A method of defining learning processes

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Currently many instructional Web sites just simply deliver course materials without integrating the role of teacher in guiding learners to use these materials to construct knowledge. Learners only passively receive the presented materials. Our research is to provide support services to actively assist learners to construct knowledge using the constructivist approach to learning. This paper focuses on providing services to assist learners to choose appropriate resources and methods, and guide them to align learning towards their study objectives. These services are implemented through electronic workspaces that manage the learning processes. A specification language will be presented to specify the learning processes in a way that constructivist learning can be supported and facilitated. The approach to managing the learning processes will be investigated. A learning environment that assists learners to use constructivist methods of learning to build new competences will be presented.

Keywords learning processes, management of the learning processes, learning design, active learning, constructivist methods of learning

Introduction

The rapid technological and social change puts forward need for life long learning. Conventional classroom learning is not able to satisfy such need. E-learning is an increasingly preferable alternative to conventional classroom learning. The move to conduct teaching and learning over the Internet is rapidly gaining momentum along with the advance of computing technology and the deep researches into the pedagogical methodology on the Internet. Web based learning has become an important part of the routine landscape of education and training (French *et al.*, 1999). It has been recognised that Web based learning can enable more learners to have access to the learning materials and provide students and teachers with unprecedented flexibility and convenience (Shen *et al.*, 2002).

However many current instructional Web sites just simply deliver course materials over the Internet and do not provide effective and efficient supports for using these materials to construct knowledge. As a result, learners only passively receive the presented materials. According to constructivist learning perspectives, knowledge cannot be transmitted to learners but must be individually constructed and socially co-constructed by learners (Jonassen, 1999). However, not all learners are equally capable of adequately conducting such knowledge on their own (Large, 1996). For instance, some may lack of necessary *prior* knowledge or abilities to independently choose a resource and adopt a proper method to conduct their learning activities. Such problems may seem trivially simple over traditional classroom learning environments because the teachers can easily find and solve these problems through face to face interactions. However, they may form an obstacle that hinders learners participating in learning over Web based learning environments, because learners in these environments are not closely located to their teachers. Moreover learners may be unable to conduct learning activities in an optimised path towards their objectives. Consequently, research is needed to develop ways to assist learners to learn independently. These must include services that go beyond simply presenting Web pages and navigation paths, but present a wider range of technological facilities, tools and services to support the learning process.

The work presented in this paper is to develop services that assist learners to use constructivist learning methods to develop new skills. It is to assist learners to construct knowledge by advising them of appropriate learning resources and methods as well as directing them to align learning towards their learning objectives. The paper is organised as follows. In section 2 we develop a specification language to describe learning processes. These are processes followed by learners to achieve a learning goal. This language provides a foundation for learning designs that create units of learning (Koper, 2001). The units of learning (UOL) define the learning process to be followed by learners to achieve their learning goal. Section 3 will describe ways to assist learners to create learning designs and to manage the learning

processes. Managing the process includes monitoring the learning progress, and directing learners to adapt learning based on the monitored events. In section 4, a learning environment will be developed, where learners independently learn and collaboratively work with their fellows and they will be provided with various services during the procedure. The environment will effectively foster them to build new competences by using constructivist methods of learning. Finally, we will conclude with a description of the on going and the future work of the research.

The specification language for describing the learning processes

The goal of this work is to assist learners to effectively learn by creating and managing their learning processes. A specification language must be defined and developed to describe the learning processes. Many learning design projects have already concerned the issue. Building on the early work, we have developed our own specification language to describe learning activities that facilitate constructivist learning. This section will be focused on the description of a unit of learning by our specification language and the main differences compared with other projects.

