A CONSTRUCTIVE MULTIMEDIA APPROACH TO E-LEARNING

Yacine Atif
College of Information Technology, UAE University

(Received November 2002 and accepted May 2003)

How can learners build their own knowledge, which is precisely tailored to their needs and background? This is the question which this paper attempts to answer by providing a framework for a flexible object-based e-learning environment. The paper recognizes that, in order to properly address learners’ requirements, instructional technologies must be more adaptive and use a variety of media. In its attempt to build an adaptive learning system, this paper highlights the role of learning objects and actually provides an implementation of such objects as well as an algorithm which constructs a learning path customized to each learner to root out the learning deficiencies of individual learners.

1. INTRODUCTION

Multimedia is an emerging technology that integrates various types of data, such as video, audio, voice, image, animation, and textual data into a wide range of applications. With recent advances in fiber optics and hardware technology, a variety of distributed multimedia applications are now becoming feasible. The recent proliferation of multimedia hardware and software has made it possible for more people to produce and to distribute these documents [1]. In a distributed multimedia system, users can now access diverse applications, such as distance-learning, video conference systems, video-mail services, and video on-demand applications. These applications spread over a wide range of industries such as business, manufacturing, computer aided design, entertainment, and digital library.

Multimedia technology is also an essential resource in delivering and managing education and training material. A vast storehouse of such resources relevant to learning is available [14][15]. These technologies have the potential to transform the learning enterprise to the benefit of learners and educators alike. These technologies are growing to support an open, widely distributed, high capacity, and intensely interactive learning infrastructure.

Successfully harnessing the potential of multimedia and education could offer unique learning experiences that fully engage and support learners, and improve the accessibility of instruction as well as the functioning of the systems by which instruction is delivered [4]. Also a significant psychology research finding reveals that multimedia instruction considerably surmount current learning barriers by reducing the costs and time for producing and disseminating educational content. One study conducted in this area recorded 71% savings in learning time with multimedia-based learning versus classroom instruction [5] prompting the development of subsequent multimedia-based educational software. The rational behind these statistics is that in one hand, multimedia-based instruction forces the courseware designer to better organize the learning material compared to traditional classroom lecture. On the other hand it allows learners to control the learning pace and interact with the learning system.

Self-paced learning is a more effective way to learn because the learner can move on to new material when he is ready. Hence, learners can personally set the pace of learning. This important learning feature is not provided in a traditional classroom instruction. Another multimedia-based learning feature that appears to have a strong positive effect on learning is interactivity. This feature can be thought of as mutual action between the learner, the learning system and the learning material. One research concluded that interactivity was associated with learning achievement and retention of knowledge [6] because it adapts the instruction to the behavior of learners who would then have better attitudes and acceptability towards the learning material.
The improved learning performance and productivity as well as the increasing size and diversity of the online educational community are also associated with the redundant multimedia versus monomedia features of the computerized learning material. Dual or multiple media with closely related content combined together in a learning channel has the potential to provide effective learning when the media clearly support one another and are presented to learners with low prior knowledge or aptitude in the domain being learned [7][8].

In this paper, we present a multimedia system that stores learning material in the form of composite document which integrates a video script (showing for instance the talking head of the lecturer or any other video material related to the subject of the course), and also a text transcript to help students who have hearing impairments or difficulties to understand the lecturer accent to read the speech of the lecturer. Such organization and presentation of course notes provide a virtual classroom environment whereby students can attend classes anywhere and anytime.

Multimedia documents forming the course notes are pre-orchestrated and stored in a multimedia database. Learners remotely access the course presentation system to view a courseware using their web browser such as Netscape or Explorer. Pre-orchestrated multimedia data refers to stored data for which the play-out scripts have already been specified at the time of authoring and storage. Our e-learning system is different from previous approaches by its multimedia course-presentation facilities and its generic capability to accommodate various learning content and modes. While other web-based systems are heavily text-based, our approach is more live through the inclusion of video-scripts in lecture notes and synchronized with other components of the multimedia document. The system includes both a playback module for learners to view a course and a course-authoring module for lecturers to design the course.

2. BACKGROUND AND RELATED WORK

The key technical challenges that confront multimedia-based learning systems fall mainly into five categories: overall learning strategy, learning content structure, sequence of learning, media allocation and modes of delivery. Below, we review each of these categories to justify the design approach adopted in the e-learning system presented in this paper.

