Designing Constructivist Learning Environments using a Concept Browser

Minakshi Sharma, Sonal Chawla

Abstract - Theory of constructivism is considered as the best way to promote self guided learning and involve the learner in his process of learning. Constructivist learning environments(CLE) are the models which are based on theory of constructivism. Concept maps can be effective tools in creating CLEs specially in the subject domains where the content is in structured form. Concept browsers present a tool that can be used to create a network of concept maps in such a manner that different concept maps are interlinked on the basis of common concepts or as generalization to specific relationships. These interrelated concept maps can be browsed simply like web and the concept nodes contain links to various content resources. Further, a CLE based on concept map networks created using concept browser may be extended into semantic web by incorporating RDF or ontologies at the back end for storing or retrieving knowledge repositories. The purpose of this paper is to 1) to study constructivism and its principles 2) constructivist learning environments, components and their design principles 3) study conceptual browsing and components of context maps and 4) how concept maps can be helpful in creation of constructivist learning environments.

Key Words - Concept browser, Constructivist learning environments, Conversation and collaboration tools, Information gathering tools, Knowledge construction tools, Learning systems, Pedagogical, Social, Technical, Theory of constructivism

I. INTRODUCTION

In today's knowledge-intensive era, knowledge enhancement and life-long learning have become an essential part of individual's learning needs but educational policies and pedagogical models on which these policies are based are not revised very often. Hence, there is an increasing demand for new approaches to create new learning perspectives that are learner friendly and support life-long learning. Constructivism, a sub-area of cognitive/rationalist learning is one such theory that defines learning as a process where knowledge is accumulated by an active process of construction and not by just passive adaptation of information. Researchers agree that constructivism learning theory, which focuses on knowledge construction based on learner's previous experience, is a good fit for learning, specially e-learning because it ensures learning among learners[12][16][17][23]. Constructivist learning environments (CLEs) are often defined as technology based spaces in which learners explore, experiment, construct, converse and reflect on what they are doing so that they learn from their experiences[18]. These are more learner-centered, support collaborative learning, engage learners in their own knowledge building and are reflective [18][37]. However, learning environments have to be properly designed in order to reap these benefits.

Conceptual browsing means presenting the user with a set of concepts where he/she can browse knowledge base, one context at a time. He may also surf different contexts in which same concept can appear. These concepts and their inter - relations in a particular context are provided in the form of concept maps. Concept browsers provide interface to the learners to browse or surf these maps just as web from where learners can begin to build their own knowledge structures depending upon individual understanding and interests using either already created maps or the new ones. Content associated with a particular concept is totally separated from it leading to multiple representations and reusability.

Concept browsers based in semantic web can be used as effective tools in creating sound CLEs Being rooted in semantic web allows them to work with other knowledge gathering tools in order to provide a huge repository of knowledge structures that is available on web.

II. REVIEW OF LITERATURE

The constructivist view of learning can be traced to Piaget [33] who believed that learning is not transmitted passively, but attained through well-defined stages by active participation of a learner. [44] too presented similar ideas but focused more on the importance of socio-cultural activities in learning in addition to introducing flexible stages of development. The importance of context and authenticity in learning has been emphasized by [5] who defined authentic activity as the ordinary practices of cultures. [24] further extended this view and stated that learning occurs through centripetal participation in the learning curriculum of the ambient community. [13] pointed out that learning environments typically provide authentic contexts and activities, access to expert performances, and support multiple roles and perspectives. In addition, such environments also support collaborative construction of knowledge and promote reflection and articulation. Finally, such environments may include coaching and scaffolding by the teacher and provide for authentic assessment of learning within tasks. For the purpose of this paper, constructivist authentic learning environments are defined as those learning environments whose design is consistent with the principles of the more recent constructivist theories on how people learn and the components of learning systems identified by [22].