A brief review of the research on learning designs

In this paper we see learning design as a way of bringing together the components needed to create a learning process that meets a learning goal. Recent research in this area is on the sharing and reusing of learning designs. The first version of the IMS Learning Design specification (IMS-LD) is one of the results. Learning design is far from being a new idea and it promotes more effective learning by carefully structuring learning activities and their workflow in a learning process. To share and reuse learning designs over different platforms, IMS-LD provides a generic and flexible language to describe a wide range of learning activities in e-learning. The language was built on the Educational Modelling Language (EML) developed by the Open University of Netherlands (Koper, 2001). At the core of EML is a description of how the teaching and learning is conducted in an environment with resources (Koper & Manderveld, 2004). Another significant development is the Learning Activity Management System (LAMS) (Dalziel, 2003). Not only it has implemented the core concepts behind the IMS-LD in terms of a focus on creating sequences of activities but also provided a simple and highly intuitive user interface for course designers to organise the activities into a sequential workflow (Britain, 2004). Other projects of learning design include the Reload project, Coppercore, Lobster, etc.

Learning object standards, most notably the IEEE Learning Technology Standards Committee and the IMS Global Learning Consortium, have proposed standards for describing reusable learning objects. These standards define standard elements that can be used to describe any learning objects that can be shared in technology enhanced learning systems. They are very general and need further development if they are to be used to implement a learning system. Other well known standards and projects include SCORM's Content Aggregation Model (ADL, 2003), the CISCO's Reusable Learning Object strategy (2001), etc.

One problem is that most of the learning object standards and learning designs are directed to support objectivist learning rather than to constructivist learning. Objectivist theory for learning believes that knowledge can be transmitted to learners. Consistent with the viewpoint, those projects deconstruct learning activities and decrease their granularity to construct instructional scenes. Teaching templates for these scenes are designed to make the knowledge transmission easier and hence facilitate the cognition changes of learners. Because it is impossible to model and encapsulate all the learning processes due to their varieties; learners may wish to learn a theme by different processes, but the designed templates can hardly match to all individual learners. The effect of the attempt is questionable while an unsuitable mode is imposed on an individual. According to constructivist theory for learning, learning systems should provide learners with a wide range of services to assist and facilitate knowledge construction, rather than imposing a particular learning method on them. In our work we use the learning object idea to construct units of learning out of more elementary objects, although we see that lower granularity of learning objects is needed than currently proposed in most standards. Such lower granularity is needed to provide the necessary flexibility to support constructivist learning.

The description of a unit of learning by our specification language

Building upon the early work in the area of learning design, particular the EML, we are developing a specification language to describe and specify the learning processes that include services for constructivist learning. The language creates UOL that are composed of more elementary objects. The

primary means is to extend the object parameters in ways that they can be flexibly combined and dynamically changed. Our specification language describes a unit of learning (UOL) that satisfies one or more learning objectives. A UOL may correspond to a course or a subject, a module, a lesson, or even a single learning activity such as a discussion to elaborate on some topic. As shown in Figure 1, the description is a structure made up of seven kinds of objects, i.e., metadata, roles, content, methods, assessments, case studies, and learning plans. These objects are respectively explained in the following.

1. *Metadata* provides a general description of a UOL. It includes the descriptions of the learning objectives for the UOL. Each objective has a brief description and a corresponding category. *Keywords* are the ones extracted from the objective descriptions and are used to match with the learning objectives of a learner.

2. *Roles* specify the intended users of the UOL. The standard users include authors, tutors, learners, and administrators. Obviously the most important users in the current research are learners with a variety of learning characteristics. *Property* describes the learning characteristics of each type.

3. *Content* is a wider concept composed of various activities and resources for the UOL. A learning activity is something done by a learner to help in knowledge construction, e.g. viewing a learning material, doing an online quiz, performing a group assignment, etc. In the description of each learning activity, *type* specifies the category of the activity (e.g. discuss, group activities, etc.), *what* gives a textual description of what will be done in the activity, and *complete* describes the change of status after the activity is finished (the change of status will affect the sequence of learning activities). *Learning resources* describe various resources available for the UOL. In each resource description, *content object* indicates the medium type of the resource and its exact position, *communication object* specifies the requirements for the communication facilities, and *tool object* specifies the prerequisite tools and facilities for using the resource.

