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**Adaptive e-Learning Environment Systems and Technologies**

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**Abstract**

This article discusses the rapidly developments of adaptive e-learning environments. Adaptive learning is an important research topic in the field of web-based systems because there are no fixed learning materials, strategies and paths which are appropriate for all learners. However, most studies in this field have only focused on learning styles and habits of learners. Therefore, it is becoming increasingly difficult to ignore adaptation in the field of e-learning systems. The term adaptive e-learning refers to the ability of a system of e-learning to provide courses and learning objects calibrated on the instructional needs of the learner. The underlying assumption is that teaching content adapted for some users may not be appropriate for the others. The adaptive e-learning systems employ utilize models of the user. A user model is an internal representation of the user's properties. Adaptive learning dynamically adjusts the level or types of instruction based on individual student abilities or preferences, and helps personalize instruction to improve or accelerate a student’s performance. Adaptive e-learning systems are generally built on three core elements: a content model, a learner model, and an instructional model. A content model refers to the way the specific topic, or content domain, is structured, with thoroughly detailed learning outcomes and a definition of tasks that need to be learned. Adaptive systems make statistical inferences about the student’s knowledge based on their performance; they must “model” the learner. Learner models continue to become more complex, considering additional variables such as the student’s motivational state and emotional response. The instructional model determines how a system selects specific content for a specific student at a specific time. This paper presents history of adaptive instructional systems, concepts and features of adaptive e-learning, approaches of adaptive e-learning, parameters of abilities and aptitudes variables in e-learning adaptive systems, types of adaptive educational systems and examples of e-learning adaptive systems.

**Keywords:**
Adaptive e-learning systems - Adaptive e-learning Technologies - Adaptive e-learning Environments
History of Adaptive Instructional Systems

Adaptive instruction has a long history and has been implemented in various forms and settings, from group-based, classroom instruction to Web-based, open space instruction. The development of computer technology has provided a powerful tool for developing and implementing sophisticated instructional systems from diagnostic assessment tools to tutoring systems generating individually tailored instructional prescription. Recent advances in information and communication technology (ICT) allow for the delivery of individually customized information and instruction to mass audiences simultaneously (Lee & Park, 2004, p. 470).

The long history of efforts in adapting instruction to an individual student’s needs and abilities has been documented by many researchers. Since at least the fourth century B.C., adapting has been viewed as a primary requirement for successful instruction, and adaptive tutoring was the common instructional method until the mid-1800. Even after graded systems were adopted, the importance of adapting instruction to individual needs was continuously emphasized. Dewey, for example, in his 1902 essay, Child and Curriculum, deplored the then current emphasis on a single kind of curriculum development that produced a uniform, inflexible sequence of instruction. Thorndike (1911) argued for a specialization of instruction that acknowledged differences among pupils within a single class as well as specialization of the curriculum for different classes. Since then, various approaches and methods have been proposed to provide adaptive instruction to individually different students. Since Cronbach (1957) declared that a united discipline of psychology would be interested in not only organisms but also interactions between organisms and treatment variables, numerous studies have been conducted to investigate what kinds of student characteristics should be considered in adapting instruction and how instructional methods and procedures should be adapted to those characteristics. (Lee & Park, 2004, p. 470-471).

The origins of the adaptive learning technology can be traced back to the necessity of assisting students with special needs, such as large font type and audiobooks, but it wasn’t until the 1980s that computer technology was identified as a means through which these students could receive the instruction and assistance they required in order to succeed in a classroom setting. These efforts were expanded in the 1990s when the emergence of interactive hypermedia, greater computer availability and the dawning of the internet age allowed for the creation of more effective adaptive and assistive technologies to aid those in need (Izumi, Fathers & Clemens, 2013, p. 6).

Concepts and Features of Adaptive eLearning

Concept of Adaptive eLearning

There are several definitions of adaptive e-learning environment, as following:

- An adaptive system for e-learning, which provides students with all paths from an initial knowledge to a desired one. The paths are retrieved and optimized based on student profile and teacher profile. Thus discarding those paths, which are not in accordance with the student's needs; the remaining paths are presented to the student to select one path and learn its course units (Carchiolo, Longheu, & Malgeri, 2002).
Learning environment is considered adaptive if it is capable of: monitoring the activities of its users; interpreting these on the basis of domain-specific models; inferring user requirements and preferences out of the interpreted activities, appropriately representing these in associated models; and, finally, acting upon the available knowledge on its users and the subject matter at hand, to dynamically facilitate the learning process (Paramythis & Loidl-Reisinger, 2004).

Adaptive learning systems refer to technologies design to adapt the learning performances of individual students and customize content based on those preferences (Sonwalker, 2005, p. 2).

Adaptation system is the central component of any E-learning system and is responsible for tailoring learning materials or contents according to the learner’s style, profile, interest, previous knowledge level, goal, pedagogical method etc. to provide highly personalized learning sessions. Adaptive E-learning systems, deal with appropriate personalization and adaptation techniques (smart curriculum sequencing, navigation guidance, intelligent problem generation and analysis of solutions, adaptable interfaces, adaptive contents, etc.) in order to maximize the effectiveness of learning (Kumar, 2006).

The term “adaptive learning” means the capability to modify any individual student’s learning experience as a function of information obtained through their performance on situated tasks or assessments (Pavlov & Paneva, 2006).

Adaptive technology is defined as software that learns and alters itself based on the user’s inputs, while allowing for interaction with a broad base of learning styles. It is based on the theoretical concept of adaptive learning (Izumi, Fathers & Clemens, 2013, p. iii).

Adaptive learning is a method of education that seeks to personalize learning by using sophisticated algorithmic technology to continually assess students’ knowledge, skill, and confidence levels, and design targeted study paths based on the resulting data (Izumi, Fathers & Clemens, 2013, p. 5).

Related Concepts

There are three terms (adaptation, adaptive and adaptable) used with interchange in this field, but they are not the same:

- **Adaptation**: adaptation is “a process or strategy for generating better-performing solutions to a problem by reducing the initial uncertainty about the environment via feedback information made available during the evaluation of particular solutions” (DeJong, 1975, p. 5). Adaptation has two levels: adaptive or adaptivity and adaptable or adaptability.

1. **Adaptive or Adaptivity**: Adaptivity refers to the capability of a system to alter its presentation according to the student characteristics automatically. Systems that can adapt automatically to the users based on the system’s assumptions about user characteristics are called adaptive.

2. **Adaptable or Adaptability**: Adaptability refers to the capability of the system to support user modification. Systems that allow the user to make changes certain
parameters and adapt their behavior accordingly are called adaptable. In designing the adaptive e-learning system, it is important to balance between these two levels of adaptation.

**Adaptive eLearning Cycle**

There are iterative processes or tasks of adaptive learning systems. Shute and Zapata-Rivera (2007, p. 9) defined four-process cycle: (a) capture, (b) analyze, (c) select, and (d) present (Figure 1):

![Figure 1. Four-Process Adaptive Cycle (Shute & Zapata-Rivera, 2007)](image)

1. **Capture.** The capture process entails gathering personal information about the student as he or she interacts with the environment. Relevant information, obtained through formative or summative assessment, can include cognitive as well as noncognitive aspects of the learner. This information is used to update the internal student model maintained by the system.

2. **Analyze.** The analyze process requires the creation and maintenance of a student model by properly integrating evidence sources from student performance in the environment. This usually involves representing information in the student model through inference mechanisms in relation to students’ proficiency states based on specific performance data.

3. **Select.** Information (i.e., content in the broadest sense) is selected according to the model of the student maintained by the system and the goals of the system (e.g., next
learning object or test item). This process is often required to determine how and when to intervene.

(4) Present. Based on results from the select process, specific content is presented to the learner. This entails appropriate use of different media, devices, and technologies to effectively and efficiently convey information to the learner.

Sonwalker (2005, p. 2) defined three iterative processes or tasks of adaptive learning systems (Figure 2):

(1) The first task is to allow for various ways to organize content, offering learner different contexts and perspectives.

(2) The second task is to identify the way a learner prefers to learn by conducting diagnostic assessment of learning preference.