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III. THEORY OF CONSTRUCTIVISM

Theory of constructivism defines teaching and learning as a process where learners are actively involved in construction of their own knowledge rather than being passive receivers of information. It encourages constructive and reflective thinking that intentionally creates collaboration and a conversational atmosphere[4]. Learning activities based on constructivist theory allow individuals to form their own representations of knowledge, uncover inconsistencies between current knowledge representation and their own experiences and allow learning to occur within a social context, where interaction between learners, peers and other members of the learning community takes place [9]. So, the learners have to construct their own knowledge both individually as well as in collaboration with others[33].

Constructivist approach also emphasizes on the need for change in the role of teachers from that of knowledge transmitters to knowledge facilitators. As guides, the teachers should incorporate mediation, modeling, and coaching as well as strive to provide rich environments and experiences for collaborative learning [36]. Teachers as facilitators can create scaffolds or support for understanding new information. These scaffolds may contain a direction or content related help or simply emphasize on important concepts of an area. Further, complex topics can be organized in a structured fashion by the facilitator.

Cognitive constructivists advocate that learning environments should be designed in such a manner that learners are able to independently explore the knowledge repositories in order to get content, related concepts and learn how to learn. Also, these environments should be able to provide multiple paths or multiple representations of the reality to the learners which they can explore. Thus, in constructivist learning environment, the responsibility of learning is on the learners themselves hence encouraging learner-centered approach.

IV. DESIGNING CLEs

Every learning system comprises of three main components namely pedagogical, social and technological[22]. This section discusses these three components as well as the principles of constructivism which should be followed to create an effective CLE.

A. Pedagogical

Pedagogical component focuses on educational purposes of a learning environment. The pedagogical design of a CLE must enable learners to construct his/her own knowledge to achieve learning objectives [19][26]. Moreover, it should also provide a support for lifelong learning. Knowledge construction is a process of internalization and reconstruction of external reality, in which individual interaction with the content plays a vital role [31]. Hence, there is need for teachers to develop a new pedagogical model that creates a stronger link between theory and practice [21].

So, the pedagogical design of a CLE should have following characteristics-

(i) It should support and satisfy learners' needs and learning objectives;

(ii) System should be flexible enough to let the learner choose the learning content and objectives;

(iii) It should involve learning resources and activities that support active learning [6][22].

B. Social

The social design of a CLE aims to provide and maintain a friendly and interactive environment in which learners feel safe and comfortable and are able to interact with one another [2][45]

According to social constructivists, knowledge is the outcome of collaborative construction in a social-cultural context where other people can also play a role in individual's learning process. Learning is a social process in which learners collaboratively construct knowledge through interactive processes of information sharing, negotiation and modification [11]. In order to promote social knowledge construction, a learning environment must provide tools for sharing of knowledge, interaction, reusability of learning objects and interoperability with other learning environments. Moderation by the facilitators also plays an important role in successful social knowledge construction. Effective moderation includes setting up grounds norms, encouraging participation, monitoring progress and providing information [15][35].

C. Technological

Whereas pedagogy determines the tools to be used by instructors, technology is a tool that supports learning. CLE based elearning applications can be designed either as web-based or as standalone applications. These applications involve computers and in most cases internet as technological element. Availability of and easy access to the learning resources is an initial requirement, to support anytime, anywhere learning [35]. Although technology cannot be guaranteed as a solution for solving all educational problems, it is 'certainly a useful tool that enables us to link various learning communities together in new and different ways' [42]. It is important for teachers to establish effective and appropriate ways to use these tools without undermining sound pedagogical practices [1]. Authentic use of technology transforms teacher's roles, learner's roles, conceptualization of knowledge and the process of teaching and learning, and assessment [34]. Whereas learners begin to conceptualize knowledge differently , teachers also begin to put more emphasis on the processes which enhance meaningful learning in the students rather than rote learning. hence, both the teachers as well as students tend to grow in their own sphere and actual knowledge development takes place.

There is a need to create a strong balance between all the three components of learning theories,i.e., pedagogy , technology and social component. A model that is a blend of all the three enables learners and teachers to make the most of the learning materials available around the world.

