Designing Domain Model For Adaptive Web-based Educational System According to Herrmann Whole Brain Model

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Abstract: Educational materials represent a domain model of Adaptive Web-based Educational System (AWBES). However, these materials should be designed to cover the differences of learners' preferences. Herrmann Whole Brain Model (HWBM) is a reliable Learning Style (LS) model which can be used to extract the learner's preferences in educational environment according to brain structure of learner. In this paper, the learning materials of an essential programming language course (C++) are organized to cover all learners' differences according to their brain dominance. The learning materials were described and classified by instructional metadata to fit the preferences of four brain quadrants (rational, organizational, interpersonal and intuitive) within diverse learning objects. The main advantage of this approach is that it is not related to particular type of learners, but it covers the different learners according to their brain-structure. The system which could apply this model can be used to detect the learner preferences dynamically and thus personalize the learning materials within Web-based Educational System (WBES).

Index Terms— Domain Model, Adaptive Web-based Educational System, Herrmann Whole Brain Model, Learning Style, Learner Model.

I INTRODUCTION

Learning Object (LO) represents any digital learning content which can be used to develop the learning environment in order to support learning process. The main importance of advent the learning objects is the need for re-using learning materials which are authored by the teacher or another person. Currently, most of the researches in learning systems tend to enhance the machine-driven and automate of generating learning objects. For instance, the lesson is presented to study by the student through gathering a set of learning objects automatically. However, the most challenge is that how the learning objects and courses can be used to personalize the content presentation to the learner through adequate matching between learner preferences and most related learning objects. But today, achieving accurate adaptivity between the learners and their related contents of learning environment is not really possible. The automatic adaptivity requires further educational metadata to carry a useful information about each learning object[1].

IEEE Learning Object Metadata (LOM) is the most widely accepted and used standard which is made to describe the learning objects from the very practical needs for assembling different learning materials from reusable learning objects [2]. This standard identified 76 different attributes to support the interoperability and adaptivity between learner and the domain of learning objects [3]. A metadata field named <Learning Resource Type> is used as the most dominant attribute that is related to pedagogical and instructional perspectives for educational resources. The possible values of this attribute are: Exercise, Simulation, Questionnaire, Diagram, Figure, Graph, Index, Slide, Table, Narrative Text, Exam, Experiment, Problem Statement, Self-Assessment, or Lecture [4].

Dublin Core Metadata Initiative (DCMI) standard has more broad-range purposes metadata schema which comprise 15 attributes in the Dublin Core metadata set to describe the wide range of learning objects [5]. DCMI has conducted different activities through working groups, conferences, global workshops and educational efforts to identify widespread acceptance of metadata standards. The Dublin Core Metadata Element Set (DCMES) was the first metadata standard which was developed through DCMI as Internet Engineering Task Force (IETF) standard. The DCMES identified different sets of vocabulary to describe the core of information property (e.g., "Title", "Creator", "Date" and "Description") [6].

Furthermore, one of the main challenges in the existing standards is that IEEE LOM failed to represent enough and sufficient level of granularity to describe and identify the instructional part of learning resources [6, 7]. The elements of data related to learning resource type should contain both of technical and instructional information. Therefore, LOM has covered the part of instructional role of learning object (e.g., Exercise, Experiment, Simulation) and the part of technical information for LO which concern their format (e.g., Figure, Graph, Diagram, Table, Slide). However, LOM and other learning object classifications have missed to cover several instructional types such as Example, Definition, Terminologies, Theorem, Storytelling, Journaling, FAQ, Drama, and others that are needed for tracking the learners' needs and preferences in the context of holistic learning environment.

To overcome this limitation, Gascueña, Fernandez-Caballero [8] proposed a domain ontology to represent and describe the components of learning materials independently through organizing the courses into set of concepts and learning objects to be capable of providing the adaptivity and the reuse of the learning objects. These learning objects were described to cover the diversity preferences of Felder-Silverman Learning Style Model. However, the previous standards and ontologies which are designed according to pedagogical learning theories missed to cover the requirements of LSs of HWBM [9, 10].

II ADAPTIVE WEB-BASED EDUCATIONAL SYSTEM (AWBES)

An Adaptive Web-Based Educational System (AWBES) is a form of online instruction that is used to address the challenges of a WBES [11]. It provides mechanisms to track the learner interactions in order to identify the learner preferences which lead to personalising the design features of a WBES [12, 13]. This system also helps learners accomplish their learning tasks and obtain their required information by adjusting the environment according to their individual differences and thus, automatically fulfil the learners' requirements [14, 15]. As shown in Figure 1, an AWBES comprises three main components [11]: (1) Learner actions, which track and audit a learner's interactions within the design features of WBES in order to derive a learner's characteristics such as learner's preferences and styles; (2) Learner profile, which uses different methods (explicit i.e., questionnaire or implicit i.e., prototype) to identify a learner's characteristics in learner model; and (3) Adaptation methods, which are derived from a learner's characteristics in a learner model. These learner characteristics are the basic features for developing the adaptation methods of an AWBES [16]. In this research we will focus on learner actions as a main source of identifying learner characteristics implicitly.

