An Educational Resources Brokerage System for Collaborative Sharing of Knowledge-Centric Content

Aparna Lalingkar*(aparna.l@iiitb.ac.in), Chandrashekhar Ramnathan*(rc@iiitb.ac.in), Srinivasan Ramani**(ramani@iiitb.ac.in)

*International Institute of Information Technology Bangalore

Abstract—Widespread connectivity of the internet over PCs and Laptops has increased the use of the World Wide Web for educational purposes. There are educational resources brokerage systems based on educational metadata standards, which search, locate and deliver educational resources to various institutions. In this paper, we justify the need of a brokerage system that can also provide collaborative sharing of educational resources, along with knowledge representation behind those educational resources among and within educational institutions. This system especially caters to two usage scenarios: (a) one where it will assist students in locating resources and (b) one where it will assist students in exploring the concepts behind a given educational resource. We have described the system's functional and process architecture. We have also provided some screenshots of the implemented system for both contributors and users. Finally, the system's educational implications are stated as summary of benefits.

Keywords-Collaborative Sharing, Topic Maps, Semantic Web, Knowledge-Representation, Brokerage System, Educational Resources

I. INTRODUCTION

Greater facility in using the computer and the Internet as compared to earlier generations makes the current generation a digital generation. The extensive availability of PCs, Laptops, Cell phones and broadband connectivity have vastly increased the role of the World Wide Web, usually called the Web, a major tool for sharing information and entertainment. The Web can also be used for sharing freely available educational resources among students, institutions and communities that are separated by large distances [1, 2, 3, 4, 5]. Brokerage systems for educational resources are systems which act as a mediator to search, locate and deliver educational resources [6].

There are educational resources brokerage systems such as GESTALT (Getting Educational Systems Talking Across Leading edge Technologies), EdNA ¹ (Educational Network Australia), ARIADNE ² (Alliance of Remote Instructional Authoring and Distribution Networks of Europe) and GEM³ (Gateway to Educational Materials) from institutions and organizations that are interested in the standardization of web-based education [6]. Here, we describe a system that can be used as a knowledge representation mechanism for capturing the domain concepts corresponding to the educational resources, and that will also enable easy sharing and locating of educational resources within and among educational institutions.

Initially, in section II, we offer discussion about the need for the system. In section III, the theoretical background is discussed, based on which the system is proposed, followed by justification of the technology that has been used to design and implement the system. In Section IV, detailed description of the system is provided. In section V, a short summary of benefits is stated, along with some future directions of the work.

II. THE NEED

While discussing development of University courses using Open Educational Resources (OERs), [7] described how even experts had difficulty finding Learning Objects (LOs) or OERs using facilities like advanced search through regular search engines. While comparing various Learning Object Repositories (LORs), [8] raised a few issues arising from different design decisions: use of peer-reviewing, availability of advanced search facility, user commitments in regard to Intellectual Property Rights over the content stored in the LOR, and decisions about the system and network architecture (for instance, peer-to-peer or client-server communication). Many researchers [9, 10, 11, 12, 13] have studied user behavior during Web searching, and found that various search engines work differently, and that it is difficult for students to find relevant information on the Web. A multidimensional conceptual framework for studying user interaction with the World Wide Web has been developed by [14], where some factors have been highlighted, such as situational factors, users’ cognitive ability, psychomotor factors, users’ affective state, design of user interface, content on the Web, and metadata of the resources. In the educational resources brokerage systems, standardized educational metadata is considered and quality of educational resources is taken care by authenticity of the contributors.

Curriki ⁴ is a web-based community of teachers, educators, learners, and committed educational experts who work together to create quality materials that can be useful for teachers as well as students. The contributors can be universities, private organizations, and individuals; besides, several professional organizations partner with Curriki, and share their resources. The content of Curriki includes textbooks, lesson plans, course outlines, tutorials, and various other types of resources. Although it has various search facilities as per keywords and subjects, users do not get any overview of the relations between various concepts.