D. Principles of Constructivism

Following is the set of principles that may be used to design constructivist learning environments and includes almost all the principles identified by various researchers in [3][7][8][10][14][19][25][32][38][39][40][41][42][46][47] -

1. Constructivism assumes learning to be a process of active construction and not passive assimilation of knowledge, so CLE models should be learner centric where learners are assumed to discover things themselves rather than being instructed to do so.
2. The process of constructing knowledge requires that every learning process should include a search for similarities between what is already known and the new. Thus, learner should be presented with multiple representations of reality where he can choose any path he desires to.
3. Constructivist learning requires learners to use their skills in constructing knowledge for solving real-world problems. Rather than applying knowledge to solve abstract problems, knowledge must be constructed in real contexts.
4. In constructivist learning environments, teachers serve only as guides and facilitators of learning and not as transmitters of knowledge. Teachers must learn how to understand learners so that they can interpret their responses better and guide them more effectively in order to facilitate learning.
5. Constructivist learning will be appropriately implemented only if learners are evaluated constructively. Such evaluation requires methods that are embedded in the learning process and approaches that take into consideration the learners' individual orientations.
6. Constructivist learning environments support "collaborative construction of knowledge through social negotiation, not competition among learners for recognition"[19]. Hence, learning is supported by the knowledge that also comes through interaction of learners with other people, e.g., instructors, fellow learners.
7. Constructivist learning environments should enable context and content independent knowledge construction so that there are multiple paths available to the learners to choose from, depending upon individual's inclination.

Fig.1 represents the components and principles that are pillars of sound and effective constructivist learning environment.

V. CONCEPTUAL BROWSING

Conceptual browsing means surfing through the web of concept maps just like normal web. These concept maps consist of various concepts linked by propositions representing relationship between two concepts appearing in a specific context. Fig. 2 shows one such concept map representing different data types in a programming language. Various concept maps can also be linked to each other using conceptual neighbourhoods, which is a set of concept maps containing a particular concept. A concept provides total separation of the context from its content. So, a concept browser tries to present conceptual relationships between a set of concepts in the form of concept maps and allows surfer to separately engage in content describing these concepts [27].

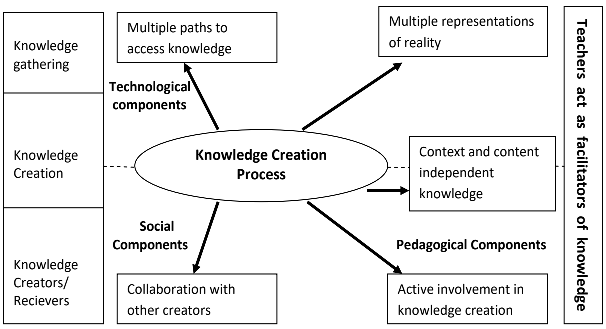

Fig. 1: Constructivist Learning Design Principles

A. Principles of Conceptual Browsing –

In order to design effective concept maps, [30] suggested following principles -

1. In order to increase reusability of the content, it should be kept separately from the content.
2. For every new context, there should be a separate map which contains related concepts joined together with the help of relationships between them called concept relations. A concept map representing concepts related to a particular context is named as a context map. Figure 2 shows one such context map showing relationships between different concepts in a particular context.
3. From every concept and concept-relation in a concept map, one should be able to move to another map through neighbourhood of that particular concept or concept-relation.
4. Every concept or concept relation should have sufficient number of resources linked to them which contain content. User should also be able to add content components if he desires to.
5. Each resource (concept, concept-relation, context or content component) should be labeled using of a standardized metadata schemes and all resources should have URIs.
6. Metadata based filtering of the content should be allowed through context-dependent aspect-filters so that content can be presented according to the context.
7. Transformation of the content, which is also a context-map, into a context or contextualization should be made feasible.
8. Lateral thinking should be supported using a concept bookmaker, which allows both concepts and contexts to be interactively constructed from content according to different content-gathering principles.