(3) The third task is to use assessment results to provide contentious intelligent feedback that motivate and provides guidance to overcome concept deficiencies and helps maximizing learning performance.

Figure 2: Adaptive eLearning Cycle (Sonwalker, 2005, p. 2).
Student’s Flow in Adaptive eLearning Environments

The following is student’s flow in adaptive e-learning environments based on two learning style models, which are VAK and Felder. The VAK learning styles include visual, auditory, and kinesthetic, while the Felder learning styles include global and sequential. This system will combine these learning styles to alter its course presentation to each student (Figure 3) (Surjono, 2011, p. 2352).

The Need of Adaptive e-Learning

Nowadays, personalized learning services are a key point in the field of online learning as there is no fixed learning path which is appropriate for all learners. However, traditional learning systems ignore these services requirements and deliver the same learning content to all learners. This approach may not be effective for learners with different backgrounds and abilities. In order to design an adaptive learning content, we need to enable the delivery of learning content according to particular learner’s needs (Yarandi, Jahankhani, Tawil 2013, p. 2).
Adaptive systems can be more efficient, more effective, and/or more user-friendly compared to their non-adaptive counterparts. For example, adaptive traffic control systems that considered traffic density to dynamically adjust traffic light cycles outperformed static systems (Eghtedari, 2005). Due to the perceived benefits of adaptivity, there is a large trend towards personalization technologies that adapt to user needs (Wolf, 2007, p. 8).

E-learning courses are designed based on “One Content-Fits All”, this is not true, because there are individual differences between students in abilities, cultures, backgrounds, preferences, and learning styles. The key issues characteristic of populations of online learners are their diversity. This diversity requires the presentation of different information to different learners in a different format. That is why it is very important to develop adaptive educational systems which consider various aspects of individual students in order to make the learning process as effective, efficient, and motivating as possible (Kareal & Klema, 2006, p.260). To attempt to ensure the success of these types of learners, online instruction must adapt strategies that acknowledge the individual characteristics of these learners.

Web-based courseware does not provide an effective instruction program that presents materials tailored to the individual; that is, all learners are provided with the same instruction content with little consideration of each learner’s learning style (Lee, 2012, p. 45).

Goals and Benefits of adaptive e-Learning

The goal of adaptive e-learning is delivering the right content, to the right person, at the proper time, in the most appropriate way-any time, any place, any path, any pace. In order to make the interface more user-friendly, more effective and more efficient.

Adaptivity in e-learning systems improves the quality of e-learning environments. The system might be used by learners differing in their goals, learning styles, preferences, knowledge and background. Moreover, the profile of a single learner changes. Second, the system can help the learner to navigate through a course by providing user-specific paths. Taking care of these differences, the system is able to provide personalized access to the content. The fact that the decisions on what is presented are based on the user’s profile allows taking care of a single user (Hauger & Kock, 2007, p. 355).

In the light of above, the goals of adaptive systems are:

● Delivering the right content, to the right person, at the proper time.
● Presenting educational framework supporting flexible instructional variations.
● Providing instructional pathways that can accommodate learning styles and learning strategies.
● Monitoring educational processes, generating reports and providing guidance more effectively.
● Providing contentious intelligent feedback.
Categories of adaptation in e-Learning environments

There are many categories of adaptation in e-Learning environments (Paramythis & Loidl-Reisinger, 2004). They are:

   This category refers to adaptations that take place at the system’s interface and are intended to facilitate or support the user’s interaction with the system, without modifying in any way the learning content itself. This level includes: the employment of alternative graphical or color schemes, font sizes, etc., to accommodate user preferences, requirements or abilities; the reorganization or restructuring of interactive tasks at the syntactic level of interaction; or the adoption of alternative interaction metaphors at the semantic level of interaction.

2. Adaptive Course Delivery.
   This category constitutes the most common and widely used collection of adaptation techniques. The term is used to refer to adaptations that are intended to tailor a course to the individual learner, to optimize the “fit” between course contents and user characteristics / requirements, so that the “optimal” learning result is obtained, while in concert, the time, effort and interactions expended on a course are brought to a “minimum”. Major factors behind the adoption of adaptive techniques in this context include: compensating for the lack of a human tutor, who is capable of assessing learner capacity, goals, etc., and advising on individualized “curricula”; improving subjective evaluation of courses by learners, etc. The most typical examples of adaptations in this category are: dynamic course (re-)structuring; adaptive navigation support; and, adaptive selection of alternative (fragments of) course material.

3. Content Discovery and Assembly.
   This category refers to the application of adaptive techniques in the discovery and assembly of learning material / “content” from potentially distributed sources / repositories. The adaptive component of this process lies with the utilization of adaptation-oriented models and knowledge about users typically derived from monitoring. At this point, we would like to make an explicit distinction between the perspective of the individual learner wishing to locate relevant material within a (possibly constrained) corpus, and the perspective of the author or “aggregator” who undertakes the task of putting together a course from existing materials and targeting a specific audience – or, seen differently, collecting and tailoring material for accommodating specific user / context characteristics, adaptation may very well be suitable in both perspectives.

   Adaptive Collaboration is intended to capture adaptive support in learning processes that involve communication, collaboration and social interaction between multiple learners. This is an important dimension to be considered as what modern learning theory increasingly emphasizes: the importance of collaboration, cooperative learning, online communities, social negotiation, and apprenticeship in learning. Adaptive techniques can be used in this direction to facilitate the communication / collaboration process, ensure a good match between collaborators, etc.
Adaptive Requirements for e-Learning Systems

Following educational requirements for adaptive systems can be identified (Kareal & Klema, 2006, p.260-261):

• Information should adapt to what a learner already knows (prior knowledge) or can do (prior skill).
• Information should adapt to a learners’ learning capabilities.
• Information should adapt to a learners’ learning preferences or style.
• Information should adapt to a learners’ performance level and knowledge state (i.e. system should provide feedback).
• Information should adapt to a learners’ interests.
• Information should adapt to a learners’ personal circumstances (location, tempo, etc.).
• Information should adapt to a learners’ motivation.

Standards of adaptive e-Learning

Wolf (2007) identified four main categories for requirements for adaptive e-learning standards. The first one comprises all aspects of describing the learning content itself. The second one deals with pedagogical issues, while the third one addresses didactics. The fourth and final category is about adapting the learning process.

A. Requirements for learning content

Generally, learning content comprises assets – atomic elements like a picture, a paragraph, etc. – and learning objects which define a digital resource that is used to support learning. The relevancy of artifacts for given situations and concepts.

(A1) Defining different types of assets (e.g. text, picture, audio, video, a hyperlink or even a link to a knowledge domain or concept).
(A2) Supporting different types of learning objects (e.g. content, exercises, examination, etc. and any combination of these types).
(A3) Providing different levels of detail for a learning object (e.g. to address different levels and types of learning objectives).
(A4) Separating content and presentation for a learning object and offering different visual representation variants (e.g. for a certain device, browser or bandwidth)
(A5) Creating a learning object through aggregation of different assets.
(A6) Modeling knowledge domains and their concepts including overlapping domains or concepts.
(A7) Modeling contexts and their situations including overlapping contexts and tasks
(A8) Modeling tuples of concepts and situations and dependencies between them, regarding the prevention of a dependency loop.
(A9) Mapping a learning object to concepts of domains and contextual situations.
B. Pedagogical requirements

Pedagogical requirements for standards mainly deal with user profiling specifications and learner characteristics.

(B1) Defining static and dynamic information attributes of a learner.

(B2) Providing management (like storage, deletion or update) of attributes in real-time.

(B3) Supporting an enhanced learner tracking and modeling (e.g. observing the learning process, the paths through the courses, all learning objects and assets).

(B4) Mapping a learning object to a learner’s characteristics.

C. Didactical requirements

Didactical requirements for standards mainly deal with describing objectives, learning activities and instructional sequences, determining the relevance of instructions for given learning objectives, defining the suitability of instructions for learners and assessing the learning progress according to given mastery levels.

(C1) Allowing to change the order of the instructional sequence.