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¹ http://www.edna.edu.au/edna/go
³ http://www.learningcommons.org/educators/library/gem.php
⁴ http://www.curriki.org/xwiki/bin/view/Main/WebHome
Hyperphysics is a website developed by the Department of Physics and Astronomy of Georgia State University especially for Physics and Mathematics content. The content here is mainly organized through concept maps, and detailed information about a particular concept is provided at the terminal node. Concept maps are visual depictions of relationships between various concepts. They are graphical tools for the structuring and representation of knowledge. The advantage of this kind of content organization is that students get to see and explore various concepts in Physics and Mathematics, and get to know relations between various concepts that are advantageous for learning (Discussed in greater detail in section III). Because of its comprehensive coverage of the content knowledge of almost the whole of Physics, and its creative use of multimedia resources, Hyperphysics was awarded the MERLOT Classics award in 2005. Despite these positive features of Hyperphysics, it has the following limitations. Firstly, content and the system are bound together with no provision for personalization. Secondly, though the content is free, there is no provision for collaboration by other institutes.

Our hypothesis is: a system that can provide knowledge representation of concepts that are included in educational resources, and that can be built and maintained in a collaborative manner by educational institutions, will help in good management and access of educational resources. It will also help to reveal the conceptual semantic connections in the resources by offering knowledge representation of resources. Current systems either have a collaborative component or some part of knowledge representation, but do not support both at a time. We have conceived and implemented a system that can support both. Moreover, if students who have access to resources can also see the knowledge structure around that resource, then they can explore more conceptual connections. To achieve this we have used the notion of content metadata based on Topic map technology. Detailed discussion about the term metadata and the need of content metadata can be found in [15].

The system essentially caters to two usage scenarios: (a) one where it will assist students in locating resources and (b) one where it will assist students in exploring the concepts behind a given educational resource. In the next section we describe the theoretical base for designing the system.

III. THEORETICAL BACKGROUND

A. Information and Knowledge

It is appropriate to discuss the distinction between Information and Knowledge while talking about information seeking for the purpose of knowledge representation. Stenmark [16] has done a theoretical study of the relationship between Information and Knowledge. Some of the definitions distinguish information and knowledge as follows. Information is nothing but facts organized to describe a situation, whereas knowledge is trusts, beliefs, perspectives, judgments, know-how, and methodologies [17]. Information is the text that answers the questions who, when, what or where, while knowledge is the text that answers the questions why and how [18]. One can say that knowledge is some sort of concrete effect gained from interaction of information with a person’s previous knowledge and/or personal ability to process the information. Knowledge can be considered an effect of analysis of information. The importance of the role of information in knowledge construction is quite evident. Providing accurate and appropriate information is the key to building knowledge blocks. Knowledge is related to understanding of the links between different pieces of information. Niggemann [19] has mentioned that humans understand information by forming a mental model that captures only the gist of the information, and which can be considered a key for building knowledge which is an important notion for knowledge construction through conceptual connections.

B. Knowledge Representation

Many researchers [20, 21, 22] have discussed cognitive model/cognitive theory of information retrieval to study user interaction with the Web. Ingwersen [20] mentions two basic concepts of the cognitive model: Short Term Memory (STM) and Long Term Memory (LTM). STM stores a small amount of memory for a short time, while LTM operates on the basis of semantic and episodic memory, which is responsible for filtering and processing the data received [20]. Semantic memory is the class of information characterized by the definitions of concepts that people have within their memory, and episodic memory is the information about particular events that have been experienced by the individual [23]. Hence, LTM holds the representation of concepts, concept relations, and categories, which are in turn used in perception and information processing. Information in which concepts are connected with a network of propositions provides mental objects which are stored in the individual’s memories [24, 25]. Novak & Canas [26] have stated, “Propositions are statements about some object or event in the universe, either naturally occurring or constructed and contain two or more concepts connected using linking words or phrases to form a meaningful statement” (p. 1). The cognitive aspect is concerned with mapping content texts onto the user’s knowledge structures [27].