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B. Components of Conceptual Browsing

In order to implement the given principles of conceptual browsing, three main components are important. These are concepts, concept maps and concept browser. All of these are briefly discussed below.

Concepts - Concepts are the resources used to describe any object. As concepts are designed keeping in view their reusability, they should have following characteristics. A concept should be represented in such a manner that it can be used on different platforms and in different context maps. Only generic visual attributes should be provided to the applications that tell it how to present a particular concept so that applications can create their own concepts. Three main attributes associated with concepts are aspect and association and content.

Aspect - An aspect of a concept is a way to provide different representations of a concept. In an example about data types of a variable in a programming language, shown in fig. 2, different aspects can be -

Operational: How to use the data types in a program?

Historical: What data types are available in different programming languages? or

Conceptual: What are data types actually?

Each aspect can have more than one presentations that describe it in some detail. Presentations of the aspects contain content which is kept separate and hence is independent of the aspect. E.g. operational aspect of the above given concept can either be visual showing memory representations of different data types or in the form of textual explanation.

Associations

Associations are the relations between concepts and are also known as propositions. These are used to describe how concepts are related to each other. In fig. 2, concepts constants and variables have an association of “have” with the concept “data types”. Similarly, concepts “Character”, “Integer”, “Float” and “Double” have the association of “is_a” with “Data Types”. Further, concept “15” has an association of “is_instance_of” with integers. Associations may also have different aspects and should be distribuatble. An association should be able to connect concepts created by different users and from different maps. Associations may be of different types and some of the examples can be -

Generalization - where one of the concept describes a larger set of objects than the other, e.g. numbers is a generalization of integers;

Aggregation - that connects two concepts where one is a part of the other as integers variables are part of topic data types in programming languages or instance of integer values.

Content - Different presentations of a concept taken together form the content of the concept. Content may be in the form of HTML pages, images, movies, simulations or simply pdf files etc or it may involve running an application on computer.

Concept Map

A concept-map is a collection of concepts and their associations and defines the layout of for those concepts and associations. Hence, a concept-map is a visual representation which contains all the information in a diagrammatic form and concepts and associations contain all the logical information. Fig. 2 is an example of initial concept map to understand data types in programming languages. Hence a concept map contains a number of

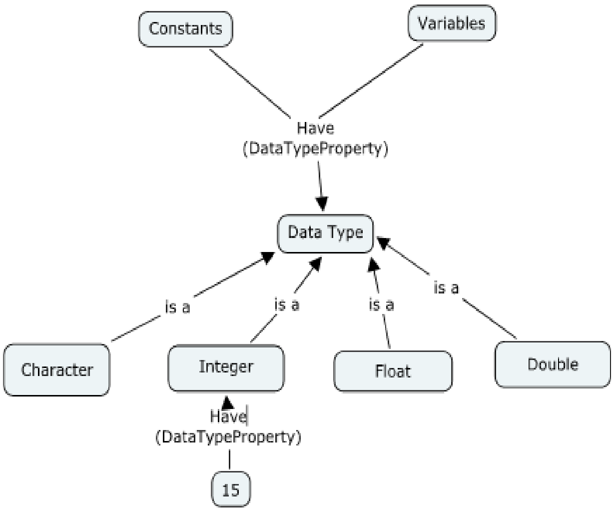

Fig 2: An example concept-map drawn in CMap tools showing different concepts and propositions in learning data types in a programming language