(C2) Providing different types to sequence instructions (e.g. linear, conditional branches, loops, etc.).

(C3) Allowing the insertion of instructions into the instructional sequence.

(C4) Defining pre and post-conditions for instructions.

(C5) Assessing mastery level of learners applying adequate activities (e.g. quizzes, submission tasks, etc.).

(C6) Mapping instructional sequences to learning objectives (e.g. didactical strategies).

(C7) Mapping instructional sequences to pedagogical states (e.g. learning units suitable for different learning styles).

D. Didactical requirements

This category of requirements for adaptive e-learning standards is about the three methods to adapt the online learning process: (1) adaptation of instructions, (2) adaptation of the instructional sequence, and (3) adaptation through providing additional instructions. Therefore, requirements for standards mainly refer to the requirements of the last subsections and can be summarized as follows:

(D1) Defining rules observing pedagogical and didactical states and models (A6-A9, B1-B4, C4-C5) and triggering adaptation of instructions (A1-A5).

(D2) Defining rules observing pedagogical and didactical states and models (A6-A9, B1-B4, C4-C5) and triggering adaptation of the instructional sequence (C1-C2).

(D3) Defining rules observing pedagogical and didactical states and models (A6-A9, B1-B4, C4-C5) and triggering the insertion of new instructions (C3).

Framework Components of Adaptive System Models

Adaptation in e-learning environments is based on a rather well-established set of models and processes. There are three common content-based matching approaches. The first approach uses stereotypes. Based on certain variables (e.g., performance in tests or results of a questionnaire), new learners are categorized into stereotypes. Examples for
these stereotypes are a classification of their prior knowledge (e.g., novice, intermediate, advanced) and their learning style (e.g., verbal, auditory, kinesthetic). The second approach uses an overlay model. In this approach, the learner’s knowledge is continually measured and then remodeled in computer memory. The computer matches the model with an existing content model (also referred to as a “domain model”). Following this, the computer identifies existing prerequisites and only offers content that is ready to be learned. The complexity of the overlay model depends on the granularity of the content. Finally, the combination model combines the stereotype and the overlay model. This can be achieved by stereotyping the learner initially and then progressively adjusting the stereotype with the acquisition of more data on learner characteristics, as pictured in Figure 4. These data are fed back into the learner model (Wolf, 2007, p.77-78).

![Figure 4: Schematic view of combination model (Wolf, 2007, p.78)](image)

This section presents brief accounts of some models that one typically encounters in ALEs: domain model, learner model, group models and adaptation model.

1. Domain Model.

Since most current ALEs are focused on adaptive course delivery, the domain-, or application- model is usually a representation of the course being offered, and may additionally contain information about workflows, participants, roles, etc. Adaptive-course models are usually based on the identification of relationships between course elements, which are subsequently used to decide upon adaptations (Brusilovsky, 2003).

2. Learner Model.

The adaptation of an educational environment is usually based on a central learner model. The term learner model is used to refer to special cases of user models, which is equivalent to a virtual representation of the learner in the memory of the computer. Most systems that interact with human users contain some sort of model of the creatures they will be dealing with. But, which parameters should this model include and how should these parameters be measured?

Several parameters have been considered in learner models. Examples include: (1) Cognitive Styles and learning styles; (2) Prior knowledge and experience; (3)
Instructional goals; (4) Performance related information; (5) Layout preferences; (6) Current work and inferred future plans; and (7) Emotions or intentions that measured heart rate, blood pressure and perspiration. These data were communicated to a learning environment, which then estimated the level of attention and interest. Accordingly, the flow and format of learning materials were adjusted.

The specific approach to modeling may vary between adaptive learning environments. Nevertheless, there is at least one characteristic shared by practically all existing systems: the model can be updated at interaction time, to incorporate elements or traces of the user’s interaction history. The learner model, not only encapsulates general information about the user (e.g., demographics, previous achievements, etc.), but also maintains a “live” account of the user’s actions within the system.

Data for the learner model can be collected implicitly, explicitly or in a combined approach. An adaptive system gathers data implicitly by observing user behavior such as time spent on a topic, navigational choices, and results of exercises. In contrast, data are gathered explicitly by approaching the learner directly with questionnaires or feedback forms. Advantages of the implicit approach are that it is less time-consuming and less intrusive. However, assumptions based on implicit data are more likely to be incorrect and thus introduce another confounding factor.

3. Group models.

Similarly to user / learner models, group models seek to capture the characteristics of groups of users / learners. The main differentiating factors between the two are: (a) group models are typically assembled dynamically, rather that “filled in” dynamically, and (b) group models are based on the identification of groups of learners that share common characteristics, behaviour, etc. Groups model are used to determine and “describe” what makes learners “similar” or not, as well as whether any two learners can belong to the same group. This dynamic approach is already used widely in collaborative filtering and product recommenders, and bears great promise in the context of e-Learning (Paramythis & Loidl-Reisinger, 2004, p. 184).

4. Adaptation model.

This model incorporates the adaptive theory of ALE, at different levels of abstraction, and defines what can be adapted, as well as when and how it is to be adapted. The levels of abstraction at which adaptation may be defined, range from specific programmatic rules that govern run-time behaviour, all the way to general specifications of logical relationships between ALE entities. The most widely known ALEs today use adaptation models that generically specify system behaviour on the basis of properties of the content model (Paramythis & Loidl-Reisinger, 2004, p. 184).

**Approaches of adaptive e-Learning**

There are four main approaches for adaptive learning, Park and Lee (2004) identified three approaches of them: the macro-adaptive approach, the aptitude-treatment interaction approach, and the micro-adaptive approach. Park and Lee (2004) are restricted to an old-fashioned view of e-learning which is focused on the content and the learning process itself. Mödritscher (2007) adds the constructivistic-collaborative approach.
1. Macro-adaptive approach

The macro-adaptive approach which can be traced back to the 1970s is about adapting instructions on a macro-level by allowing different alternatives in selecting a few main components such as learning objectives, levels of detail, delivery system, etc. In this approach, instructional alternatives are selected mostly on the basis of the student’s learning goals, general abilities and achievement levels in the curriculum structure. As adaptation decisions are determined before instruction – for example on the basis of rules – the macro-adaptive instructional approach can be characterised by the concept of adaptability (Mödritscher, 2007, p. 47).

Several macro-adaptive instructional systems were developed in the 1960s, 1970s, and 1980s. Examples of macro-adaptive instructional systems include Keller’s Personalized System of Instruction (PSI), the Program for Learning in Accordance with Needs (PLAN), Mastery Learning Systems developed by Bloom and his associates, Individually Guided Education (IGE), and Individually Prescribed Instructional System (IPI). Although many macro-level systems have been criticized as being unsystematic, they were practiced in many school classrooms for a long time, and some systems are still used. The Adaptive Learning Environments Model (ALEM) developed by Wang and her associates (Lee & Park, 2004, p. 471-472).

2. Aptitude-treatment interaction approach

Cronbach (1957) suggested that facilitating educational development for a wide range of students requires a wide range of environments suited to their optimal learning. He proposed prescribing one type of instructional sequence for a student with certain characteristics and another type for a student with different characteristics. This strategy has been based on aptitude–treatment interactions (ATIs). Cronbach and Snow (1977) defined aptitude as any individual characteristic that increases or impairs the student’s probability of success in a given treatment, and they defined treatment as variations in the pace or style of instruction.

Several studies have been conducted to find linkages between learning and aptitudes. The most important classes of learner characteristics can be summarised with the following ones: intellectual abilities, cognitive styles, learning styles, prior knowledge, anxiety, achievement motivation and self-efficiency (Mödritscher, 2007, p. 48).