2.1. LEARNING APPROACHES

The education research community advocated two separate learning strategies: the instructive model and the constructive model [3]. The instructive model simulates the instructor task in a classroom environment whereby a learner is guided through a step-by-step process towards the targeted course objectives. Learning systems based on such a model have limited interactive capabilities and typically offer a single learning path. The instructive approach eventually led to a class of multimedia-based e-learning software labeled as Computer Aided Instruction systems, which are typically composed of hyper-media documents.

The constructive model allows learners to rather build their own knowledge following possibly different learning paths based on the level and the background disparities of learners. This constructivist approach leads to a modern class of multimedia-based e-learning software, which automatically adapts the presented multimedia learning material to the behavior of the learner. The key feature in designing such multimedia software is that by interacting with the course concepts, learners construct their own understanding of these concepts.

In our proposed system, we adopted the constructivist approach for learning. The concepts used in the learning material are represented as multimedia documents, which are composed of synchronized and pre-orchestrated media objects. Our multimedia document integrates three media objects, which are a video-clip, a sequence of images (representing related viewgraphs or slides) and an animated text-script (as shown in Figure1). When a concept is presented to the learner, a specific video-script is played concurrently with the display of a sequence of images at specific time-slots. The video could show the talking head of a lecturer, a chemistry-experiment in progress or a medical treatment provided to a patient. The slides shown sequentially on a separate window could highlight the major steps of the video content. Slides presentation instants and durations are inserted within the video timeline to be displayed at predefined time frames. The text component of a concept represents the textual version of the speech in the video. This text component automatically scrolls down during the video playback so that the appropriate speaker notes are displayed when the related video content is reached. Text acquisition is done automatically by the course author using speech-recognition software.

2.2. CONTENT STRUCTURE

A major current focus in designing modern e-learning content is the actual concentration on efficient
production of instructional components or objects which are interoperable and reusable [9][10]. With no doubt the concept of reusability becomes a key issue for new e-learning initiatives. The reusability of learning objects provides a framework that builds on past experience and creates new mechanisms for producing and exchanging knowledge. There is an actual need to discover ways for the integration of the various sources of knowledge within a business or educational organization and especially to collaborate and to exchange learning objects. These learning objects should accommodate heterogeneous learning sources (text, presentation, audio or video) or a combination of any of these media. The e-learning system presented in this paper promotes such generic object-based learning and is capable of capturing any learning source. Learning objects can represent small instructional components such as a course unit or an entire course that can be reused a number of times in different contexts or even an entire curriculum. However coarse grain objects reduce their reusability. In addition, learning objects are assumed to be delivered over the Internet in an open system framework free from any vendor-specific container. The learning object design forces a certain e-pedagogy discipline in order for instruction designers to operate under a well defined framework that prevent the design of lengthy and discursive material which may not benefit learners.

The Learning Technology Standards Committee defines learning objects as “entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning. Examples of technology-supported learning include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and collaborative learning environments. Examples of learning objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology supported learning” [10].

In this paper, learning objects are defined broadly enough to encompass resources currently available on the Internet including multimedia resources. Our learning objects synthesize an instructional design able to capture instruction in any Internet-transferable media as well as their combination to allow instruction and practice for instance to use different media. Moreover, learning objects are inter-linked to form a network of learning resources through which learners navigate to build a personalized learning path. Hence, learning objects appear as modular building blocks to allow a constructive approach to manage e-learning content.

2.3. SEQUENCE OF LEARNING

The Learning Objects Metadata Working Group’s (a working group of the Learning Technology Standards Committee) aims at promoting adaptive e-learning systems to enable computer agents to automatically and dynamically compose personalized lessons for an individual learner. To achieve this objective, this working group stated that “instructional design should not be structured in the traditional sequential format whereby all learners get the same instruction regardless of their individual needs and background”. Alternatively, learning objects should be invoked dynamically to form a learning path that is suitable to root out the learning deficiencies of individual learners. A huge focus is currently taking place to build personalized learning “road maps”. For instance, in its vision to become a leader for e-learning, Cisco’s approach shows to each learner which learning objects they have experienced and which are recommended to get them to a skill “destination”[14].