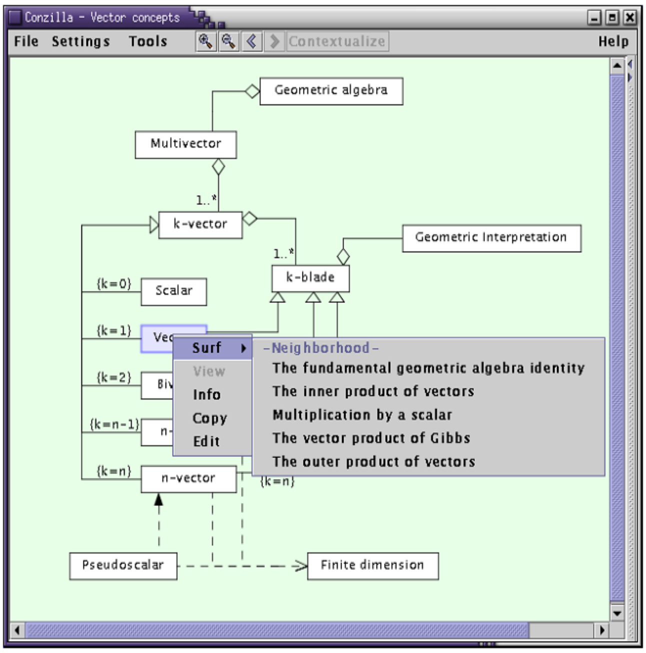

Fig. 3: A concept map in Conzilla explaining surfing in the conceptual neighbourhood of concept “Vector” Source: [29]

concepts, a number of associations between those concepts and visual information necessary to draw concept maps. As these concept maps should be distributable, they should be platform independent, should be able to contain concepts from different locations and simple concept maps should be generated automatically from a set of concepts.

Concept Browser

A concept browser provides an interface to present conceptual relationships or associations between a set of concepts in the form of concept maps and allows surfer to have independent access to the content describing these concepts. A concept browser presents the logical information contained in concepts, presents the available aspects of concepts and also provide a way in which the content of concepts can be accessed. Using concept browsers, detailed map of a concept can also be viewed in addition to surfing other concept maps in the conceptual neighbourhood of a particular concept. Conceptual neighborhood is the collection of all the concept maps in which a particular concept appears. [29] explains surfing of conceptual neighbourhood of concept “Vector” in one of the context maps designed for learning geometric algebra.(Fig. 3) .

VI. DESIGNING CONSTRUCTIVE LEARNING ENVIRONMENT USING CONCEPT BROWSER

While section IV discusses the design specifications and principles for designing an effective CLE, section V discusses the features and components of conceptual browsing which can act as powerful tool to create pedagogically strong and effective CLE. [18] suggested three kinds of tools that can act as strong pillars of effective CLEs. These are -

Information-gathering tools that should help learners in finding information to get deeper understanding of the problem. The web contains a huge reservoir of information and if these tools are able to access the relevant knowledge without any human intervention, CLEs can become really powerful. Semantic web can play a crucial role if knowledge gathering tools of a CLE are rooted in it and more and more semantic web technologies are used in marking up web pages. One such example is Schema.org initiatives which help search engines to improve search results based on semantic web information.

Knowledge construction tools - As learners need to actively work, develop and construct their own solutions to the given problems, they need knowledge construction tools like visualization and knowledge modeling tools. Concept browser is one such tool that provides an interface to the learner to open an existing knowledge structure or create his own in the form of concept maps. Semantic web can enhance the use of knowledge construction tools also as if these tools are based on semantic web technologies, the integration of different CLEs would become easier as there will be less need to develop support for new APIs for every tool. Conzilla is one such tool that is semantic web based, uses RDF at backend which is a convenient tool to produce new knowledge as well as to relate to existing knowledge[28].

Conversation and Collaboration tools that are required to support teamwork among students.