For subjects such as Mathematics and Science, basic concepts are very important for understanding the applications. Many of the science textbooks ignore the basic concepts and relations among them by focusing instead on technical terms and trivial details [28]. This leads to rote learning and fails to help students to develop a systematic and integrated understanding of complex phenomena [29]. While describing a knowledge model for mathematics teachers, Ernest [30] has mentioned various components of knowledge that are important for developing mathematical understanding and one of them is: subject knowledge i.e. structure of the subject, which is expressed as the relationship of various concepts to each other. Collins & Ferguson [31] have supported the idea of use of conceptual representations providing organizing frameworks across domains, and is important for knowledge construction. Researchers have [29, 32] supported the idea of the use of non-linear hypertext systems and multiple linkages among items of content, i.e. conceptual hyperlinks and multiple links among concepts.

\[\text{http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html}\]
facilitating the student’s learning. While writing about the evaluation of learning using the constructivist paradigm, Holmes & Leitzel [33] have argued that concept mapping is one of the techniques for knowledge construction, as it provides a conceptual schema of patterns and associations by relating them to a given concept. While studying the visual data mining of graph-based data, Nigemmann [19] supported connection between human comprehension and structure recognition. While discussing meaningful learning, Novak [34] mentioned, “the construction and reconstruction of meanings by learners requires that they actively seek to integrate new knowledge with knowledge already in their cognitive structure”.

C. Constructivist Learning

Cognitive and social constructivist psychologists, such as Jerome Bruner and Vygotsky, always believed that learning is a process of knowledge construction directed by experiences [27, 35]. The major concept of Vygotsky’s social constructivist theory is “zone of proximal or potential development” (ZPD) [36]. Verenikina [36] also mentions ZPD as the distance between what a person can do with and without help, i.e. it is the difference between the actual level of development determined by independent problem solving, and the problem solving under guidance or in collaboration. When users seek information and learn, they use their previous knowledge and experiences in order to process the new information, which takes constructivism into the scenario of information retrieval [35]. Like teachers, technology does not teach students; rather, students only learn when they construct knowledge, think, and learn through experience of using the technology. Technology is just a tool for constructing knowledge. Neither teachers nor technology convey understanding to students; rather, students construct or develop understanding with the help of these two. Our hypothesis is that the use of knowledge representation will help to develop the ZPD for information seekers and learners.

D. The Technologies

David Ausubel [37] has developed a theory of meaningful learning through advance organizers, which claims to be helpful in orienting students within the information which they will be learning. Meaningful learning occurs when new knowledge gets assimilated to old knowledge. The hypothesis in the use of advance organizers is: hierarchically organized conceptual structure provides appropriate and relevant subsumption of knowledge which enhances learning [37]. The notion of concept mapping has been drawn from the theory of meaningful learning. Information processing theory has connections with semantic memory, which includes the storage of ideas in the form of a connected network. Hence, it will empower information seekers and learners if the educational resources get linked with the knowledge representation of the resource. There are several criticisms of Ausubel’s theory regarding the creation of advance organizers, chiefly lack of systematic process and objectivity [38]. Concept maps are also criticized for similar reasons. Hence, there is a need for systematic schema or the use of ontology for the creation of such knowledge structures. Therefore, we decided to explore topic map technology in order to provide an ontological base for the design of the desired system.