Tobias (1989) pointed out a number of difficulties for this approach like the dependency on the subject area, the poor applicability to actual classroom situations, growing abilities during learning process, etc. Therefore, he proposed an alternative model, the achievement-treatment interactions, to reduce some of the difficulties. This model focuses on task-specific variables relating to prior achievement and subject matter issues. However, the fluctuating abilities and characteristics of the learner – a major problem of the ATI approach – still cannot be solved by idea of achievement-treatment interaction. Furthermore, this model also has the problem that useful information may be lost by not observing possible influences of factors like intellectual abilities, cognitive styles, anxiety and motivation.
Learner control is important concept of adaptive instruction which deals with supporting the learning process according to different abilities of the students by giving them full or partial control over the style of the instruction or the way through the course content. Snow (1980) defines three levels of control: (1) complete independence, (2) partial control within a given task scenario and (3) fixed tasks with control of pace.

Concerning learner control, it is proven that the success of different levels of learner control is strongly dependent on the students’ aptitudes, for example it is better to limit the control for students with low-prior knowledge.

3. Micro-adaptive approach

This approach to adaptive instructional learning is about adapting instructions on a micro level by diagnosing the student’s specific learning needs during instruction and providing instructional prescriptions for these needs. Researchers have attempted to establish micro-adaptive instructional models using on-task measures rather than pre-task measures. On-task measures of student behavior and performance, such as response errors, response latencies, and emotional states, can be valuable sources for making adaptive instructional decisions during the instructional process. Such measures taken during the course of instruction can be applied to the manipulation and optimization of instructional treatments and sequences on a much more refined scale. Thus, micro-adaptive instructional models using on-task measures are likely to be more sensitive to the student’s needs (Lee & Park, 2004, p. 473).

Adaptive e-learning in terms of the micro-adaptive approach is comparable to one-on-one tutoring and has to be separated in two main processes: The first part is a diagnostic process assessing learner characteristics, such as aptitudes or prior knowledge and indices of the task, for instance difficulty level, content structure or conceptual attributes. The second is a prescriptive process optimizing the interaction between the learner and the task by automatically adapting the composition and sequencing of instructions according to the students’ aptitudes and recent performance. Thus, it is necessary to define a strategy for selecting the appropriate amount of instruction and time to achieve a given learning objective (Mödritscher, 2007, p. 49).

4. Constructivistic-collaborative approach

During the eighties and early nineties, adaptive computer-based instructions focused mainly on the acquisition of conceptual knowledge and procedural skills. Computer-based learning systems were criticized by many researchers for their limited ranges and adaptability of teaching actions. In the late nineties, researchers began to examine approaches such as meta-cognitive strategies, collaborative and constructivistic learning and motivational competence in adaptive instructional systems. The approach focuses on modern aspects about how an e-learning system can be used within the learning process and deals with pedagogical approaches like constructivism, the Vygotsky’s Zone of Proximal Development and Contingent Teaching, etc. An important element of this approach is the usage of collaborative technologies which are considered often to be an essential component of e-learning.

Akhras and Self (2000) argues that constructivistic learning may benefit from a system’s intelligence including mechanism of knowledge representation, reasoning and decision making. An adaptive system enables learning by focusing on how knowledge is
A new pedagogical approach to adaptive instructional systems is to support collaborative learning activities which can be a powerful learning experience as proven by studies. The following characteristics of effective collaborative learning can be identified: (1) participation, (2) social behavior, (3) performance analysis, (4) group processing and conversation skills and (5) primitive interaction. Based on these characteristics, components for a collaborative learning system, such as a collaborative learning skill coach, an instructional planner, a student or group model, a learning companion and a personal learning assistant, can be derived. Using such components, online courses could be extended from instructional design for individual learners to collaborative activities for groups of learners (Mödritscher, 2007, p. 47).

### Parameters of Abilities and Aptitudes Variables

#### In E-Learning Adaptive Systems

E-learning adaptive systems based on many parameters, strategies and techniques. The various preferences and requirements of an individual can be captured in a learner model that can be extracted from personality factors like learning styles, behavioral factors like user’s browsing history and knowledge factors like user’s prior knowledge (Abraham, Balasubramanian, & Saravanaguru, 2013, p. 23). Adaptive learning can be based on many different abilities and aptitudes variables (Park & Lee, 2004, pp. 656-657).

1. **Intellectual Ability.**

   General intellectual ability consisting of various types of cognitive abilities (e.g., crystallized intelligence such as verbal ability, fluid intelligence such as deductive and logical reasoning, and visual perception such as spatial relations). There are interaction effects with instructional supports. For example, more structured and less complex instruction (e.g., expository method) may be more beneficial for students with low intellectual ability, while less structured and more complex instruction (e.g., discovery method) may be better for students with high intellectual ability.

2. **Cognitive Styles.**

   Cognitive styles are characteristic modes of perceiving, remembering, thinking, problem solving, and decision making. Among many dimensions of cognitive style (e.g., field dependence versus field independence, reflectivity versus impulsivity, haptic versus visual, leveling versus sharpening, cognitive complexity versus simplicity, constricted versus flexible control, scanning, breadth of categorization, and tolerance of unrealistic experiences), field-dependent versus field independent and impulsive versus reflective styles have been considered to be most useful in adapting instruction.
3. Learning Styles.

Learning style is the way a student prefers to learn. Learning style influences the effectiveness of learning. Some people may be fast learners while some may be slow, some may need to practice more problems while others may need just example. These preferences are in general called the learning styles of an individual. Majority of the research work carried out are based on the learning styles as these are the most dynamic and give the best results if catered to properly (Dag & Geycer, 2009). Efforts to match instructional presentation and materials with the student’s preferences and needs have produced a number of learning styles. Holists and Serialists; Deep-processing and Shallow processing; …etc.

4. Prior Knowledge.

Prior achievement measures relate directly to the instructional task, they should therefore provide a more valid and reliable basis for determining adaptations than other aptitude variables. The value of prior knowledge in predicting the student’s achievement and needs of instructional supports has been demonstrated in many studies. Research findings have shown that the higher the level of prior achievement, the less the instructional support required to accomplish the given task.

5. Anxiety.

Many studies have shown that students with high test anxiety performed poorly on tests in comparison to students with low test anxiety. The high anxiety interferes with the cognitive processes that control learning, procedures for reducing the anxiety level have been investigated.

6. Achievement Motivation.

Motivation is an associative network of affectively toned personality characteristics such as self-perceived competence, locus of control, and anxiety. Thus, understanding and incorporating the interactive roles of motivation with cognitive process variables during instruction are important.

7. Self-Efficacy.

Self-efficacy is a student’s evaluation of his or her own ability to perform a given task. It influences people’s intellectual and social behaviors, including academic achievement. The student may maintain widely varying senses of self-efficacy, depending on the context.

8. Multiple Intelligences

According to Howard Gardner (1998), the founder of the theory of multiple intelligences, each student has different learning methods, teachers need to realize and recognize the value of the difference (Gardner & Korth, 1998). Human cognitive abilities by multiple intelligences theory is divided into nine areas: 1) Verbal/Linguistic Intelligent 2) Logical/Mathematical Intelligent 3) Musical/Rhythmic Intelligent 4) Body/Kinesthetic Intelligent 5) Visual/Spatial Intelligent 6) Interpersonal Intelligent 7) Intrapersonal Intelligent 8) Naturalist Intelligence 9) Existential Intelligence. Considering all nine areas, it has been discovered that many have a different dominant intellectual parts. The
most important thing is that all areas are stimulated to encourage development. In addition, some dominated areas can be used to help weaker parts. The Multiple Intelligence model is depicted in Figure 5.

![Multiple Intelligence model](image.png)

Fig. 5. Multiple intelligence model (Kaewkiriya, et al., 2013. p. 623).

9. Locus of Control.

One of the major research issues in the field of adaptive interfaces is the “adaptivity versus adaptability” debate. In adaptive systems, the locus of control lies with the system, whereas in adaptable systems the locus of control lies with the learner. Therefore, adaptable systems are also referred to as customizable systems. The more these four stages are controlled by the system, the more adaptive is the environment. Conversely, the more stages are controlled by the user, the more adaptable is the environment. The finding of researches concluded that a mixed approach, where the system and the user share control, seems most promising (Wolf, 2007).

Types of adaptive educational systems

The following are e-learning adaptive systems based on one or more of these theoretical approaches.