4. *Methods* provide various approaches to arranging learning activities to achieve the learning goals defined in the UOL. They are divided into groups based on the learning characteristics of their targeted learners, and each group is put into an *activity structure*. Each method, described in an *activity sequence*, which define a learning process as an activity sequence followed as a set of learning steps. A step is a reference to either learning activities defined in the UOL or other units. In the latter case, other units are referenced to implement the learning steps of the UOL, which constructs a

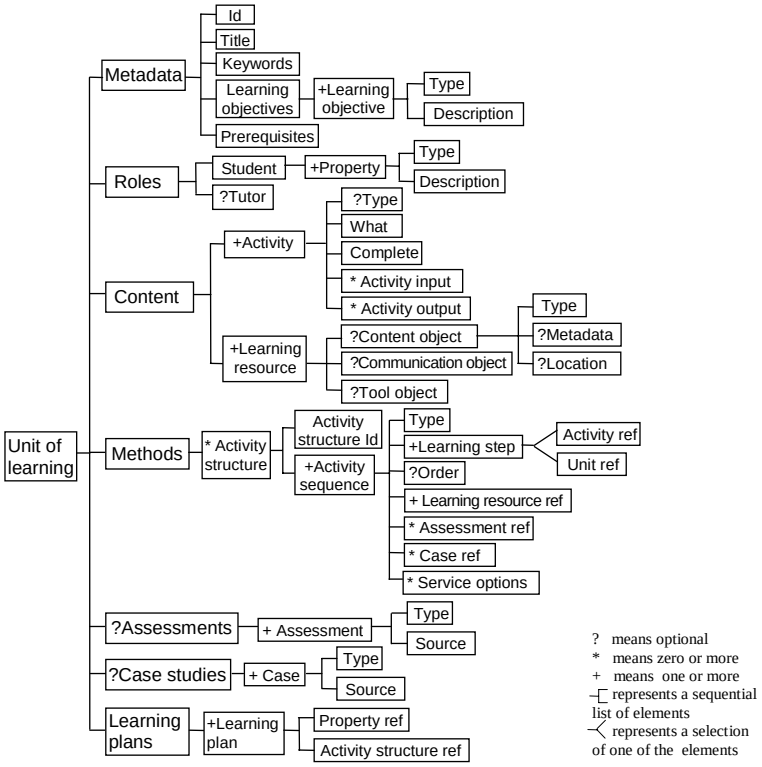

Figure 1: The architecture of a UOL

hierarchical architecture of a module, or a subject. The learning method may also define the sequence or conditional learning path of the given learning steps, allowing sequencing, conditions and repetitions of some learning activities. In the description of a learning method, *type* specifies its methodology category, e.g. knowledge acquisition, problem based, case based, project based, informative testing, learning by designing, discovery learning, etc. *Learning resource ref* specifies the learning resources that can be used for the learning steps. It is likely that there is more than one learning resource available for the learning, which enables a learning process to be conducted by using different resources. *Assessment ref* specifies which assessment items can be used to assess the learning outcomes. *Case ref* specifies which case study materials can be used for reference in the learning activities. *Service options* describe the computer supported collaborative tools that are required in the learning activities, e.g. workspaces, discussion forums, etc.

5. *Assessments* describe a set of approaches to assessing the learning activities defined in the UOL. In the description of each assessment, *type* specifies its category, e.g. question answering, interactive program, etc., and *source* indicates where to find it.
6. *Case studies* describe a set of case study materials related to the UOL for scaffolding the learning. In the description of each case study material, *type* specifies its category, e.g. document material, interactive program, etc., and *source* specifies where to find it.
7. *Learning plans* provide links between to alternate learning methods to suit learners with specific learning characteristics and allow them to choose the most suitable learning process.

