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TO DEVELOP CONSTRUCTIVIST LEARNING ENVIRONMENTS ON THE WEB WITH THE HELP OF SOFTWARE AGENT TECHNOLOGY

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ABSTRACT
There has been a widespread increase to conduct teaching and learning over the Internet. However, many instruction sites just provide teaching materials on the Internet to support traditional face-to-face methods. Learners then passively retrieve information from the Web pages. They are not engaged in actively constructing meaningful understandings of the topics being studied by using constructivist learning methods. This paper proposes that software agents be used to develop constructivist learning environments (CLEs) on the Web, to assist learners to construct new knowledge. The constructivist theory of learning is first reviewed and the characteristics of the CLEs are then outlined. The paper then suggests a process constructed out of constructivist learning methods over the Internet. Ways of using software agent technology to assist learners in constructivist learning are then investigated, along with the relevant implementation approaches. Finally future work in this area is presented.

KEY WORDS
constructivist learning, learning environment, software agent, Web, personalized learning, collaborative learning

1. Introduction

The move to conduct teaching and learning over the Internet is rapidly gaining momentum with the development of the WWW technology, the multimedia technology, and the technologies pertaining to teaching and learning over the Internet. Web based learning has become part of the routine landscape of education and training [1]. It has been recognized that Web based learning enables more learners to have access to the learning material and provides students and teachers with unprecedented flexibility and convenience [2].

However many instruction sites just emulate the course teaching of face-to-face over the Internet where the course providers focus only on designing a set of instructional sequences with predetermined outcomes for the learners. In such courses, information is divided into small parts and built into a whole conception via a series of Web pages [3]. Learners are passively involved to receive all necessary critical information from the learning material. They are directly told about a solution for the problem being studied or are taught how to get the solution using a designed mode. There is little room for learners to independently explore possibilities and invent their own solutions and actively construct new knowledge in the process. Obviously this mode has not made use of the full capabilities of the Web based technology [4], and it has not developed the full abilities of the learners in cognition, either. The Internet is a fairly powerful resource of information, some places provide detail whereas others provide comparison or synthesis, which is especially helpful for learners to construct meaningful understandings and competencies through self-directed inquired, guided activity, or community-based co-participation [5].

Here the requirement is in fact a new learning environment, i.e. a constructivist learning environment (CLE) where learners can work together and support each other as they use a variety of tools and information resources in their guided pursuit of learning goals and problem-solving activities [5]. The challenge here is to be able to provide efficient and effective supports for all these learning activities.

There has been considerable research on CLEs and a variety of technological means and facilities have been applied to assist learners in constructing meaningful understandings, for instance, the projects described in Wilson's book [5], Jonassen's design model [6][7], and Lefoe's work [4]. However, much of the early work has been in specific circumstances, mostly from theoretical level and provided only limited supports for learning activities. No doubt, there will be more attempts to apply new technologies in this area.

This paper proposes software agent technology be used to develop CLEs over the Internet to help learners build skills relevant problem solving. The software agent here is referred to a computer program which has a goal and autonomously solves problems through interaction, e.g. collaboration, competition, negotiation, etc [8]. Our

My thesis is that software agent technology can assist learners to use constructivist learning methods to develop new competencies. Software agents are integrated with the Web based learning to help learners find out appropriable learning resources, facilitate personalization of learning, promote collaboration and conversation among communities of learners, and assist the evaluation of learning outcome.

The paper is organized as follows. In the next section constructivist theory of learning is reviewed and the characteristics of the CLEs are outlined. In section 3 constructivist learning methods on the Web are structured and modeled and a learning model is presented. In section 4 various supports of software agents for assisting learners in constructing new skills by using constructivist learning methods are investigated and the relevant implementation approaches are conceptually described. In the last section the preliminary results and the outlooks of the research are presented.

2. The constructivist learning environments

Constructivist learning is a central conception of constructivism although there are diverse perspectives on what constructivism means [3]. The work of Dewey, Montessori, Piaget, Bruner, and Vygotsky provided historical precedents for constructivist theory of learning. Resnot has provided a summary of these theories and described constructivist teaching practice [9]. The fundamental epistemological assumptions underlying constructivist learning can be summarized as follows [10]:

- Knowledge is physically constructed by learners who are involved in active learning;
- Knowledge is symbolically constructed by learners who are making their own representations of action;
- Knowledge is socially constructed by learners who convey their meaning making to others;
- Knowledge is theoretically constructed by learners who try to explain things they don't completely understand.

An important way to view constructivist learning is to compare the differences between constructivist learning and instructivist learning. Based on the behaviorist model of learning, instructivist learning has been used as a dominated approach to learning in classrooms since the mid sixties last century [4]. The instructivist approach assumes that knowledge objectively exists in the world whereas constructivist considers it is individually constructed and socially co-constructed by learners through interaction with their environments. This subtle difference has profound implications for all aspects of these two learning approaches. The five among those aspects are highlighted in Table 1 [1].