Different techniques can be used to track learners’ behaviour in order to provide personalized learning content. As learners interact with the e-learning content, results could be communicated to the e-learning system which may then adapt the content based on the learner information. For example, learners might be sent to different places in the content based on user-initiated request for clarifications, learning style, corporate role in an organization and other data. In our proposed e-learning system, each learning object has semantic connections with other objects. Different users navigate across the learning web composing the learning objects interconnectivity following different paths. The learning path-building process which contains the sequence of objects exposed to a learner is performed dynamically based on the user requests for clarification. Each request is formulated in the form of a hyperlink embedded in the text component of a learning object which links that learning object to a prerequisite learning object.
2.4. MEDIA ALLOCATION

Multimedia contributes further to learning when instructional designers use the most effective medium to present specific information. Hence, there is a need for instructional designer to map a learning content to an appropriate media. A number of empirical studies suggest how to select specific media or a combination of media for successfully presenting specific kinds of learning content as summarized in table 1. [9].

<table>
<thead>
<tr>
<th>Learning Content</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly instructions</td>
<td>Text with supportive pictures</td>
</tr>
<tr>
<td>Procedural information</td>
<td>Text with animation or video</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>Animation with explanatory verbal narration</td>
</tr>
<tr>
<td>Recognition</td>
<td>Pictures with text or verbal narration</td>
</tr>
<tr>
<td>Verbal</td>
<td>Sound or video and text</td>
</tr>
<tr>
<td>Story details</td>
<td>Video with a soundtrack</td>
</tr>
</tbody>
</table>

The content-to-media mapping shown in Table 1 has been confirmed through empirical experiments to provide the best media allocation for learning content. Assembly instructions are best comprehended when an assembly task is presented using a combination of illustrations and text highlighting the major steps. Procedural information for operating a particular device for instance, appears to be more helpful for learners to acquire when a combination of animation or video and text is presented to learners. To learn problem-solving, an animation with verbal narration was shown to be effective. For instance, solving a mathematical equation may be better illustrated through a graphical illustration. Pictures increase recognition accuracy especially when combined with text to drive the learner to focus on specific features of the pictures. Sound appears to be an effective way to communicate. For instance, in learning a particular foreign language, it would be more helpful for a learner to hear the words. But some words are context dependent and the context may be better understood if shown through video. And to help the language-learner further, a textual version of the words’ phonetic would reinforce the learning process of such verbal information. Finally, recalling story details would be more effective with a video or a soundtrack.

The e-learning system presented in this paper would be more effective with a video or a soundtrack. Verbal information. Finally, recalling story details would reinforce the learning process of such verbal information.

Table 1. Media Allocation

[See Table 1.]

2.5. DELIVERY MODES

Due to the advances made in networking technology as well as the widespread availability of personal computers, the focus of e-learning has shifted from delivery considerations to development considerations [11]. The above network term is used here to refer to computer network. In e-learning environments, the term network also refers to the “people network” reflecting the process by which the learners access learning material. This process includes collaboration for learning as well as the two major existing e-learning delivery modes which are synchronous and asynchronous modes. Asynchronous mode of delivery should be considered to bring to reality the vision that anyone can access education at anytime or anyplace. Synchronous delivery mode requires the learner to synchronize his or her schedule with anyone else or with any other event. By this definition, attending a class, either face-to-face or through interactive TV, or even being connected to a peer group or an instructor or a tutor are synchronous learning delivery modes.

We adopted an asynchronous approach for e-learning delivery in order to deliver learning without regard to distance or time constraints to support the “anytime, anywhere self-learning” principle. Furthermore, this mode of delivery increases the access to education to a pool of learners who currently may not have this access (either due to time, distance or technology constraints) and so it increases the scale of on-line learners community. This approach allows learners to benefit from self-learning and adaptive opportunities available on-line.

3. SELF-ADAPTIVE E-LEARNING ENVIRONMENT

This paper proposes a model for packaging learning content into learning objects and a web connectivity of learning objects through which a personalized learning route is identified automatically. We first introduce a generic representation of a learning object. Then we describe the learning web as a directed graph of learning object instances and finally we present a procedure for constructing a sequence of learning objects representing a personalized learning path within the learning web.

3.1. LEARNING OBJECT

When developing courseware content, the instructor may break down the subject matter into a network of concepts representing several layers of varied details and depth to achieve the instructional goals. Supporting this same process, learning objects represent small and reusable chunks of instructional media. This object-based segmentation of knowledge has been adopted in this paper to provide a constructive approach to e-learning [13]. Learning objects are assembled to form courseware content in a process centered on the learner to “free them from the drudgery of doing exactly similar tasks unadjusted and untailored to their individual needs” [11]. The
structure of a learning object that we propose to capture learning in different media is depicted in Figure 2. A courseware structure is represented as a web of learning objects for a particular course representing the various concepts interdependencies among learning objects. A learning path is a subset of the courseware web represented by a sequence of learning objects to which a particular learner get exposed during a learning session.