1. Computer-Managed Instruction

This type of system based on the macro-adaptive approach, which is related to Computer Assisted Instruction (CAI). CMI systems offer functions for diagnosing learning needs and prescribing instructional activities appropriate for these needs. As an example, the Plato Learning Management (PLM) system provides tests on different instructional levels, such as a module, a lesson, a course and a curriculum. According to the performance of a student, specific instructional prescriptions like repeating the
assessment or the whole unit, offering additional instructions for a course, etc. are provided. When mastery of all objectives in the module has been reached, a student may proceed to the next module.

In addition to the test–evaluation–prescription process, a CMI system may have several other features important in adapting instruction to the student’s needs and ability: (a) The instructor can be allowed to choose appropriate objectives, modules, lessons, and courses in the curriculum for each student to study; (b) the student can decide the sequence of instructional activities by choosing a specific module to study; (c) more than one learning activity can be associated with an instructional objective, and the student can have the option to choose which activity or activities to study; and (d) because most learning activities associated with a CMI system will be instructor-free, the student can choose the time to study it and progress at his or her own pace (Park & Lee, 2004, p. 654).

CMI systems provide many important macro-adaptive instructional features allowing a teacher to monitor and control the student’s learning. However, the increase of personal computer capabilities enables aspects of personalization within CMI systems. The development of a CMI system implementing features of macro and micro-adaptive models. Contrary to other macro-adaptive instructional systems and programs, CMI systems are much more effective in terms of adaptability of the online learning process.

2. Intelligent Tutoring Systems (ITSs)

ITSs are adaptive instructional systems developed with the application of AI methods and techniques. ITSs are developed to resemble what actually occurs when student and teacher sit down one-on-one and attempt to teach and learn together.

Components of ITS.

There are three main components for ITS (Figure 6):

![Figure 6: General ITS structure](image)

1. The student-modeling module for assessing the student’s current state and determining his conceptions and reasoning strategies,
2. The expertise module for generating instructional contents on the basis of the learner’s performance
3. The tutoring module for selecting and presenting instructional material.
AI methods for the representation of knowledge make it possible for the ITS to generate the knowledge to present the student based on his or her performance on the task rather than selecting the presentation according to the predetermined branching rules.

3. Adaptive Hypermedia Systems

AHSs which is inspired, in the early 1990s, by intelligent tutoring systems arose to combine hypermedia-based and adaptive instructional systems, where adaptive and personalizing interfaces were integrated into hypermedia systems. Hypermedia-based systems allow learners to make their own path in learning. Since 1996, the field of adaptive hypermedia has grown rapidly, due in large part to the advent and rapid growth of the Web. The Web had a clear demand for adaptivity due to the great variety of users and served as a strong booster for this research area (Brusilovsky, 2001).

Definition of adaptive hypermedia.

According to Brusilovsky, adaptive hypermedia environments are “all hypertext and hypermedia systems which reflect some features of the user in the user model and apply this model to adapt various visible aspects of the system to the user” (1996, p. 88).

There are similarities and deferential aspects between adaptive educational hypermedia and intelligent tutoring systems. In comparison, intelligent tutoring systems are based on “explicit representations of tutoring, student knowledge, rules of inference about possible ways to teach content knowledge and dynamic generation of customized paths through the knowledge in response to student behavior”.

As is evident, the two definitions share the same criterion: adaptation to a model of the learner by adjusting the teaching approach. Due to these similarities, it is sometimes not easy to classify an adaptive system as one or the other. Two main criteria differentiate an ITS from AHS. Firstly, AHS is, by definition, implemented by using hypermedia, whereas in an ITS the use of hypermedia is optional. Secondly, an ITS primarily focuses on customized problem solving support and less on educational materials. In contrast, AHS is primarily concerned with adapting educational materials to alleviate learner difficulties with regards to comprehension and orientation.

Goals of adaptive hypermedia.

The goal of adaptive hypermedia is to improve the usability of hypermedia through the automatic adaptation of hypermedia applications to individual users. For example, a student in an adaptive educational hypermedia system is given a presentation that is adapted specifically to his or her knowledge of the subject and a suggested set of the most relevant links to pursue rather than all users receiving the same information and same set of links (Park & Lee, 2004, p. 667).

Components of adaptive hypermedia.

Adaptive hypermedia methods can mainly be divided into two areas of adaptation (Figure 7) (Brusilovsky, 2001):

A. the content-level adaptation or adaptive presentation, where the content is assembled or presented in different ways or orders. The goal of adaptive presentation is to adapt the content of a hypermedia page to the learner’s goals, knowledge, and other information stored in the user model. The techniques of
Adaptive presentation are (a) connecting new content to the existing knowledge of the students by providing comparative explanation and (b) presenting different variants for different levels of learners (De Bra, 2000).

B. and the link-level adaptation or adaptive navigation support, where links are generated according to different methods like direct guidance, adaptive sorting, adaptive annotation and link hiding, disabling and removal. The goal of adaptive navigation support is to help learners find their optimal paths in hyperspace by adapting the link presentation and functionality to the goals, knowledge, and other characteristics of individual learners. The techniques of adaptive navigation are: direct guidance, adaptive sorting, adaptive annotation, and link hiding, disabling, and removal links (De Bra, 2000).

Figure 7: The Taxonomy of Adaptive Hypermedia Technologies (Brusilovsky, 2001)

4- Adaptive Web-Based Learning Environments Systems (AWBLESs)

Web based learning environments have increased in popularity because they allow for teaching and learning to occur independent of place and time; and more importantly because they promise many advantages by allowing for a more interactive, personalized, and independent learning experience. Being flexible, interactive, and
resource-rich in nature, web based learning environments have great potential to support student-centered learning. Learning management systems (LMS) are powerful integrated systems that support a number of activities performed by teachers and students during the eLearning process. Although web based learning environments have unlimited prospects for educational use, namely the numerous implementation problems and challenges that are confronted when it comes to meeting all students’ instructional needs, it offer their users "one size fits all", regardless of their knowledge, goals, and interests., a recognized class of adaptive Web systems attempt to fight the "one size fits all" approach to E-Learning.

AWBLEs are a form of online instruction which attempt to address many of the aforementioned challenges of Web-based learning, by providing mechanisms to individualize instruction (e.g., content, interface, strategies, and assessment) for online learners based on their individual differences, by providing students with a more personal experience through the incorporation of various instructional strategies, resources, assessments, and interfaces.

As a general outline, an adaptive web based learning system: (1) gathers user information and preferences; (2) builds a user model based on the learner’s preferences, prior knowledge, skills and attitudes; (3) makes inferences based on the collected data and employs adaptive methods to accommodate each individual based on the developed user model; and (4) continuously monitors the user’s actions, errors, navigation, and learning process in order to update the user model depending on the collected and monitored data. Figure 8 illustrates the basic architecture of an AWBLE (Inan, Flores, & Grant, 2010, p. 149).

![Figure 8 architecture of an A-WBLE](Inan, Flores, & Grant, 2010, p. 150)
Adaptive Methods

Adaptive methods are techniques, treatments, and strategies used by AWBLES to make adjustments and variations to Web-based instructional system components in order to more fully accommodate individual differences (e.g., instructional needs, background, knowledge, and preferences) (Inan & Grant, 2008). There are several common adaptive methods used by early adaptive systems (Brusilovsky, 2001). These include such things as adaptive interfaces, content, and navigation. Inan and Grant (2008) propose a broad range of additional adaptive methods such as adaptive interaction, support, collaboration, social context, and assessment. Recently, adaptive self-regulation and learner control strategies to help students regulate their own learning in web-based learning environments (Inan, Flores, & Grant, 2010, p. 150).

Content Presentation

Content presentation relates to the best way of presenting content (e.g., amount, difficulty, sequence, resources, etc) based on a learner’s goals, prior knowledge, and other personal information. Adaptive content incorporates the use of strategies to modify the organization, format, and/or the amount of content (Brusilovsky, 2001). Additionally, adaptive sequencing, which involves the effective ordering of content, can be used to ensure that students acquire the intended knowledge or skills to be taught (Brusilovsky, 2003).