A rich learning environment is considered as a major goal in constructivism where learners are engaged in active manipulative, constructive, intentional, complex, authentic, cooperative and reflective learning activities [6]. Constructivist environments present learners with opportunities to construct new knowledge based on prior one from authentic experience. Learners are allowed to confront problems full of meaning. In solving these problems, learners are encouraged to explore possibilities, invent alternative solutions, collaborate with others, try out ideas and hypotheses, revise their thinking, and finally present the best solution they can derive. Summarily, the characteristics of the CLEs should include the following [7]:

- Provide space for problem representation and problem manipulation;
- Provide information resource for knowledge construction;
- Provide related cases, experience and appreciation for conveying multiple perspectives;
- Provide cognitive tools for various metacognitive activities;
- Support learner-centred learning activities;
- Provide computer-mediated communication tools for conversation and collaboration;
- Provide criteria and methods for evaluating the learning outcome.

Table 1. Comparison of two learning approaches

Instructivist learning	Constructivist learning
Objectives are determined by the teacher.	Objectives are determined by learners collaboration based on their needs.
Objectives are determined for all in hierarchical form and sequenced from simple to complex.	Stresses the importance of divergence based on the uniqueness of the learner.
Learners are seen as passive or as holes to be filled with static data.	Problems are solved that have personal relevance to learners.
Knowledge is separate from knowing.	Knowledge is individual and socially constructed, based on personal experiences.
Learning consists of acquiring "truth" or the ability to mimic and can be measured with the tests.	Learning can only be measured through direct observation and dialogue.

3. The model of constructivist learning on the Web

In order to assist learners to build new knowledge at the Web based CLEs, it is essential to explore how learners study in the environments. There are several ways to conduct this investigation as many researchers have been concerned on the issue before. Unlike others, we based on constructivist perspectives, structure the learning activities and model them into a process explained by nine stages. In the model, the learning is initiated and driven by a

question or issue, problem, case, project that a learner wants to solve or resolve [7]. After the learning goal is constituted, the learner experiences a learning process to reach it. The process can be viewed by the following nine stages.

(1) **Choose** an appropriate learning resource on the Internet. The learning resource related to a particular problem may be on several web sites over the Internet. These sites may contain the learning material related to the problem in different ways, e.g. some provides details and some provides synthesis, etc. It thus demands to choose an appropriate learning resource which satisfies the learning requirement and suits individual learning style, background and skill level as well.

(2) **Access** the learning resource. This is in fact to capture relevant information from the learning resource to construct new knowledge.

(3) **Comprehend** the concepts and terms in the learning material based on the prior knowledge. This is to construct the learner's own understandings of the concepts and terms in the learning material. The learner may consult other reference materials and as well as other people in this process.

(4) **Discuss** with others if necessary. Ask for assistances if there are problems in understanding the relevant concepts and terms, by using email, taking part in a discussion in a Chat room, etc. This is to solve problems in understanding the concepts and terms.

(5) **Practice** the understandings of the concepts and terms to see if they are correct. This includes performing exercises or simulated experiments. It is probably performed together with other learners.

(6) **Elaborate** the constructed meanings. This may require harnessing multiple methodologies such as self-question, imagery, metaphors, analogies, etc.

(7) **Memorize** the constructed meanings. This includes to abstract the main ideas and concepts in the learning material and to remember them.

(8) **Articulate** the new meanings with the prior knowledge. This may require paraphrasing the ideas and concepts in the learning material, analysing and comparing them with the help of relational aids, e.g. chart, table, etc., and tap prior knowledge.

(9) **Evaluate** to see if the learning goal has been achieved. This includes choosing an appropriate method to conduct the evaluation, performing the evaluation and assessing the result of the evaluation. The result of evaluation decides the next learning activities to be taken. This gives a kind of cyclical structure of the learning procedure.

The nine stages are not necessary in a linear sequence. For instance, evaluation can occur at all points along the learning process. The prime emphasis in the process is placed on self-regulation and building of ideas and concepts through reflection, abstraction and interaction with the environments. The concept development and the deep understanding are the focus of the process.

4. The supports of software agent technology

The supports of software agent technology for assisting learners to use constructivist learning methods to develop new competences can be implemented through the following ways:

- Assist learners to find out appropriable learning resources over the Internet;
- Facilitate personalization of learning;
- Promote collaboration among learners and between learners and their teacher;
- Assist the evaluation of learning outcome.

We will investigate the relevant implementation approaches in this section.