A Learner Actions

Learner actions are used to identify the interaction preferences of learner in the system. The learner behaviour is usually used to describe the real actions of a learner within the system. Therefore, it is considered a more realistic and accurate source to build the learner model. There are two approaches of managing behaviour information within the system. In the first approach, in case of repetition of learner behaviour in the system, the system can translate the consistently repetitive behaviour into learning patterns. These patterns can be used to identify the learner's real interests and preferences according to his/her real behaviour, and thus, derive more accurate adaptation methods [17]. The second approach is a Cognitive-Science based approach, which focuses on investigating literature in different domains, such as the educational and psychological domains. For example, the Learning Style (LS) model was used to gather the prospective relationships between learners and their preferences by analysing the learners' interactions within a learning environment. These relationships are represented by predefined learning patterns [18]. Therefore, this research is conducted based on HWBM as a brain-based learning style model [19]

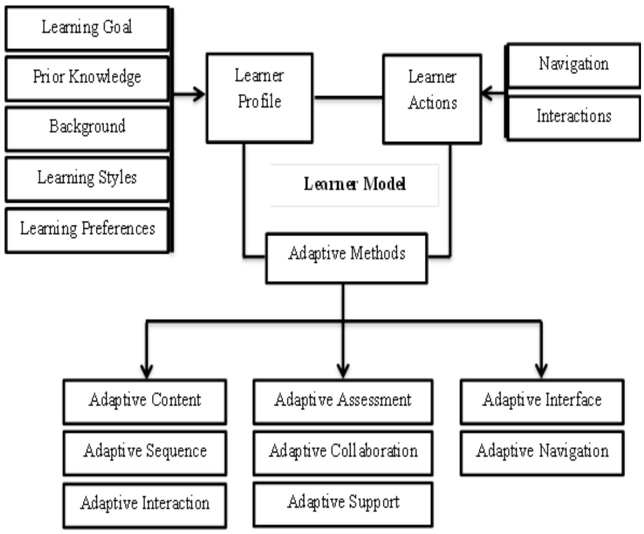

Figure 1: The Architecture of AWBES

B Herrmann Whole Brain Model Learning Style

Learning Style is used to clarify the habitual approach and individual preferences and to organise and represent information [20]. LS reflects the individual learning preferences that affect how a learner tends to acquire knowledge in the learning process [21]. Keefe in Brown, Brailsford [22] defined LS as the "characteristic, cognitive, affective and psychological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to, the learning environment.". This research has attempted to apply a brain-based LS model, where, the learner's brain structure is the dominant factor in promoting effective learning [23]. Additionally, BECTA and Radwan [24] has showed that the best approach to integrate LS with the most innate and psychological preferences is to exploit LS based on brain-based learning theories. For example, the right hemisphere of the brain accommodates creative activities, while the left hemisphere of the brain accommodates logical activities. Furthermore, LS is conceptualised as consistent patterns of learning activities that reflect the attitude, preferences, beliefs and motivational orientations of a learner towards his/her learning environment [25]. Therefore, incorporating learning patterns of LS models with the design features of a WBES is useful in linking the identification process of the LS according to the behaviour of a learner with the system rather than make the identification process static. This research in particular has benefited from using HWBM LSs for modelling the most innate and intrinsic learner preferences implicitly and automatically.

The HWBM is one of the most reliable and important LS models [26-29]. HWBM is used to extract the most innate and intrinsic learner preferences, which are derived from identifying a learner's brain dominance [27]. Furthermore, HWBM is represented by predefined learning patterns. These patterns aim to integrate a learner's brain dominance with several learning preferences and styles into the features of a learning environment [27, 30]. The HWBM shows that every learner's brain is classified into four brain quadrants [31], where each brain quadrant corresponds to a set of homogeneous LSs. QA learners can be described as having rational, analytical, logical and theoretical LSs. QB learners can be described as having organising and sequential LSs. QC learners can be described as having interpersonal, emotional, kinaesthetic, expressive and practical LSs. QD individuals can be described as having holistic, intuitive, integrated and synthesising LSs [31].

III DESIGNING CONTENT MODEL FOR ADAPTIVE WEB-BASED EDUCATIONAL SYSTEM (AWBES)

Based on the review of the HWBM LS which was conducted in [32], it has been found that learning content is an important part of the WBES design feature particularly when auditing and tracking learner behaviour in a WBES. The content model of a WBES should address the diverse learner requirements according to the HWBM LS. Here, the content model was used to propose an adaptive learner model by identifying learner preferences and LS in the WBES, via analysis of learner behaviour interaction with learning content design features. This section presents a dedicated way of structuring and classifying learning content in a WBES. The learning content should be presented using more descriptive information so that more information can be gained from the behaviour of learners within each aspect of the learning content.