Instructional Activities

Adaptive instructional activities include: (1) Instructional approaches to support learners and to increase their engagement in the learning process; (2) Adaptive support involves providing individualized help, tailored to student needs, during the learning process; (3) Providing timely feedback in response to student actions; (4) Adaptive communication, another form of adaptive instructional activity, involves adjusting interaction type so that it is more compatible to the user model; (5) Collaboration which allows for the formation of matching collaboration groups by using system knowledge about individual users (Inan, Flores, & Grant, 2010, p. 151).

Learning Environment

The usability, accessibility, and climate of learning environment help students develop a more positive attitude towards the system. Adaptive interface is one way to instill a more positive attitude the system, the visual appearance of adaptive interface (e.g., color, font style) can be altered to better suit individual preferences. Adaptive navigation can also be used to support learner orientation in the online environment by changing the appearance and structure of navigations. Lastly, adaptive social context can be employed to provide an adjusted social context and activities, it have been reported to help maintain user interest and user appeal (Inan, Flores, & Grant, 2010, p. 151).

Student Assessment

Adaptive assessments provide learners with exposure to different types of learning tasks and problems (e.g., quizzes, product development, or group work), and can be used to target and remedy weaker skills.
Learner Control

Learner control techniques provide learners with the opportunity to control and manage their learning strategies, progress, and to manage and structure their learning environment. Adaptive system control gives each learner the option of setting system adaptation level and adaptive methods, individually or cooperatively. Adaptive self-regulatory strategies help students plan, monitor, and evaluate their own learning in web-based learning environment (Inan, Flores, & Grant, 2010, p. 151).

Researches and Studies of Adaptive Web-based e-Learning examples

There are several researches and studies of adaptive web-based e-learning:

□ **Task-Trait-Treatment Interaction (TTTI) approach.**

Abu Raihan and Han (2013) conducted study to design an adaptive Web-based e-learning environment for converging-types in light of their traits and treatment (learning strategies) characteristics. This study has identified the learning style of students by using the scientific theory of Kolb’s. It takes Task-Trait-Treatment Interaction (TTTI) approach to design the adaptive Web-based e-Learning environment for Engineering students of technical and vocational education and training in Bangladesh which considers the learning tasks and individual differences of learners such as prior knowledge, instructional strategies and learning styles that have demonstrated significant effects on students’ learning (Figure 9). This environment is an interactive system that personalizes and adapts e-Learning content, pedagogical models, and interactions between participants in the environment to meet the individual needs and preferences of users if and when they arise. The adaptation entails presenting different structured e-Learning resources in a variety of ways including, when appropriate, advice on using the materials available.

Figure 9. TTTI-approach (Abu Raihan & Han, 2013, p. 8).
The Architecture of adaptive Web-based e-Learning environment has been constructed where task-traits-treatment interaction (TTTI) focused on as it is one of the best instruction-develop approach. The adaptation i.e., the adjustment of learners have taken place with well-combinations of (i) the task characteristics (Mechanical engineering, electrical engineering, civil engineering, and computer engineering), (ii) traits of students (Assimilating, converging, diverging, and accommodating), and (iii) learning strategies (Role playing, lecture, problem solving, and group discussion). This architecture merely for TVET arena: the context of Bangladesh. In general, TVET in Bangladesh has three goals in teaching-learning: (i) to provide the technical skill rather than knowledge, (ii) to train up students with competency-based technical know-how by hand-on practice, and (iii) to develop capability with new information on science, engineering and technology. The architecture in figure 10 has made to attain the above mentioned goals.

![Architecture of adaptive Web-based e-Learning Environment](image)

**Fig. 10:** Architecture of adaptive Web-based e-Learning Environment (Abu Raihan & Han, 2013, p. 9).

□ **Adaptive Model Based on Grid Agent Technology.**

The e-learning environment is a virtual grid organization that supplies the learner with flexible and reusability learning resources, and resource sharing among learners and cooperative use of resources, so the e-learning environment can have grid architecture. So that, Liu & Liu (2008) presented a grid agent model based on artificial psychology to realize personalized e-learning. Liu & Liu (2008) saw that while learner model is considered as a part of the e-learning system in many applications, and can only be used within that particular system they belong to. Every system uses its own learner model, and therefore, several models of the same user exist within different personalization systems. This issue prevents the e-learning systems to provide better personalized support to meet the individual learning requirements.
Access Grid technology is an advanced videoconferencing application that uses audio and video tools allowing many people in different locations worldwide to meet and exchange audio and video between different computers in a virtual venue (virtual meeting room) in real time. The application software of access grid is called access grid toolkits. This is a freeware that anybody can freely download from its web site.

The architecture of this system encompasses a grid agent environment composed of three kind of agents: (1) general control (student’s agent), (2) a communication manager (manager’s agent), and (3) knowledge service (teacher’s agent). A grid agent is any agent in the grid space or Grid unit which is similar to classroom. Grid member will self-organize into grid unit. Any grid agent will register with grid manager to publish the service description of him and it can join or leave the grid unit at any time. A grid agent can contain behavior rules, and interacts with other grid agents using specialized communication language. Every grid unit has just one communication manager (fig 11).

All actions of student’s data accessing are taken by the student’s agent, thus when a teacher agent is required to update the student’s historic, this agent sends to the student agent data to be updated. The tasks performed in teaching are decomposed and performed individually or in groups of agents. The knowledge base plays an important role in this system. User psychology, a kind of implicit knowledge, is quantified and a new adaptive model involving artificial psychology. It communicates by exchanging information about the knowledge base of the whole system.

To implement the process of adaptive service, every grid agent has a repository to record the evaluation of former cases. Every grid agent should remember the evaluation of the former cases made by user and analysis the evaluation to gain experience. The grid agent use Artificial Psychology (AP) to analysis the preference of user. First, the grid agent collects the adjectives used by user to describe his or her requirements of the service. Second, the user should fill a questionnaire to describe the service that he needs. At last, the grid agent will select the appropriate service according with the user’s preference.

5- Adaptive Learning Based on Semantic Web

Recent developments of semantic web technologies have shown a trend of using ontologies to promote adaptive learning which allows us to create specific user profiles and content models. Ontology is a formal, explicit specification of a conceptualization of the specific content. They support instructors on content creation or learners on accessing content in a knowledge-guided manner (Yarandi, Jahankhani, & Tawil, 2013, p. 2).

Yarandi, Jahankhani and Tawil (2013) proposed an ontology-based knowledge modeling technique to designing an adaptive e-learning system in which learner’s knowledge, abilities, learning styles and preferences are considered in the learning process. In this
system, the ontological user profile is updated based on the abilities that learner’s achieve. The focus of this work is in proposing an ontology-based approach for developing personalized e-learning where personalization and adaptation are achieved by designing the domain model, user model and content model separately to increase flexibility and reusability of the system.

**Ontology Models**

One of the technical aims of proposed approach is to generate adaptive Online learning by offering separate content models, learners’ models and domain models to facilitate independency between any of the building models and enable the flexible adaptation of content delivery. Therefore, the domain topics and content structure is separated into separate models. Consequently, they propose an approach where three ontological models are used; user, domain and content models.

1. **User Model:** An ontological user model is designed to describe learners’ profiles (Figure 12). The Learner class is a central concept as it includes all the properties of a learner. The learner’s properties are structured in two groups including user identification information (e.g. names, passwords and emails) and learning profiles.

![Graphical representation of user model ontology](image)

(Figure 12. Graphical representation of user model ontology (Yarandi, Jahankhani, & Tawil, 2013, p. 7)

2. **Domain Model:** The domain model is a semantic ontology which is specified by the course author and forms a logical taxonomy for the knowledge domain. It specifies the topic hierarchy of learning objects. The domain ontology contains classes and properties that describe topics of a domain and pedagogical relationships between proposed topics.

3. **Content Model:** The content model ontology defines hierarchical structure of learning content with three aggregation levels namely course, lesson and instructional objects. The Course class aggregates several lesson classes via the hasPart domain property. Lesson class is an aggregation of the InstructionalObject class through hasPart property. The topic of each lesson is determined by Domain ontology through hasDomainTopic property.