4.1 To assist learners to find out appropriable learning resources

The first step of constructivist learning is to find out a learning resource over the Internet based on the learning requirement of individual learners. Because the information on the Internet has been exponentially increased, it is difficult for a learner to search for a specific learning resource through navigating in such an information sea. The general search engines, e.g. Google, AltaVista, Yahoo, offer little help for such search because they were designed for assisting in the search for general-purpose resources and thus are not good at the search for a specific learning resource. The other reason for that is they can only search for public Web sites over the Internet and thus can not search for the learning resources in an internal database. Software agents can be designed to help individuals to find out appropriable learning resources over the Internet. This can be implemented through one of the following methods:

(1) ***Search by the learner's personal agent.*** The personal agent for a learner transfers the learning requirement into the keywords suitable for a general search engine after getting it from the learner. It then, adds some extra information directing the search process to the keywords and using their combination, calls for a general search engine, e.g. *Google* to perform the search [11]. After the output is returned by the search engine, the agent filters the result through various clues, e.g. title, summary and URL to prune out the links not suitable for teaching/learning. It downloads the remained sites to further check whether their content is suitable for the learner. Finally it presents the learner with a list of the web sites which it believes are suitable for the learner.

(2) ***Consult the agents associated with the teacher.*** The personal agent first finds out a teacher who teaches the subject covering the learner's learning requirement from a facilitator agent on the CLEs. The facilitator agent is an agent responsible for the management of all agents on the CLEs. The personal agent then consults the teacher's agent for a suggestion of appropriable learning resources.

It sends the learner's learning requirement and learning characteristics, e.g. background, interest, style, motivation, capability, etc. to the teacher agent. The latter finds the learning resources suitable for the learner by retrieving its knowledge base based on this information, and sends back a list of the resources. After having received it, the personal agent presents the list to the learner as the suggested learning resource.

(3) ***Consult the agents associated with fellow students.*** The personal agent first gets a list of the fellow students who have experienced the relevant study from the facilitator agent. It then consults the agent for a student in the list to ask for a resource for the learning requirement by sending the learner's learning characteristics, e.g. background, interest, style, motivation, capability, etc. While the latter receives the message, it will compare the learning characteristics with its master's. If both can be matched, it will retrieve the relevant learning resources from the learning history records in its knowledge base, and then send back a hyperlink pointing to the suggested learning resource. In this way, the personal agent gathers the resource information from several fellow students in the list, and then orders the resources by the recommended rates from them. Finally it presents the resources with higher recommended rates as the suggested learning resources.

Each of these three methods has advantages and disadvantages respectively [11]. Their combination is probably a better method. The agent for the learner first consults the teacher agent to get a suggestion (using method 2), then verifies the suggestion by asking the fellow students (using method 3) if there are students online, and further checks the suggestion to see its availability on the Internet (using method 1).

4.2 To facilitate personalization of learning

Constructivist learning assumes knowledge is individually constructed by learner. Individual learners may have unique learning characteristic due to their different backgrounds, interests, styles, motivations, capabilities, etc. It has been recognized that personalization of learning can offer learners many benefits and enable them to get more efficient and effective learning outcomes. The prime emphasis of CLEs is placed on facilitating personalized learning. Personalization of learning involves multiple paradigms [12]. Context is tailored towards the learning desires of individual learners. Methodology is adapted to best suit individual styles, interests and skill levels. This means, to facilitate personalized learning, the teaching and relevant services should be customized based on the needs of individual learners.

A multi-agent architecture can be configured to facilitate personalization of learning on the CLEs. It consists of a number of agents with different expertise and they are integrated with the Internet-related programs at both the learner side and the teacher side [13]. Each learner is assigned a personal agent to manage his personal profile, including background, interest, style, motivation, capability, etc. Each teacher is assigned a personal agent to help the teacher timely respond to the requests pertaining to individual learning. Each of the Internet-related programs is also respectively assigned an agent to assist its users, i.e. the teachers or the learners, to use it in such ways that are beneficial to the individuals in learning. All the agents work together to coordinately assist the individuals in learning. The personalization of learning on the CLEs can be facilitated through the following ways:

(1) ***Provide personalized assistances for individual learners.*** The personal agent for a learner, acting as an assistant, assists the learner to arrange learning schedule [14] and choose learning method and resource, presents suggestions of learning strategies and supplies other facilities for his learning based on his profile and the messages collected from the interactions with other agents.

(2) ***Provide resource advisors for individual learners.*** All the agents associated respectively with the Internet-related programs at the learner side provide various conveniences and assistances for individual learners to high efficiently use these programs in the learning process, e.g. priority, forward, sort and archive email messages on behalf of individual learners [15], recommend reference resources, suggest appropriate discussion groups or chat rooms, etc.