The primary features of our specification language

Compared with other specification languages in the current learning design projects, our specification language has some particular features most to support constructivist learning. The main characteristics are summarised as follows.

1. It enables the system to use multiple strategies to assist learners to construct their own representations to a knowledge object. In the description of a UOL by our specification language, there is more than one optional approach to arranging learning activities available for a particular type of learners to achieve their learning goals. This design is consistent with the principle of the constructivist theory of learning, i.e. learners may construct their own meaningful understandings to a learning theme from different paths (Jonassen, 1991).
2. It enables the system to present learning materials in personalised ways by choosing one of the methods in the UOL. According to constructivist perspectives, knowledge is actively constructed by individual learners (Jonassen, 1999; Lefoe, 1998). Individual learners may have unique learning characteristics due to their different backgrounds, interests, styles, motivations, capabilities, etc. Our specification language supports such descriptions that more than one learning resources are available for a learning activity. This makes it possible to dynamically determine learning resources based on individual learning characteristics while a learning activity is being conducted.
3. It enables the system to evaluate learners' learning behaviours in a timely way. The constructivist theory of learning emphasises the procedure of knowledge construction, not just the final results (Jonassen, 1991). The assessment can be directly associated with a learning activity in our specification language. This design makes it possible to evaluate the procedure of learning while learning is progressing.
4. It enables the system to supply learners with more scaffolds for knowledge construction. Our specification language allows case study materials to be associated with a learning activity. This makes it possible to help learners to conduct a learning activity by related case study materials.

Managing the learning processes

An underlying model for managing the learning processes

An approach for managing the learning processes in a Web based learning environment can be inferred from the model shown in Figure 2. The learning environment is constructed to provide a variety of support services for a learning process. The learning goals are what to be achieved through the learning. The learning activities define the learning steps for the learning goals. The learning materials are the

learning resources available for the learning. The support services are made up of various support services to be used in the learning. The learning methods define how learners conduct the learning activities in the learning process. The learning activities define the method to be used to achieve the learning goals. The method will use any support services provided by the learning environment. The semantics of conducting a learning process follows the idea "use the goals to select learning materials and define the learning activities that define the methods to be followed in the learning process to achieve the learning goals with the help of the services provided by the learning environment".

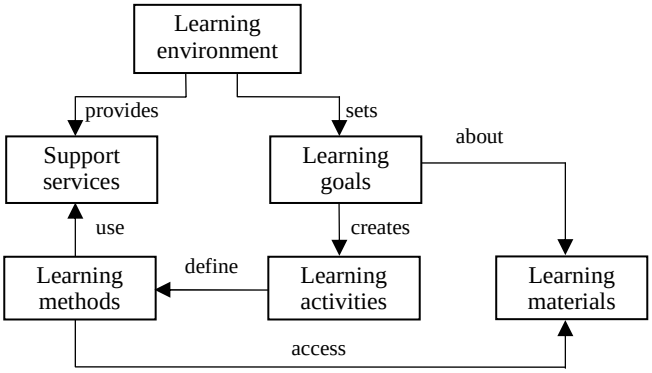

Figure 2: The underlying model for managing the learning process

The model in Figure 2 indicates how to manage a learning process in a Web based platform. The learning plan, which includes the learning activities and their sequence, and the resources, will be used in these activities. The actual progress of the learning will be measured and compared with the plan and based on the result, the learning process will be further adapted so that the learning goals can be achieved.

The approach to designing a learning plan for an individual learner

A learner defines their learning objective based on the problem, project or case under study. A UOL will then be created that provides a plan to achieve the learning goal. The UOL will identify the learning activities to be conducted and the learning resources to be used while conducting these activities. This mainly includes the three steps, as shown in Figure 3. These are:

1. *Create a custom-UOL*. If the learner's learning objective matches to the *keywords* in a generic-UOL, a custom-UOL for the learner will be created from the generic-UOL.