From the discussions in previous sections, it can be proposed that the concept browsers, especially those rooted in semantic web are fitting tools for designing constructive learning environments. Following points support the above given statement -

1. Concept browsers provide an interface where learner is involved in every step, right from the construction and selection of concept maps related to specific context to the content he wants to study. Moreover, he may choose to move between different contexts in which a particular concept appears or may move into depth of a concept to know about that concept in detail. All of this facilitates learner-centric model where he has full freedom to construct his own knowledge.
2. Since same concept can have different explanations in different context maps and every aspect associated with a concept represents different side of its reality, multiple representations of the knowledge are provided to the learner and it is possible for him to select a particular representation depending upon the requirements and the context under which he is studying a concept. Studying different contexts also enables him to find similarities and differences between two different forms of same concept.
3. Designing problem based context maps will lead to context based learning by performing rather than by just learning abstract instructions out of context. Case based learning, real world problems can also be implemented using context maps.
4. In concept browsers, surfing through context maps is similar to surfing the web and anyone can easily use them. It means there is no need for constant vigilation by the teacher. Learners themselves can decide the learning path they want to follow and eventually know about the concept. Teachers can provide the learners with initial set of maps that contain some real world problems or case studies and then they can eventually surf different context maps to learn the required concepts.
5. How much knowledge a learner has acquired can be assessed from his ability to solve the given problem. Learner can start with problem solving right from the beginning and learn about the concepts as and when they appear.
6. Collaborative construction of knowledge is possible as anybody can access context maps, modify them according to the permissions and create new maps which can further be shared by others.
7. Since content is kept separate from the concept and is linked to a concept through certain attributes, there is no restriction in the number of concepts to which a content resource may be linked to or vice-versa. Hence, the knowledge creation is context as well as content independent enabling learner to choose from multiple paths available to him.

Table 1 shows how effectively three main components of learning systems namely pedagogical, social and technical and discussed in section IV are implemented in constructivist learning environments designed using concept browsers.

Table I: Components of learning systems and their implementation using concept browsers

Components of learning systems	Implementation in CLE using concept browser
Pedagogical	1. Concept browsers very effectively enable learner to construct his/her own knowledge by using context maps. These context maps can be traversed either horizontally where different maps are connected using conceptual neighbourhood or he can also go deep into a topic by moving between different concepts using concept-relations in the same map. 2. A learner can use existing maps, create his/her own map and modify maps(depending on the permissions), all of these facilitating knowledge construction. 3. Content is separate from the concepts and linked to it through properties, hence learner may choose the content from different options depending on what context he is using concept. 4. Semantic web based concept browsers may support effective semantic based search so that most appropriate content can be selected for learning.
Social	A concept browser uses a collection of context maps to explain a concept. These concept maps are shareable among different users who can either use or modify the existing context maps or the content or can also create new maps. E. g. Conzilla provides an easy to use tool in the form of unified language modeling (ULM) to create context maps. As any user can contribute to the context maps, features like sharing of knowledge, interaction, reusability of learning objects and interoperability are provided easily leading to collaborative construction of knowledge.
Technical	Concept browsers provide a strong technical background required effective implementation of a CLE. Semantic web based concept browsers along with knowledge gathering tools can provide perfect platform for extracting knowledge that is precise and exact using annotated data Although a concept browser can be used either as a standalone or a web based application, content can be accessed from anywhere, in any form as all the resources in it are identified using unique universal resource identifiers (URIs). Moreover, users can add their own resources also and share them with other users. So these CLEs are technologically strong enough to enhance the actual learning among learners.

VII. CONCLUSION

Constructivism in education is an important area of research as it places learner at the center of the process. The learner decides what to learn and which learning path to explore from the multiple paths available in order to fulfill his needs. Constructivist learning environments present the environments which follow the principles of theory of constructivism and can be used to implement them. Concept browsers, the term coined by Ambjörn Naeve in [27], provide the tool and that can be used to effectively implement a CLE. This paper explores the study of design principles of CLEs as given by different researchers time to time and tries to include most of them for further studying their implementation using a concept browser. Further, this paper analyses the implementation of components of learning systems described by [22] in designing a CLE using concept browser and concludes that these may be implemented quite effectively. Moreover, if the concept browser is based on semantic web, it may add to the reusability and interoperability of the components and hence increasing their value. So, it can be concluded that as concept browsers can be quite effective in creating a constructivist learning environments which adhere to the principles of three learning components as is described in detail in table 1, this field can be further explored to see the practical implementation of such systems.

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