**System Architecture**
Figure 13 illustrates the architecture of proposed system. The system has a central unit named Adaptive Engine and two mediators to access information and a user interface. The functionalities of the proposed units of system architecture are explained as follows:

- **User Interface**: Provides a user friendly and adaptive interface for communicating with learners. The interface communicates user characteristics to the user model ontology and returns the tailored learning content from the Adaptive Engine to the learner. The User Interface also returns learner’s responses to the Adaptive Engine.

- **Adaptive Engine** is responsible for generating personalized learning content based on the information available in the learner’s model. It obtains knowledge about learner and learning objects through related mediators. The engine also contains an assessment unit to re-evaluate the level of knowledge and ability of learners. This component gets learners’ responses to regular tests and evaluates the learner’s performance in the selected topic and also learner’s ability based on the item response theory. The user model is updated based on this evaluated information.

- **User Model Mediator**: The Mediator is responsible for handling any kind of requests for accessing and updating the user model repository.

- **Content Mediator** is responsible for searching the repository and retrieving different Instructional Object (IOs) based on different instructional role. This mediator also composes the retrieved IOs into Lessons and annotates lessons automatically. The architecture includes two repositories namely IO and user profiles. The IO repository contains all learning contents and their metadata based on the content model ontology. User profile repository contains general and educational characteristics according to user model ontology.
Adaptation Process

This system provides adaptive navigation and adaptive content for learners based on their prior knowledge, abilities and learning style. Therefore, learners should complete a registration process at the start of the first session. During this process general and educational characteristics of individual learners are recorded and a first version of the user model is created. The learner is presented with an annotated table of content (Figure 14) based on the information available in both user and domain models.

![Annotated Table of Content](image)

Fig. 14. A screenshot of the annotated table of contents (Yarandi, Jahankhani, & Tawil, 2013, p. 10)

6- Social Personalized Adaptive E-Learning Environment (SPAEE)

The various social features such as sharing, tagging, rating, commenting can be applied in e-Learning systems and thus can offer new opportunities for communication, collaboration, and active participation in the learning process. Discussions and group work are often integrated into collaborative and participative learning practice, providing a range of educational benefits by introducing a social dimension (Shi, Cristea, Foss, et al., 2013, p. 14; Shi, Awan, Cristea, 2013, p. 103).

Meanwhile, adaptive educational hypermedia use a user model to personalize the content, according to a range of characteristics, taking into account aspects such as learning goals, background knowledge and preferences. Brusilovsky (2001) and Knutov et al. (2009) classified the personalization techniques utilized in Adaptive Hypermedia into three broad areas: Content adaptation techniques; adaptive presentation techniques, and adaptive navigation techniques. However, none of these adaptation techniques takes into account any information about the user’s social connections, and there is no integration of social interaction features and adaptation techniques. Therefore, Shi, Cristea, Foss, et al. (2013, p. 14) that combining the benefits offered by existing AEH systems with the social affordances of Web 2.0 tools, offers a great potential to improve adaptive e-learning systems and learning experiences and learning outcomes via a social adaptive learning paradigm, based on social features, personalized recommendations and Facebook-like appearance of a system. They have evaluated Topolor from various perspectives, focused exclusively on studying the usefulness and ease of use of the social features in an adaptive personalized social e-Learning environment (Shi, Cristea, Foss, et al., 2013, p. 14; Shi, Awan, Cristea, 2013, p. 103).
Topolor is featured as a social personalized adaptive e-learning system, and has been used as an online learning environment at the University of Warwick to present adaptive and/or adaptable learning materials, providing Web 2.0 tools for social interaction, and monitoring learners’ behavior. Topolor consists of three sub-systems. Each of them contains a set social interaction toolset, as follows:

- **Topolor-Home** provides a chronological list of the posts shared by the students. It also provides access to the interaction tools as shown in Figure 15.

![Figure 15. Home page (Shi, et al., 2013, p. 18).](image)

- **Module Center** offers an online modules, and provides learning content, learning path, learning peer recommendation, and social interaction tools such as sending messages to recommended learning experts (Figure 16), where learners can check the module structure, go to the recommended concept page, review the concepts learnt, the quiz and questions, comment on the module, ask and answer questions related to the module, contact other learners who are learning the same module. In the concept learning page (Figure 17), the learners can learn the concept, navigate to other related concepts, contact recommended learning expert, comment on the concept, ask and answer questions related to this concept, take a note and make a task related to this concept.
Figure 16. Module page (Shi et al., 2013, p. 19).

Figure 17. Concept page (Shi et al., 2013, p. 18).
Q&A Centre maintains various lists of questions/answers related to the learning contents, and provides adaptive question, concept, and expert learner recommendation for the personalized adaptive e-Learning.

Adaptive E-Learning through Eye Tracking

Many currently available solutions are not able to fulfill all the conditions needed to solve the main problems of semantic adaptivity and personalisation. Furthermore, they do not consider important pedagogical features in any depth. Taking into account these depicted aspects, García-Barrios, et al. (2004) saw that a more extensive solution framework is needed, which allows the binding of effective modern technologies and solution approaches in order to enhance the adaptation of knowledge provisioning and to increase the effectiveness of personalization. Within the bounds of AdELE they use an eye tracking system in order to deliver interfaces adapted to users’ needs and to improve content adaptation according to the gained behavioral information of the user (García-Barrios, Gutl, Preis, et al., 2004, pp. 2-3).

AdELE defines an innovative framework for enhancing adaptive and personalized knowledge transfer processes. This is done by exploiting the advantages of merging real-time content tracking and real-time eye tracking technologies at the user’s side of the system, and encompassing the functionality of a dynamic background library at the content delivery side.

Eye movements can be divided into two components: fixations and saccades. Fixations are periods of relative stability (about 100 to 400 ms) during which part of the visual scene is focused upon in the centre of the fovea. During fixations, visual information is processed. Saccades are very rapid eye movements, about 25 to 100 ms, which bring a new part of the visual scene into focus. During saccades, little or no visual processing can be achieved. The smaller eye movements and tremors, which occur during fixations, often have little meaning in higher-level analysis.

Saccadic velocity can serve as an indicator for activation in the sense of tiredness or mental effort. It decreases with increasing tiredness and to increase with increasing task difficulty. Blink means to close the eyes for a very short period to cover them with a thin film of tears. Blink velocity and frequency together with the eyelids’ degree of openness can provide information on the user’s tiredness level.

In the AdELE framework, the intention is to observe users’ learning behavior in real time by monitoring characteristics such as objects and areas of focus, time spent on objects, frequency of visits, and sequences in which content is consumed.

The architecture of the AdELE framework is shown in Figure 18. The core module is the Adaptive Semantic Knowledge Transfer Module (ASKTM). The ASKTM coordinates all the surrounding modules and sends and requests information to and from them, and compiles pieces of content and meta-information for delivery to the learners. Separate interfaces are provided for the other two groups of users: course creators (authors) and lecturers (teachers, trainers or tutors). Content delivery is shown in the upper left and lower left parts of Figure 18.
User-centered modules are shown in the upper right part of Figure 18. The core functionality for gaining enhanced and more precise user information is located in the combination of the Eye Tracking Module (ETM) and the Content Tracking Module (CTM). ETM in combination with CTM provides real-time fine-grained data regarding the user's reading and learning behavior. The entire set of information of user interaction and behavior is supplied to the User Information Module (UIM). The Interactive Dialog Module (IDM) allows users to set and change user profile settings actively. If tiredness is suspected, IDM also may be used to suggest a short break or provide a relaxation exercise to the user. The UIM encompasses three user information databases of different granularity: the User Profiling Database (UPD), Collaborative Filtering Database (CFD) and Statistics Database (SD).
Lecturer-centered modules for the course creation process are shown in the lower right section of Figure 1. The Course Creation and Maintenance Module (CCMM) represents the core module for the entire course management and controls the Courseware Module (CM), the Course Topics Module (CTM) and Background Knowledge Module (BKM).