2. *Determine the learning activities to be conducted*. The position of the learning methods for a particular category of learners can be attained in the *learning plans* of the UOL. There may be several learning methods in the *activity structure* applicable to the learner. Based on the category of the methodology for the learning steps, the available services, and the case study materials, etc., the suitable ones will be chosen for the learner to adopt. This learning method, described in an *activity sequence*, contains a set of learning steps, i.e. the references of either learning activities defined in the UOL or other units, and their conduct order.

3. *Determine the learning resource*. The *activity sequence* contains several references of the learning resources that may be applicable for conducting the learning activities determined in the previous step. To select the suitable ones it is necessary to check their definitions in the *learning resource*. Based on the medium type, the communication requirements (synchronous or asynchronous) and the required technological tools, etc., the suitable ones will be chosen as the learning resources to be used while conducting the learning activities.

The approach to measuring the progress of learning

Measuring the progress of a learner’s learning can be realised through three ways: (1) execute the assessment associated with a learning activity; (2) evaluate the artifact files defined in the *activity output* of a learning activity; and (3) monitor the change of status defined in the *complete* for a learning activity.

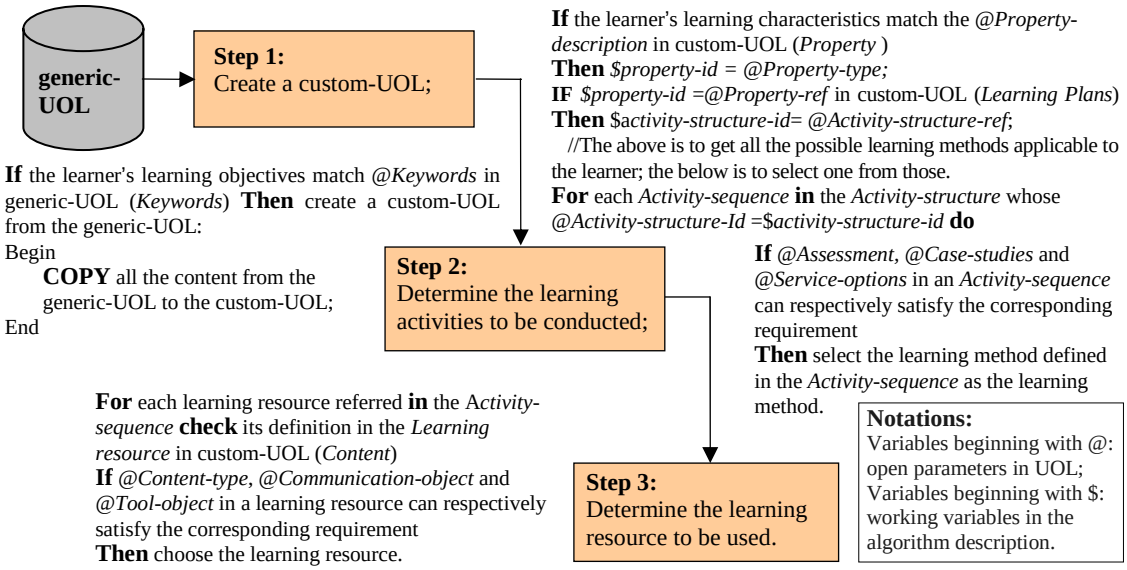

Figure 3: The procedure of drawing a learning plan for an individual

The supports derived from the management of the learning processes

Learners will be offered two types of suggestions during the learning process. The first type of suggestions is to assist them to choose learning resources and methods to conduct learning. The second type of suggestions is to guide them to dynamically align their learning process to their learning goal.

The first type of suggestions is offered through advising learners of appropriate resources and methods to conduct learning while they are learning a theme. This information can be attained from the relevant learning plans since they specify the learning activities and use the learning resources needed for learning a unit. With such suggestions, learners will be able to choose between a number of different learning resources and learning approaches that suit them.