As shown in Figure 2, our learning object construct is rather media-centric which captures both tangible and intangible formats of learning. The text script, video and images represent the static attributes of the learning object. These are the attributes which cannot be modified when reused. Assessment, synchronization, correlation, customization, analogy, media selection and layout represent the dynamic attributes which can modify some aspects of the learning objects when reused. Media selection allows a learner to customize the object to zoom on a particular media in case the learning object is a combination of multiple media. Synchronization refers to the level of synchronization involved in combining multiple media. Layout describes the actual space distribution of the learning media in user interface. Identification represents the ID of the learning object. Assessment corresponds to a particular assessment strategy by which the learner can assess his understanding of the material embedded in the learning object. The rest of the attributes are described in some more details in the following sections.

a) Correlation
The correlation attribute provides the self-adapativity nature of the learning process. Adaptivity is obtained as independent learning objects are assembled and implemented in response to current learner states. As a response to a learner state, a new learning sequence of learning objects may be generated to control the self-adjustment of the presented material to the learner state. The question is how to identify a learner state in order to trigger the corresponding sequence of objects? One possible way that has been adopted in the system presented in this paper to identify the learner state is through the inserted hyperlinks in the learning objects’ text script. Note that this also an alternative to index the video script. These hyperlinks provide learners with opportunities to interact with the system to define their own learning state. That is, should the material presented in the current learning object requires prior knowledge about other concepts for which learners may not have the necessary background, the required concepts (represented by their textual terms) are hyperlinked to a sequence of learning objects authored or reused by the course instructor. While some learners may have knowledge about the necessary prerequisite concepts, and thus do not wish to waste their time re-learning them, some other learners who may lack such background will be able to reach the understanding of such background with the comfort of a single mouse-click which will trigger the corresponding sequence of learning objects to be automatically visualized. The system is thus able to self-adjust the presented learning material based on the behaviour of the learners as dictated by the constructivist approach. Different learners follow different learning routes suitable to their background and understanding level. Later in this paper we present an algorithm that builds a learning route dynamically based on the learners’ interaction with the system.

The learning objects’ correlation model is an attempt to model the student’s understanding of the subject matter. Such modeling aims at detecting deficiencies in the student comprehension and to reinforce the presentation of certain subject matter [2]. Learning models have ordinarily been heavily dependent on specific topics and were not directly applicable to arbitrary courseware so far.
b) Customization
Learners are given here the opportunity to augment learning content during instruction. This process assumes an authentication process for learners who may then take notes through the system at playback time to reflect their own understanding of the presented material. These notes are attached to the profile of the learner for the object currently being played.

c) Analogy
In many instances, different instructors or courseware authors may teach the same subject and may consequently develop their own learning objects. The analogy attribute reflects the set of other objects which semantically represent the same concept. It gives to the learner alternatives to comprehend further the same subject matter.

3.2. LEARNING WEB
A learning web represents a particular courseware designed by the course author. An example of a learning web is shown in Figure 3. The learning web is constructed by the courseware author simply by identifying the sequence of learning objects references which participate in the courseware. These learning objects are mandatory objects in the sense that the learner must visit them to fulfill the courseware understanding requirements. The mandatory learning objects are the objects through which the learning path must pass i.e. the learner must be exposed to those objects. After the selection of the mandatory learning objects and their sequence, the courseware author considers then each mandatory object individually to identify its correlative sequence of references to secondary objects. The process of building a correlative sequences is re-iterated on each secondary object. Secondary objects are objects of the learning web which may be added to the learning path dynamically based on the learner interactions with the learning objects.

The above learning web structure represents a body of knowledge, which is highly structured. Full comprehension of a topic may be dependent on the understanding of one or several other concepts. In a properly organized course, a particular concept is presented only after all concepts, on which it depends, have already been presented. Furthermore, a competent instructor will not proceed before insuring that the majority of the students have mastered or at least have been exposed to the prerequisite concepts otherwise, the instructional process will not be very effective. All this leads us to the conclusion that the organization of knowledge within a subject matter has the form of a directed graph, similar to the PERT charts used in project management.