A Organising Learning Content of WBES

In this study, the online course is the most complex learning object; the smallest learning objects can be represented using different parts of the learning resource including the introduction, abstract, image, figure, video, and example. The proposed structure was designed to give learners the main role in a learning process, in the context of traditional education classrooms or educational systems, as it is based on book taxonomy rather than course taxonomy.

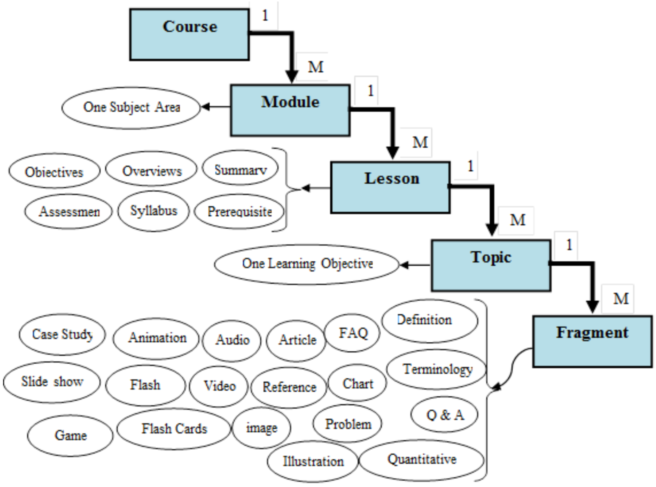

Figure 2: Organising of Learning Content in a WBES

This research conceptualises learning content using a hierarchical organisation as shown in Figure 2. Each course consists of several modules; each module consists of a set of lessons; each lesson contains a topic or a set of topics; and each topic comprises of several different types of educational resources represented by fragments. The lowest granularity level comprises the smallest learning objects, which were implemented and stored as a physical file along with its associated metadata. The programming language C++ course was selected for this study. The structure of the learning content was designed according to this hierarchy: (1) the C++ course consists of several modules, where each module covers only one subject area; for instance, statements, loops and arrays represent three different modules that demonstrate three different subjects; (2) each module consists of different lessons designed to cover a set of learning objectives; for instance, the 'for loop', 'while loop' and 'do while loop' are three different lessons related to the module of loop statements; (3) every lesson has different topics designed to achieve different learning objectives; each lesson comprises different global learning objects such as syllabus, objectives, overview and assessments; (4) every topic aims to achieve one learning objective and comprises different fragments represented by the smallest granularity of learning objects such as introduction, abstract, prerequisites, tests (pre-test or final test), example and other learning objects, which present the concepts in the topic with different styles.

According to Popescu [33], this organisation is the most applicable structural way that teachers tend to use when organising their material. Moreover, this organisational manner can be used to resolve the following issues: (1) exchanging and reusing the learning objects in different manners; (2)

tracking the learner's interactions with the different types of content learning; and (3) achieving the fine granularity of adaptivity.

B Designing Learning Object Metadata

Educational metadata was used to add descriptive information to the learning object. The metadata was applied to facilitate the association between learning objects and learner preferences so that learner preferences of learning content could be modelled. For example, Ullrich [7] and Gascueña, Fernandez-Caballero [8] proposed two independent ontologies to represent the educational metadata that associates LS with the most appropriate learning objects. However, the proposed approach by Ullrich [7] is fraught with problems. For example, the ontology that links the metadata with particular dimensions of LS is static and not related to the behavioural interactions of the learner. It also does not apply implicit techniques in learner modelling. Also, the learning object does not have enough information about the learner. The limitations of the work of Gascueña, Fernandez-Caballero [8], on the other hand, are related to linking learning objects with the Felder-Silverman learning style model. Learning objects are classified into limited categories without including significant learning objects, which may be related to other LSs such as communication LOs, help and support LOs, and several fundamental LOs (e.g., definition, objectives, problems, case studies, experiment information, etc.). Therefore, this research has added some extensions to the metadata file to better cover the requirements of the HWBM and the design features of a WBES. These extensions aim to enhance previous approaches, including the Dublin Core Metadata Intuitive, Gascueña, et al.'s [8] instructional ontology, and Ullrich's [7] instructional material. Below are the metadata characteristics of the learning objects used in this research.

C General Metadata Characteristics for Learning Object

The following metadata characteristics were selected from the standard metadata characteristics that describe learning content:

a. title (resource name) → dc:title;
b. identifier (refer to resource address e.g., URL) → dc:identifier;
c. type (refer genre, nature or form of the content of the resource e.g., service, software, collection, moving, image or sound) → dc:type; and
d. format (the digital or physical manifestation of the resource e.g., size, number of pages, and duration) → dc:format.