The second type of suggestions is offered while it is found that a learner is not conducting his learning in the path to the objectives designed in his learning plan. To offer such suggestions, it is obviously necessary to monitor learner's learning and compare the actual learning progress with the learning plan. *Activity lists* and *check lists* are used to implement the function. All the learning activities in a learning plan will be inserted into the *activity list* for an individual learner while the plan is built. The learning activities will be recorded in the *check list* for an individual learner while the monitoring mechanism shows that they have been successfully completed. By comparing the *check list* and *activity list* for an individual learner can generate the conclusion about how to align one's learning. As an example, a suggestion will be derived and presented to a learner for advising him to adjust learning if it is shown from the *check list* for him that he has not completed a learning activity which should be conducted prior to the one he is conducting.

The active learning support system

Active learning and learning management

Now that the management of the learning processes can be implemented through managing the learning plans, is it suitable to take full control of learners over their learning by the management? This is an issue of how the managerial role should be organised in a Web based learning environment. According to the constructivist theory for learning, knowledge is constructed by learners who are involved in active learning (Akhras & Self, 2000). That means learners have to do many activities on their own to build new knowledge. Many methods of learning can be considered as *active* to some extent but usually active learning entails learner independent learning in which the learner constructs meanings, often working in collaboration with their fellow learners (Tarassov & Johansson, 2003). Clearly it will not benefit learners for constructing knowledge if they are taught how to get the solution for a problem using a designed

mode. To give learners good learning experience and make the learning processes optimal, active learning should be encouraged. Therefore, we use a strategy that allows learners to employ *active* learning methods in knowledge construction and the system offers suggestions or advices to direct their learning. The assistances from the system are based on the management of their learning processes.

In such a learning system, learners are not directly told about the methods for how to use the learning materials to solve the problem under study. Thus learners can *independently* explore possibilities and invent their own solutions for the problem and *actively* construct knowledge in the processes. Their autonomy in the learning processes has been supported and encouraged by the system. Meanwhile the system will offer suggestions or advices to direct them to select the learning resources and the learning activities while learners have problems in the processes. This contrasts with current learning management systems, which just present course materials and require learners themselves to determine how to use them to achieve their learning goals.

The architectural framework of an active learning system

In the proposed learning system, it is clearly impractical to create and manage the learning plans by learners on their own. We thus suggest the management be undertaken by a software agent that is capable of autonomous actions based on the monitored events. The actions will, based on the management, provide learners with personalised assistance to help them build knowledge by constructivist methods of learning.

The architecture of the learning environment we are establishing is depicted in Figure 4. A mechanism for the management of the learning processes is integrated into a Web based platform to provide learners with assistance based on their learning behaviours. The overall learning system is implemented relying on a client server computing model. Learners interact with the system via a Web browser at the client side, which communicates with it by the HTTP protocol. The mechanism silently monitors the progressing of the learning. While an opportunity that it can offer assistance or advice arises, it will actively take actions. For the purpose of providing an entrance for the learners to directly request assistance from the mechanism, an image icon for the mechanism is installed on the interface for Web based learning. Learners can click the icon to request assistance from the mechanism if they like.

