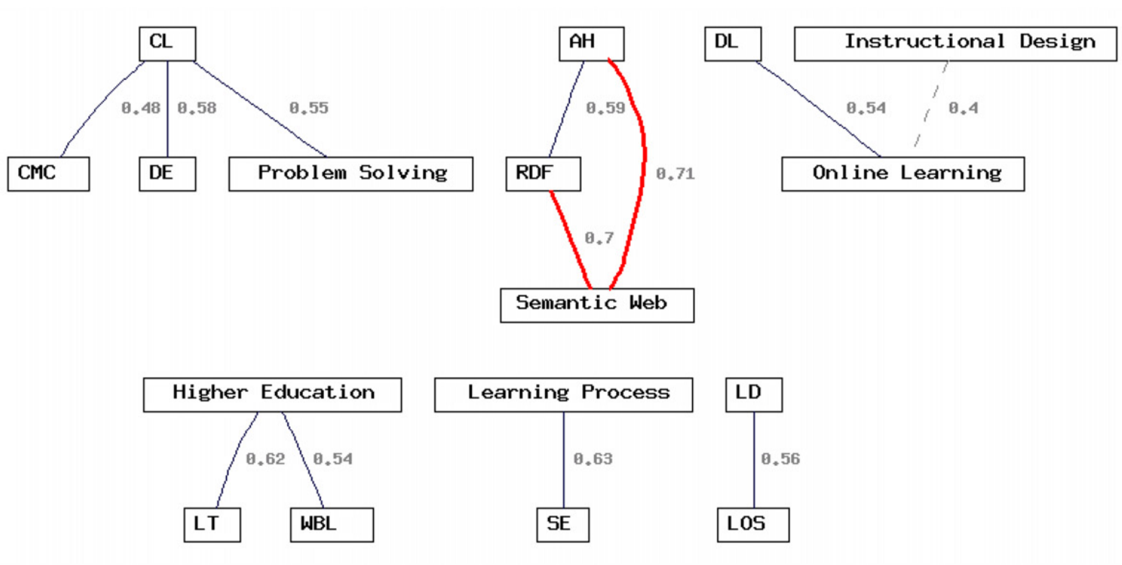
The top 30 concepts in e-Learning Domain from 2003 to 2004

1. Information Technology	16. Semantic Web
2. Intelligent Tutoring Systems	17. Adaptive Hypermedia (AH)
3. World Wide Web	18. Higher Education
4. Information and Communication Technologies	19. Learning Process
5. Collaborative Learning (CL)	20. On Line
6. Web Based	21. Computer Science
7. Learning Technologies (LT)	22. Learning Object Metadata
8. Learning Object Systems (LOS)	23. Self Efficacy (SE)
9. Distance Education (DE)	24. Knowledge Management
10. Resource Description Framework (RDF)	25. Instructional Design
11. Learning Management System	26. Web Based Learning (WBL)
12. Learning Community	27. Web Sites
13. Problem Solving	28. Information Systems
14. Online Learning	29. Learning Design (LD)
15. Distance Learning (DL)	30. Computer Mediated Communications (CMC)

Appendix B. The constructed concept maps



The constructed concept map using the top 30 concepts from 1999 to 2004



The constructed concept map using the top 30 concepts from 2003 to 2004

Appendix C. Questionnaire for concept maps evaluation

Given the constructed concept map from 1999 to 2004, please rank 1–10 for the following two questions?

1. The ranking in the top 30 concepts is according with your knowledge about e-Learning.
2. The relationship among concepts in the constructed concept map is according with your knowledge about e-Learning.

Given the constructed concept map from 2003 to 2004, please rank 1–10 for the following two questions?

3. The ranking in the top 30 concepts is according with your knowledge about e-Learning.
4. The relationship among concepts in the constructed concept map is according with your knowledge about e-Learning.

Overall:

5. Overall, I think these two concept maps are according with my professional knowledge about e-Learning.

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