While this paper focuses on learning objects as an atomic learning structure, a future work considers a higher-level structure which is a courseware object which structure is similar to a learning web. Learning
objects constitute then the building-blocks for the courseware objects. The objective of such future work is to allow learning objects reuse as well as courseware objects reuse. This multi-layer learning reuse would provide coarse and fine-grain reuse. As mentioned earlier in this paper coarse grain learning objects such as courseware objects reduces their reusability and that is why we provide a finer-grain reuse at the level of learning objects.

3.3. LEARNING-PATH CONSTRUCTION

ALGORITHM

The learning web represents the algorithm’s search space for a learning path. The entities of the learning web are references to learning objects. These are entities through which the learning path passes. The mandatory learning objects must be in the learning path. The algorithm requires the cooperation of further secondary learning objects to find a self-adjusted learning path over the learning web. Initially, a learner initiates the learning process by requesting a courseware represented by its associated learning web. This request triggers the search for a learning path. Thus, a learning web forms the input of the self-adaptive e-learning algorithm. The goal of this algorithm is to define a learning path for each learner. The learning path gets updated dynamically throughout a learning session when a learner invokes a correlative learning sequence. A correlation is triggered by the learner in hope of clarifying some misunderstood concepts in the current learning object. As a result, the sequence of objects associated with the current learning object correlation become mandatory objects and are scheduled for playback. This type of navigation provides the self-adaptive dimension of the e-learning system proposed in this paper. As shown earlier, learning objects construct a correlation attribute which represents the alternative sequence of learning objects to expose to the learner should he lack some prerequisite concepts. When no interaction occurs during the playback of a learning object, the transition to the next learning object is dictated by the current sequence of mandatory objects.

The learning-path planning process complexity is cut down by pruning the alternative correlations that do not satisfy some constraints. For example, a learner can specify not to have certain learning objects on the path, because for instance he is aware of the corresponding concepts. This can be stated by indicating the identity of each individual learning object or even by pointing out a courseware. Another constraint that can be specified is the maximum time the learner is going to spend for a learning session. This unique feature self-adjusts the sequence of the presented learning objects based on the time a learner can afford to allocate to a learning session. The time attribute corresponding to each learning object is calculated based on the length of the learning media (i.e. video-clip time). Other constraints can be the number of intervening objects.

The algorithm described in Figure 4 is event-driven where events are triggered whenever a learning object is to be invoked. Learning objects are invoked remotely since they are assumed to be distributed in the learning network of an institution. Each invocation results in the construction of a local copy of the learning object which is then inserted in the learning path. An Object Request Broker assumes the responsibility of fetching remote learning objects. Once a learning path has been constructed, it then represents the learner’s version of the courseware customized to his background. The learning path is then stored in the learner profile for the particular courseware he initially requested to attend.

The e-learning system architecture is based on a client/server framework where the server’s role is to fetch the invoked learning objects by the client application. A 5-tuple data-structure is maintained by the client application \( [R, P, E_P, C, D] \) which are described in Table 2. The event-driven algorithm shown in Figure 4 recognizes three types of events that can occur during the playback session of a learning object: correlation, backward move and forward move. Correlation move occurs when the user invokes the playback of a correlative sequence which results in inserting the actual objects of the correlative sequence in the learning path to prepare their playback. Backward event occurs when the learner moves backward in the learning path constructed so far. This move results in restoring the learning path to the state in which it was prior to playing the current object. Forward event corresponds to a move to the next learning object to play in the current learning sequence of mandatory learning objects.

The algorithm starts by invoking the first learning object in the learning sequence \( P \). A local copy of the invoked object is created and inserted in the learning path, and then its media content is visualized. If the learner clicks on a hyperlink inserted within a learning object during its media playback, a correlation event has then occurred. The objects in the corresponding correlative path are then scheduled for playback and their references are inserted in the list of mandatory objects. Learning objects are displayed to the learner as long as the following constraints are satisfied:

1. The learning objects should not be in the path constraint \( E_P \)
2. The learning object has not already been visited
3. The learning object does not violate the cost or time constraints function \( C \).
Table 2. Algorithm’s Data Structure