The technology of Topic Maps is covered by a number of papers [39, 40, 41, 42, 43, 44]. The basic concept model of Topic Map is TAO, where T stands for Topics, A for Associations and O for Occurrences [39]. An interesting facility provided by Topic Map is that we can group the Topics under Topic Types, Associations under Association Types, and Occurrences under Occurrence Types. Also, there are Role Types, which are used in the Topic Map to represent the roles played by different topics in the association. More discussion and information about features of topic maps can be found in [15]. Several researchers [45, 46, 47] have pointed out the usefulness of Topic Map technology for representation of Knowledge Structures. Topic Maps support the representation of information as a semantic network (i.e. Topic-Association-Topic2) [48, 47]. Many researchers [49, 50] have used concept maps as tools for knowledge representation and for improving learners’ understanding of various topics at various educational levels. Learners need graphical representation of concepts in order to understand easily the logical connections between various concepts, and for easy navigation among a network of topics. The use of concept maps alone has its limitations: for instance, concepts in concept maps do not have unique Subject Identifiers. Topic Maps have an ontological base at the back end, which can be used for machine processing and inference. Topic Maps offer both navigation facilities and a view giving all the ontological details. Along with easy navigation, the technology provides for a scoping and filtering facility, which concept maps do not have. Finally, Topic Maps can also be written as RDF (Resource Description Framework), and have an XML (Extensible Markup Language) Topic Map (XTM schema) structure, which can be machine readable and processable. Concept maps cannot be used for searching or processing by machine. Hence, it is useful to use topic map technology for the system which is described in the next section. This system can also be implemented by using semantic web technology and RDF. Some of the benefits of use of ontology are collaborative creation of the knowledge structure and re-usability of it. We visualized resources as being describable in terms of a set of content metadata triples. The same triples can be used for knowledge representation.

IV. THE SYSTEM

A. Functional Architecture and Structure

The system functional architecture (Please see Fig. 1 on next page) includes a web-based Front End and XML/SQL Back End. The following sub-sections describe the front-and backend components in detail.

1) Front-end Components

Front end includes User Registration and Login module, system User Interface (UI), Admin/Teacher User Interface (Admin/Teacher UI) and Content Metadata Upload Module. Through the User Registration and Login module, users can access the system UI, and if the User is Admin/Teacher, then the Login module gives access to Admin/Teacher UI. Admin/Teacher UI also gives access to system UI. Admin/Teacher can upload the Content
Metadata for resources and upload resources for existing topics-associations through the Content Metadata Upload module.

2) **Back end Components**

   The back end includes Topic Map Ontology, Personalization Module, Post-processing Module, User Models for storing User information and Content Metadata Triple Store database. Topic map describing basic hierarchical relationships is considered as a topic map ontology. Usually for topic map applications, people use a separate Published Subject Identifiers Server (PSI Server) on the Web, which provides global unique identification to each topic.

   ![System's Functional Architecture](image1.png)

   Here, we also planned to use our own PSI server. For scalability one can use the unique subject identifiers created and published in OKKAM [51], a large scale integrating project funded by the European Union (EU) for generation of universally unique entity identifiers. OKKAM has various APIs for using the OKKAMized entities, for interacting with various Web services containing those entities, or linking those entities to the linked data for further use [52]. This project is also closely working with W3C standards in order to improve recall of the Semantic Web applications [52]. The uniqueness of the topic can be checked by using the OKKAM client APIs through SOAP binding in the application. These can serve users all over the Internet, including creators of educational resources, to work within relevant standards while creating Content Metadata for their resources. When users register, that information is stored in the User Models database, which is used by the personalization module. Content Metadata upload module from the front end is connected to Content Metadata Triple Store database, which is used by Post-processing module. Also, Content Metadata Upload is used in the topic map entities existing in the Topic Map Ontology. Admin/Teacher can also edit the Topic Map Ontology. Topic Map Ontology can also provide topic map data to the system UI.