(3) ***Provide private coaches for individual learners*** [16]. The personal agent for a teacher, supported by all the agents associated respectively with the Internet-related programs at the teacher side, monitors the learning progress of individual learners, collects the information about their learning behaviors, and based on these information, on behalf of the teacher, directly responds to the related learner agents or even the learners as a predetermined condition is detected.

(4) ***Provide the facilitators for individual learning.*** The agent for a teacher, based on the information collecting from the interactions with others, presents the teacher with suggestions of how to update the already-existed learning resources or produce new learning resources towards the needs of individual learners.

4.3 To promote collaborative learning

Constructivist learning assumes knowledge is socially co-constructed by learners through interaction with their environments. The collaboration, both learner/learner and learner/teacher, is especially significant for constructing meaningful understandings of the real world. Collaborative learning is referred to a variety of learning activities that seek to promote learning through collaborative efforts among learners working on a given learning task.

Software agents can be designed to help learners accomplish various collaborative learning activities on the CLEs. They can be autonomous but coordinate to actively control these processes. Possible support by software agents includes:

(1) ***Assist to compose a collaborative learning group.*** The personal agent for a learner assists the learner to choose peers over the Internet to study together. It first acquires the information about collaborative groups currently existed on the CLEs through a set of database queries and information exchanges with the facilitator agent. It then selects a group for the learner to join based on some pre-defined criteria, e.g. the size of a group, the learning characteristics of the learners in a group, etc. After that, it consults with the agent for the candidate group to apply for joining the group. While being allowed to join, it recommends the group for the learner to consider, or directly puts him into the group without asking him, depending on the predetermined threshold.

(2) ***Assist to partition the learning task.*** The agent for a collaborative group provides assistances in dividing the overall learning task for the group into several sub-tasks for each learner in the group. It is implemented by use of the distinguished characteristics of software agents; learning through observations. The agent observes task partitions conducted by learners, and for each partition, it records the task type, the adopted learning modality, the learning style of each learner, and their respective sub-task, etc. When it is asked to partition a new learning task, it searches in its parameter base to find a partition most approximated the current conditions. Then it takes this as a preliminary partition plan and negotiates with all the agent members in the group in attempting to carry out the plan. If the plan can be implemented, the rank of the partition in the parameter base will be increased. Otherwise, necessary changes for the plan are made based on the negotiation and a new partition record will be inserted into the parameter base.

(3) ***Assist to combine the learning achievements.*** An autonomous agent can be designed to provide the assistance to combine individual learning achievements into an entire learning outcome on the CLEs. The concrete implementation depends on the type of the learning task because the way of combining learning achievements of individual learners is determined by the type of the learning task. One agent is employed for a specific type of the learning tasks. As an example, the agent for the task working to co-author a research report in turn gives the control to an individual learner based on some rules to let him copy his own private version into the overall version.

4.4 To assist learners to evaluate the learning outcome

Evaluation of learning outcome is an integral part of the learning. Rather than taking behaviours or skill as the goal of learning, constructivist assumes concept development and deep understanding as the focus of learning [9]. Multiplicity is an important concept in the evaluation because there are divergent paths to construct specific knowledge. The evaluation of the learning outcome should be focused on the different dimensions of knowledge, skill, and attitudes. It can only be implemented through direct observations and dialogue.

Software agents can be designed to assist the evaluation. They are autonomous and coordinated to control the procedure. An autonomous agent, supported by others, conducts an evaluation for a specific learning task. The agent for a learner recommends one of the evaluation methods based on the available system resources and the learner's preference.

During the evaluation, the agent timely gives feedback, with sound or/and animations. It gives compliment and encouragement if it believes the thing a learner has done is correct; otherwise it gives advices or warns. After the evaluation is over, the personal agent will assess the evaluation result and gives the learner an evaluate report.

If the result of evaluation is not good, it will suggest the learner go back to do the relevant work again.

5. The research perspectives

The constructivist group of theories believes that learning is an active process of constructing knowledge. In this paper, we suggest software agents be used to develop the CLEs on the Web, to assist learners in constructing new knowledge. Software agents are integrated into the Web based learning to help learners find out appropriable learning resources, facilitate personalized learning, promote collaboration among learners, and assist the evaluation of the learning outcome. The experiments for the major module components in the CLEs have been conducted respectively. Very positive results have been achieved. Software agents can assist learners to use constructivist learning methods to develop new skills for problem solving.

The integration of the individual modules to create the entire CLEs is currently under implementation. We will be pursuing a concise and easily used user interface, and as well more supports from software agents in the process of knowledge construction. Meanwhile we will put the CLEs into practical applications, e.g. subject teaching, and further improve the architecture of the software agents and their performance characteristics in knowledge construction based on the feedback from the students.

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