<table>
<thead>
<tr>
<th>Label</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P$</td>
<td>A sequence of references to mandatory learning objects representing the targeted learning concepts initially containing the mandatory learning objects for this courseware. $(P=[p_1,p_2,...,p_n])$</td>
</tr>
<tr>
<td>$R$</td>
<td>The actual learning path for the current courseware object containing initially an empty set $(R={})$ but will be updated during a learning session by the visited learning objects and their sequence.</td>
</tr>
<tr>
<td>$E_P$</td>
<td>Path constraints; i.e. a list of learning objects to be excluded from the learning path</td>
</tr>
<tr>
<td>$C$</td>
<td>Cost constraints; i.e. constraints such as the number of learning objects on the path or the maximum time the learner can afford to allocate to a learning session.</td>
</tr>
<tr>
<td>$D$</td>
<td>Accumulated cost along the learning path.</td>
</tr>
</tbody>
</table>

The algorithm analyzes each learning object prior to its playback to show to the learner the appropriate correlations that satisfy the time and cost constraints and do not lead to a cycle. These correlations are reflected in our case through hyperlinks in the text script area of a learning object. The hyperlinks will not be active if the associated concept or sequence does not satisfy the abovementioned constraints.

1. While $(P\neq \emptyset)$ // As long as the target objects have not been visited
2. $t_i \leftarrow$ Invoke $(P,First)$ // Retrieve the object at the head of the targets list and // create a local copy of the object.
3. $T_i = t_i.Correlation$ // Retrieve the sequences of correlative paths. $T_i$ refers to // all the learning objects in the correlative sequences of $t_i$. $T_i^{(1)} \leftarrow T_i^{(1)} \cap E_i^{(1)}$ // Remove the excluded learning objects
4. $T_i^{(2)} \leftarrowApplyCost(T_i^{(1)})$ // Remove the correlations which violates the cost constraints
5. $T_i^{(3)} \leftarrow T_i^{(2)} \cap (T_i^{(2)} \cap R))$ // Remove the visited correlative objects to avoid cycles
6. $t_i^{(1)} .Correlation \leftarrow T_i^{(3)}$ // Update the learning object $t_i$ with the correlations in $T_i^{(3)}$ // i.e the empty correlations as a result of the // above transformations are not proposed to the learner.
7. Play $(t_i^{(1)})$ // Play the learning object $t_i$ and display the correlations in $T_i^{(3)}$
8. WHILE (NOT EndPlayback($t_i^{(1)})$) // As long as $t_i^{(1)}$ did not terminate
9. SWITCH (Event($t_i^{(1)})$) // Listen to events
   a. CASE Correlation // A correlation has occurred
      i. $CS_i \leftarrow$ Retrieve $(T_i^{(1)})$ // Retrieve the activated correlation i.e retrieve the // path of

objects’ references associated with the // activated hyperlink
   ii. $P^{(1)} \leftarrow Insert(CS_i,P)$ // $CS_i$ is inserted at the head of P.
   iii. Append $(t_i,R)$ // $t_i$ is appended to the tail of R
   iv. GOTO 1 // To play the first object in the correlative sequence
   b. CASE Backward // The learner invoked the previously played object
      i. $t_j \leftarrow R.Last$ // Retrieve the previously played object
      ii. $T_j \leftarrow t_j.Correlation$ // Retrieve the correlative sequences in $t_j$
      iii. $P^{(1)} \leftarrow Remove (T_j,P)$ // Remove $t_j$’s correlation in P if any.
      iv. $P^{(2)} \leftarrow Insert(t_i,P^{(1)})$ // Insert back $t_j$ at the head of P.
      v. GOTO 1
   11. ENDCASE
   12. ENDWHILE (9)
   13. $P^{(1)} \leftarrow Remove (t_i^{(1)},P)$ // Remove the played learning object $t_i$ from P
   14. Append $(t_i,R)$ // Add $t_i$ to the tail of R
   15. ENDWHILE (1)

Figure 4. Learning Path Construction Algorithm.

4. CONCLUSION

While existing educational tools attempt to simulate the role of a teacher, this paper focuses rather on the learner by offering self-adaptive multimedia learning opportunities to comprehend courseware concepts. In doing so, this paper made the following contributions to the learning process: 1) Defining an object-based approach for e-learning, 2) Developing an algorithm for self-adaptive learning to adjust the presented material based on the learner background, 3) Presenting learning material using a variety of media such as video, images and text, 4) Providing interactivity features with the courseware to involve learners in building their own understanding of the presented concepts.

5. REFERENCES