Models Based on Multiple Intelligences

The researches proposed methods suitable for general students but failed to offer lesson content to those who slowly fall behind (Kaewkiriya, et al., 2013, p. 622). Siksen & Tiantong (2011) presented a conceptual framework of an online based learning system with a learner guidance system base on multiple intelligence analysis, but again, lesson content was not customizable to the aptitude of the students, and focus on learning the project only (Kaewkiriya, et al., 2013, p. 622). From these problems discovered in previous researches, Kaewkiriya, et al. presented a conceptual model of an adaptive e-learning guidance system according to 3 different patterns of multiple intelligences. Each student will receive a lesson that matches their aptitude.

The Multiple Intelligence theory is divided into 3 groups. 1) Analytic group, this group focuses on analysis and the thinking processes, including logical-mathematic, musical, and naturalist intelligence. 2) Introspective group, this group focuses on imagination and understanding, including intrapersonal, spatial, and existential intelligence. 3) Interactive group, this group focuses on communication and interactive, including linguistic, interpersonal and kinesthetic intelligence. Kaewkiriya, et al. presented a conceptual model of an adaptive e-learning guidance system which consists of 5 modules (Figure 19):

![Diagram of adaptive e-learning guidance system](image-url)

Fig. 19. Framework for adaptive e-learning guidance system (Kaewkiriya, et al., 2013, p. 624)
(1) The Rule base module separates the form of students’ learning into 3 patterns from the aptitude of multiple intelligences. (2) The Recommendation module introduces students to detailed content which matches their aptitude. This module matches with rules from the adaptive module. (3) The LMS module for learning and teaching. This module is responsible for the medium between the students and the entire system. (4) The Adaptive module automatically sends the instructions to the students who need assistance. (5) The Content module stores contents of multiple intelligences approaches which consists of three types 1) Analytic content 2) Introspective content 3) Interactive content.

Models Based on Multiple dimensions

In her research Luisa dall’Acqua (2009) proposed a holistic ID model, defined PENTHA Model (acronym of Personalization, Environment, Network, Tutoring, Hypermedia, Activity), based on five conceptual dimensions: Knowledge-, Cognitive-, Didactical-, Semiotic- and Social dimension (Figure 20). It proposes rules, conditions and typologies of an adaptable e-learning process.

A. **Knowledge dimension** is a three level structure of abstraction: 1) “Learning Object” (LO), elementary didactical module, which can be used, re-used or referenced during the course session; 2) “Ontology”, graphical structure which formally describes an educational domain through the specification of a vocabulary of concepts and the identification of relations between them; 3) “Metadata”, structured data which describes the characteristics of a resource.

B. **Cognitive dimension** involves: 1) The “cognitive state” of the student, dedicated to represent the students knowledge, at any given time; 2) The “learning preferences” (such as: difficulties, language, context, typical learning time, interactivity type and level, learning resource type, semantic density, etc.); 3) The “evolution rules” of the cognitive state and learning preferences, obtained: a) confronting the test results at the end of the assessment activities and previous test results; b) observing the used

![Figure 20: PENTHA Model Dimensions (dall’Acqua, 2009)]
didactical materials, the acquired knowledge and skills, in order to determine the degree of receptivity (retention) of the learner to various types of issues/subjects.

C. **Educational dimension** consist in a set of “selection rules”, responsible for selecting the appropriate didactical nodes, and a set of “sequence rules”, to apply a proper order of the content in question. The design rules must be able to access the learner’s profile, which contains didactical preferences or prerequisites for the learner. In doing so, an individual content selection and learning process can be defined. Selection rules define the relations which were jointly responsible to identify the subsequent nodes. The result is a learner specific content graph, referred as *individual content graph*. In the learning process, the learner navigates through the individual content graph by mainly following its relations.

D. **Semiotic dimension** is realized in the specific construction of texts and their hypertext organization, the introduction of multimedia elements in the creation of "communicative situations", and the relationship between production-reception-signification.

E. **Social dimension** is a combination of the above mentioned four dimensions for the use of collaborative tools and the definition/introduction of cooperative activities (external arrows of the PENTHA model – Figure 20).

**Examples of Adaptive E-Learning Systems**

**CAST UDL Lesson Builder**

Developed by the Center for Applied Special Technology - CAST the UDL (Universal Design for Learning). Lesson Builder is a web-based resource that provides educators with models and tools to create and adapt lessons that increase access and participation in the general education curriculum for all students. Lesson Builder provides a framework for creating and implementing lessons with flexible goals, methods, materials, and assessments that support learning for all students. Once a user creates an account on the site, he/she can proceed to create lesson plans. A lesson plan template is provided with all the major headings already in place. The user then enters content in spaces provided under these sections (Figure 21).

![Lesson Builder](Figure 20: Lesson Builder)
SMART.FM (IKNOW!)

Smart.fm (formerly iKnow!) is a social learning and community website created by Cerego Japan, Inc. The website uses intelligent software algorithms to assist users retain facts in memory and increase learning speed. Users can create, manage and share lists of facts to memorize. The data is used to automatically plan a curriculum and learning strategy. In addition to the website base, Smart.fm also has an iPhone/iPod touch application, a Twitter feed, a YouTube account, and a Facebook application. Smart.fm represents the first phase of a platform that combines personalized learning applications and content creation tools in a collaborative, social environment where members study, create, re-mix, share, and manage learning content of any kind (Figure 22).

![smart.fm](image)

Figure 22: smart.fm.

iWeaver

iWeaver incorporated the adaptive navigation techniques link sorting, link hiding and link annotation. The main goal was to suggest different media experiences depending on the learner’s current preferences, whilst minimizing cognitive load.

iWeaver’s matching approaches were based on the description of styles and recommended strategies in Rundle and Dunn. iWeaver offered a number of learning tools as an addition to the described media experiences. These tools were tailored towards the different preferences in the information processing dimension of the Dunn and Dunn model. The learner model used by iWeaver was primarily based on the participant’s learning style profile. The model also included demographic data (as provided in the sign-up form), pre- and post-test answers, lesson feedback (including experience ratings),
and all navigational choices. The current learning style profile, experience ratings and navigational choices were used for adaptive recommendations. iWeaver implemented a combination of adaptive navigation and adaptive content presentation techniques to express the importance, status and relevance of hyperlinks. Learners had to choose a media experience before entering a lesson under the choice condition. Then, they could switch between experiences within the lesson by using the media experience bar. In addition, iWeaver considered implicit feedback on media experiences.

![iWeaver Interface](image)

Figure 23: iWeaver.

**CS383**

The CS383 appears to have been the first AEH system that incorporated individual learning styles. The project was motivated by the problem that learners were confused by a plethora of multimedia materials that was available in a computer systems course. CS383 was a computer systems course covered a range of topics including Internet, networks, artificial intelligence, computer graphics and office automation. CS383 used the Felder & Silverman learning style model. The learning style profile was assessed in an initial survey. CS383 adapted itself once, after the survey. Learners could choose different resources to those suggested, but they could not influence future suggestions nor change their learner model. (Figure 24).
CS383 showed four limitations in the design of the environment. Firstly, active and reflective learners were not addressed explicitly. Secondly, learners were classified as stereotypes at the beginning of the course and there was no ongoing adaptation. Thirdly, the media materials existed first and then they were classified as to how suitable they were for specific learning styles. Fourthly and lastly, learners could not influence their learner model in the environment.

**CAMELEON**

CAMELEON is an acronym for Computer Aided Medium for Learning on Network. The system used the Felder & Silverman learning style model and the respective “index of learning styles questionnaire”. The learning style profile was assessed in an initial survey. Available media types and course tools were rated on a scale from 1 to 100 on how suitable they were for particular learning styles. CAMELEON adapted itself once, after the survey. It assembled a set sequence of materials for individual learners based on their learning style. However, learners could choose to ignore their learning style and freely explore the environment.

CAMELEON showed two limitations in the design of the environment. Firstly, the active/reflective learning style elements were dismissed based on the assumption that these learners are inherently catered for by the nature of an AEH system. Secondly, the media materials existed first and then they were rated on a scale as to how suitable they were for specific learning styles. (Figure 25).
References


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