   ![System's Process Architecture](image2.png)

   **B. Process Architecture**

   For describing the process architecture it is assumed that users have already registered and their profile information is stored in the database. The flow-chart diagram given in Fig. 2 is quite self explanatory. The usual flowchart convention has been followed for showing different parts and processes. The sky blue colored elements are part of the front end, and tan colored elements are part of the back end. All the database stores are also part of the back end. After User Login and verification of the password, the system will identify the type of user based on the profile information stored in the database. If the user is Admin/Teacher, then it will take the user to Admin/Teacher UI; otherwise, the user will be given access to the system UI. Admin/Teacher can also access the system UI, but in addition they can edit the topic map ontology and upload the Content Metadata Triples with resources to the Content Metadata Triple Store database by using the Content Metadata Upload module (Pl. see Fig. 3-5). Figure 3 shows first part of the content metadata upload module where Teacher or Admin can upload a new resource URL in the system by selecting various scopes, including type of resource, subject, and knowledge level to which the resource will be appropriate.
Figure 3. New Resource Upload

Figures 4 shows the second part of the module, where Teacher can associate multiple resources to one triple. Figure 5 shows the third part of the module, where Teacher can associate multiple triples to one resource.

For editing or creating a topic map by teachers, at present we have attached Omnigator [53] Topic Map editor (developed by Ontopia Knowledge suit). However, it has the following limitations for the creation of topic maps from an educational perspective. Firstly, it is designed for creating an encyclopedia of knowledge, and thus has a complex structure and does not support the connection of internal and external resources to the topic types. Secondly, it does not allow editors to add scopes; however, editors who create XTM files can add scopes in the XTM file. Thirdly, while creating each topic editors have to put its PSI URI. Finally, due to its complex nature, learning to create and edit topic maps with Omnigator is a bit difficult for non-technical background people, and needs a fair amount of training. Hence, we plan to write a simple topic map editor based on XTM schema, which can be integrated in the system and used by the system users. In this system, complexities such as creation of PSIs will be automated by the system in order to disambiguate the URI.

In the system UI module, when the user needs to locate resources, she can type a term in the dialogue box of the system accessible from the browser. A term means either a word or a phrase. If the user types a term that does not exist in the system, then the system will provide possible terms that the user might want to use by using word sense and the topic map ontology stored at the back end. Once the user selects the term, then the system presents a drop-down menu indicating the different scopes in which the term occurs in the Topic Map (if the term has more than one scope), and the user can then choose one scope as per the need. The filtering facility in Topic Maps will be used here, and this will remove the possibility of the content being related to ambiguous terms. Once the user selects the scope, the system will offer a choice for viewing the topic map in either its hierarchical index view or its graphical view. Once the user selects one of the displays, she will have to confirm the selection by clicking on the submit button. Once the submit button is clicked, the system will show the user either a graphical display or an index display based on the selection. There, the user can view the knowledge structure around that term, and can navigate to move on. A sample screen showing the graphical view rendered is shown in Figure 6.

We have explained the process by considering the graphical view display as an example, but the same can be applied to the index view display. The graphical display will show a view with the term (topic) as centre and displaying connected arcs to the other topics that are associated with it. This display map will be derived from the Topic Map ontology by filtering it to suit the profile of that particular user. The user can see the name of the association displayed on the connecting arc between two topics by putting the cursor on it. The user can navigate through the displayed map by clicking on the next focus of attention and following the connector arc, thereby getting a revised display centered on that topic along with topics associated with it. After the first selection of topic-association-topic triple, it will be visible below the screen (as shown in Fig. 6).
Meanwhile, it will also create an individual triple query for this triple, and wait for the learner’s confirmation. During the exploration of knowledge, the system will ask the user to confirm the triple selection in order to generate a query. By individual triple query we mean a query generated for the selected one triple which includes selected type of resource. For example, if a user selects association “instance” between two topics, say “Event” and “Getting Score 1” [i.e. instance (Event, Getting Score 1)], then this will be one individual triple query. One can see that a user gets an idea that “getting Score”, “Getting Score 2”, “Getting Head”, “Getting Tail” are the instances i.e. examples of “Event” which is “containedIn” “Experimental Probability”. Further example of navigation i.e. after having topic “Getting Head” as central topic the further knowledge representation can be as follows: the association between the two topics “Tossing a Coin” and “Getting Head” can be “hasEvent” and can be expressed in terms of triple as [hasEvent (Tossing a Coin, Getting Head)]. In this example “Tossing a Coin”, again can be understood as associated to the topic “Outcome” by the association “instanceOf”. The user can continue the navigation while the system keeps track of the triples of interest to the student. In this way user can get a knowledge structure of concepts in Probability. After two or three navigations, the system will ask the user to look at the selected set of triples, and confirm the selection of triples in order to trigger the queries. The triggering of queries is done as part of post-processing, described further.