D Educational Learning Object Metadata

The hierarchal educational learning objects were used to describe the learning resources, which are related to the learners' preferences according to the Herrmann Whole Brain learning theory. The proposed metadata does not describe the learning content. However, it is used to classify the learning content, where each class of metadata refers to a particular instructional role and its related learning resource [34]. The instructional role is a kind of protocol specification that identifies characteristics and behaviour, but not the role player itself [35, 36]. Integrating instructional roles into the metadata model can solve the problem of annotating different theories and instructional principles in the learning design [36]. In other words, instructional roles can facilitate learner modelling, enable automatic modelling, and are initiated as centres of reference.

As illustrated in Figure 3, the proposed hierarchy of educational learning objects aims to represent the different instructional roles for learning resources. The hierarchy components were identified from the confirmed requirements design features of the HWBM LS, which investigated in [19, 32]. Each class of the proposed metadata represents a particular instructional role that allows mapping, exchange, reuse and search at this level. The proposed hierarchy presents a set of categories; and each instructional role identifies a set of vocabulary within a category. The Educational_object is the root of the metadata structure. Two main classes are identified as subclasses of Educational_object, i.e. the Fundamental_concept and the Auxiliary_concept. Both classes are grouped into four categories of learning objects (i.e., theoretical, procedural, practical, and interactive) according to the confirmed learning content design features of HWBM LS. Fundamental_concept refers to the main learning objects being presented for the whole lesson (covers a number of topics) in a particular course. Auxiliary_concept covers the supplementary knowledge or resources being presented i.e. presentation of the details of each topic in a particular lesson. For instance, theoretical classes are subsumed under Fundamental_concept and Auxiliary_concept. Theoretical class for Fundamental_concept can be presented by a number of learning objects such as objectives, prerequisites, problems and individual assignments. On the other hand, theoretical class for Auxiliary_concept can be presented by a number of resources and learning objects such as book chapters, flowcharts, and explanations.

The aforementioned descriptors are structured based on the HWBM LS. However, a WBES can infer the actual learning preferences of learners by analysing the their behavioural interaction with the designed learning objects described by these metadata (e.g., time spent, hit rate and visited rate on each learning object). Furthermore, the hierarchy of educational metadata is useful in gathering more behavioural information since the information about the visited learning resources will be identified later by the designer or teacher. The proposed structure of the instructional role is frequently associated with the diverse population of learning objects that cover all requirements of learners according to the brain-based structure. A teacher has to annotate these learning objects (static descriptions) once only. The behavioural interactions of a learner with the WBES are used to annotate the dynamic descriptions. Therefore, learner modelling based on metadata is dependent on both static and dynamic descriptions.

Educational_object

- **➔Fundamental_concept**
  - **➔ Theoretical**
    - ➢ Pre-requisites
    - ➢ Objective
    - ➢ FAQ
    - ➢ Wiki
    - ➢ Individu-al_assignment
    - ➢ Open_question
  - **➔ Procedural**
    - ➢ Guideline (Instructions)
    - ➢ Exercise
    - ➢ Brochures (Catalogue)
    - ➢ Wizard
  - **➔ Practical**
    - ➢ Introduction
    - ➢ Video_tour
    - ➢ Group_assign ment
    - ➢ Group_discussi on
  - **➔ Interactive**
    - ➢ Abstract
    - ➢ Overview
    - ➢ Outline
    - ➢ Mind_map
    - ➢ Summary
    - ➢ Multi-ple_choices
    - ➢ Comprehen-sive_exam
- **➔ Auxiliary_concept**
  - **➔ Theoretical**
    - ➢ Reference
    - ➢ Flowchart
    - ➢ Explanations
    - ➢ Rule
  - **➔ Procedural**
    - ➢ Slideshow
    - ➢ Tutorial
    - ➢ Notebook
  - **➔ Practical**
    - ➢ Example
    - ➢ Simulation (Try and error)
    - ➢ Case study
  - **➔ Interactive**
    - ➢ Animation_flash
    - ➢ Flash_cards
    - ➢ Interactive_game

Figure 3: Hierarchy of Educational Learning Objects Based on HWBM

IV CONCLUSION AND FUTURE WORK

Learning Styles of HWBM is a new approach to be used for designing a domain model for AWBES. The domain model is a basic feature of designing a learning environment. It can be used for tracking, auditing and identifying learner preferences, and thus adapt the behaviour of a system to match his/her preferences. This research overcomes the limitations of incorporating the educational and pedagogical theory in describing and organizing the learning content of educational systems. The outcome of the research aimed to help the web developer for building learner model implicitly as well as for adapting the learning contents of WBES to match the learner preferences according to the brain structure of learners. Further research should be conducted to explore the impacts of domain model on designing AWBES.

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