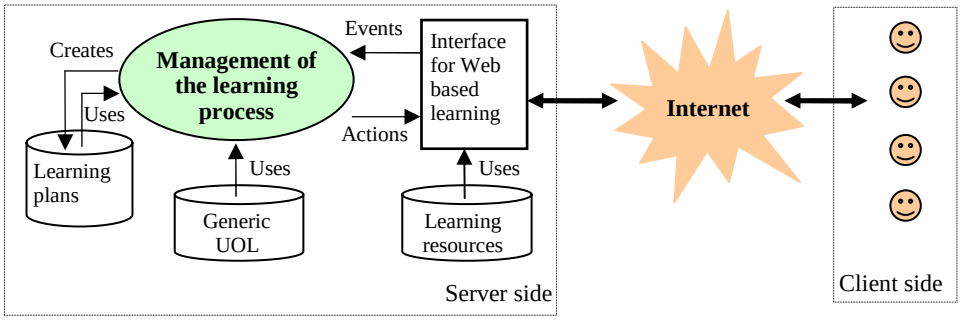

Figure 4: The architecture of the learning system

We are using software agent technology to implement the mechanism because of their distinguished characteristics and their successful applications in projects of intelligent controls (Weiss, 1999). A number of software agents will be enacted to take the duty of the management. Since it is not the objective of this paper to describe all parts of the research, we are not going to present the implementation details. Instead, we will briefly describe the related services provided by the mechanism for active learning in the remaining part of the paper.

The services to support active learning

The services to support active learning, provided by the learning environment through managing learners' learning processes, are concentrated on assisting learners to use constructivist methods of learning to build new competences. They can be summarised as below.

1. *Personalised learning resources and learning methods.* The recommendations on the learning resources and the learning methods for learners are determined in light of individual learning objectives and individual learning characteristics. They can be quite matched to the individual

requirements of learners and thus assist them to analyse, comprehend and understand the learning theme in an efficient and effective mode.

2. *Open and flexible strategies for knowledge construction*. The suggested learning strategies, including the selection of the learning materials and the methods to conduct the learning activities, are open and can be dynamically adapted as the learning is progressing. This ensures not to impose a particular learning strategy to learners and thus enables learners to use the optimal ones to construct knowledge. No doubt learners will be benefited for constructing their own knowledge representation from the dynamic adaptation of the learning strategy.
3. *Timely and focused evaluation of the learning. Timely* means the evaluation is associated with a learning activity rather than just the final result of the learning. *Focused* means the evaluation results in a meaningful suggestion or advice for the next learning activities, or even an actual action undertaken by the mechanism. Clearly this can bring significant influence to knowledge construction because any problems in a learning process can be timely identified and the corresponding remedy can accordingly be made immediately.
4. *Multiple services for collaborative learning.* These include organising and managing discussion forums for learners to exchange ideas and supplying workspaces for them to share information and conduct group activities. These also include supplying tools and means to help the participating learners to set up a collaborative learning group, partition a learning task, and combine the learning outcomes achieved by individual learners, etc. Such services can provide strong supports for various collaborative activities for knowledge construction.
5. *Effective scaffoldings to individual learning activities*. The case study materials associated with learning activities can produce significant impact to individual learners for constructing their own meaningful understandings of the theme under study.

Conclusion and outlook

The work described in this paper is a part of our research to *facilitate constructivist e-learning using intelligent agent technology* (Pan & Hawryszkiewycz, 2004), which is currently in progress. This paper has been focused on the specification language for describing and defining the learning processes in Web based learning environments and the approach to managing the learning processes through learning plans. The implementation of a mechanism for the management by software agents has not been included in the paper and will be presented in other papers.

To make e-learning efficient and effective, various technology supports should be provided for learners. Providing suggestion and advice pertaining to the selection of the resources and methods for conducting learning as well as the dynamic adjustment to the learning processes is one of such supports. To implement the support requires ways of describing the learning resources and the learning activities, defining the learning plans, monitoring the learning behaviours of learners, adjusting the learning, etc. Up till now we have experienced the development of the specification language for describing the learning processes and an approach to managing the learning processes. We are currently, by using software agents, implementing a mechanism to undertake the management task. The mechanism will be integrated into a Web based platform to present learners a learning environment that provides supports for *active* learning.

The approach presented in this paper, i.e. the mechanism for managing the learning processes silently monitors the learning behaviours of learners and offers them suggestions or advices based on their learning behaviours, can provide a natural extension of active learning methods. Such a learning environment can effectively facilitate *active* learning and thus benefit learners for constructing knowledge to solve the problems being studied.

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