1) Post-processing: Once the user confirms the selection of triples collected during the course of navigation, these will be sent to the Content Metadata Triple Store database, which is connected to the post-processing module. Each triple will be searched separately in the database. Each query will get a set of quadruples that are comprised of the three elements of the triple and the set of links to resources (URLs) that are fetched for each triple, i.e. the set of URLs that are fetched by an individual triple query. If S1 is a set of quadruples fetched for the first triple, and S2 & S3 are sets of quadruples fetched for the second and third triples respectively, then the post processing module will process these URLs by following a simple algorithm to S1, S2 & S3 derived from set theory. The algorithm is as follows:

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\text{(Set of processed URLs)} = (S1 \cap S2 \cap S3) \cup (S1 \cap S2) \cup (S2 \cap S3) \cup (S3 \cap S1)
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Post-processing is further enhanced by using personalization, which prunes the list of URLs by including only those relevant to the user.

2) Personalization: When the user logs in, the scope for the user (i.e secondary level, higher-secondary level, or university level) will be noted by the system based on the user profile information stored in the User model database. The topic map only with respect to that scope will be shown to the user. Detailed discussion of the term personalization can be found in [54]. This is one level of personalization. When the user is allowed to select the type of resource, there is another level of personalization. When the relevant URLs will be shown to a user for the first time, the user will be asked to rate the URLs as per the usefulness of the resource. This average rating of the URLs will be used for displaying that resource in the descending order of the resources. If a user has accessed the system three or four times, and has preferentially selected, say, videos as the type of resource, then the system will learn from that pattern, and will provide videos as the preference for subsequent selections.

C. Comparison with existing systems

The major difference between our system and the existing systems like GESTALT and ARIADNE is this: these systems are based on metadata standards such as IEEE Learning Object Metadata (IEELOM) and Dublin Core Metadata standard; while our system tries to capture the semantics in terms of content metadata that is based on semantic triples. These metadata standards cannot provide the semantic connections between the concepts included in the content because they are of the nature attribute and value. Moreover, to create these triples we have used standards like Topic Maps XTM schema defined by ISO standards, and it can be created by using RDF, which is developed by W3C standards. Existing brokerage systems only search, locate, and deliver the educational resources; whereas our system is for sharing the educational resources, providing users with the knowledge structure behind the resources. Our system reflects an effort to facilitate collaborative sharing of educational resources, and to provide a bird’s eye view of the conceptual structure underlying the shared educational resources. Educational implications are stated in the summary of benefits below.

V. SUMMARY OF BENEFITS

One key benefit of combining knowledge and content using topic maps is that the same system can be used for accessing both knowledge-centric content and content-centric knowledge. For example, if someone is trying to gain knowledge by navigating the concepts via topic maps, they can access additional content relevant to the topic of their interest. This is possible because in the system we can associate a link to the content for every topic-association-topic triple. Similarly, if someone is just going through the content, an additional frontend can easily be added to the system for leading them from the resource link of the content into the associated topic map using the same
VI. CONCLUSION

We have described a topic map based brokerage system that will provide assistance in locating shared educational resources among and within educational institutions. This system will also provide assistance in understanding the knowledge representation of the concepts behind the resources, and the semantic connections among those concepts. The system can be evaluated by educational institutions. The teachers/faculty members can be the contributors to the system, and students of those institutions can be considered as users (consumers). These institutions can use the system for a period of one year or more. After this period, a user study can be conducted for the contributors as well as the users. Both contributors and users can be interviewed regarding the usefulness of the system for locating shared educational resources and for knowing the knowledge representation behind the resources.

REFERENCES


