Enhancing web-based instruction/learning: the use of 'Cognitive, Object-Oriented Teaching Model'

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Abstract

This paper proposes the use of 'Cognitive, Object-Oriented Teaching Model' as a way of enhancing adaptive web-based teaching, learning, and materials construction. The Cognitive, Object-Oriented Teaching Model emphasizes not only the use of learners' alternative characteristics, but also the resolutions of the relationships between the teaching strategies and the features of materials, using critical cognitive objects, events or explanations and relevant strategies which build adaptive curriculum. There is no single comprehensive adaptively solution that can be suitable for everyone. Learners and Learners' characteristics in learning will change constantly, so teaching strategies must be adapted in suitable situation. In this paper we base on a model, named *Cognitive, Object-Oriented Teaching Model* (COOTM) to build an architecture for adaptive teaching/learning environments. Based upon this model, we will integrate methodology for learners' cognitive characteristics, channels of information communication, presentation types of teaching materials, knowledge management and content management to construct an adaptively web-based curriculum. These will have benefits to solve these inabilities to satisfy the need of the heterogeneous learners. The challenge of an educational system is not only to make studying available to learners at any time, in any ways, and anywhere but also to deliver suitable contents in suitable forms to suitable learners. The adaptive solutions of COOTM will be arranged to learners in complex mix characteristics, attributes of teaching materials, and presentation types in differently cognitive channels during learning processes. For individual learning, we build an adaptive teaching knowledge base to conquer the different features in teaching environment. We define the objects of learning/teaching environment and construct the objects with Object-Oriented properties which are inheritance, polymorphism and encapsulation into knowledge base. This object-oriented based approach of decomposing educational factors into COOTM is a channel to refine characteristics of educational environment. And we will explain the functionality, usability, reusability, reliability, and scalability of COOTM. Accordingly, we also design an adaptive learning system via inference engine accesses contents and teaching strategies from the knowledge base on web-base educational system. Finally, a teaching scenario and empirical evaluation have been done on COOTM to express multilayer、multifactor authentication and show the model is available.

Instruction

Owing to the development of web technologies, there are more and more systems to be auxiliary tools for learners to study (Kay, 2001). However, many e-learning initiatives have failed to achieve the learning outcomes, for unsuitable design, technology and management to instructors and

learners (Engelbrecht, 2005). Most educational systems have made huge improvements in related information technology, but few have yet based on pedagogic theories, teaching/learning psychology and made commitments to information as an educational resource. Web-based educational systems have great potential to deliver digital materials and teaching/learning strategies to learners via the network. For the reason that learners will learn via the web pages then the more important in educational system the more momentous mechanisms will be necessary to design teaching materials and deliver mechanisms on web-based educational system. Ayersman and Minden (1995) assert that Adaptive hypermedia Systems can be developed to accommodate various needs of learners. And Brusilovsky（2001, 2002）highlighted three major adaptation technologies －adaptive content selection, adaptive navigation support, and adaptive presentation to solve the adaptive problems. In this paper we base on a model, named *Cognitive, Object-Oriented Teaching Model* (COOTM) to build an architecture for adaptive teaching/learning environments. Based upon this model, we will integrate methodologies for learners' cognitive characteristics, channels of information communication, presentation types of teaching materials, knowledge management and content management to construct an adaptively web-based curriculum. These will have benefits to solve these inabilities to satisfy the need of the heterogeneous learners. The COOTM is an architecture for educational system to scaffold, design, use, reuse and share of curriculum, information and knowledge. Through the architecture, we define some mechanisms on the information communication between learning and teaching will make easier to view, commit and manipulate certain types of information. These mechanisms will maintain how to improve efficiency and effect which base on one's learning experience.

Common vulnerabilities

Vulnerabilities are any unsuitable constructions and access control in teaching/learning environment. Common reasons for vulnerabilities of web-based educational system include the following:

In case of web-based teaching/learning materials:

1) To neglect the cognitive levels between teaching/learning materials and learners' characteristics. 2) To express the same representations or presentations on single teaching material that will neglect multiple presentations of adaptive factors and multi-cognitive channels for learners to learn. 3) Teacher may have difficulties to diagnosis possible misconceptions of learners in multi-cognitive concepts in a teaching material. 4) In generally, the adaptively educational system may arrange materials form easy to difficult but what are principles to distribute the teaching materials into different difficult levels. 5) There are many multimedia teaching materials to be displayed in various ways on web pages but the diverse multimedia teaching materials lack some mechanisms to direct the multimedia teaching materials to teaching or learning processes adaptively. 6) As we know the progress of web technologies improve rapidly, but what are the channels to perform the technologies take effect or enhance the effect on educational system.

In case of web-based teaching:

1) Lack of pedagogic theories support and evaluate then the teaching effect on educational system may lose focus or mislead learning processes. 2) The web-based educational system may not have tutors assist on line or real time then how to maintain an adaptive educational environment. 3) How to make a quick adaptation for learners to learn in the new learning curriculum? 4) What kinds of learning objects will benefit for learners' style to learn? 5) How to maintain the cognitive mental levels of learners in order to support adaptive cognitive strategies build in educational system? 6) Which information need to be kept and what criteria should be set for adaptation? 7) The educational system can keep some necessary information and criteria to database then how to make the information as feedbacks and suggestions for teachers/systems to modify adaptive mechanisms.

In case of web-based learning:

1) How to learn more effectively and accurately from new learning objects? 2) What kinds of learning objects should be selected to benefit for one's style to learn? 3) Which learning strategies should learner need to assist or direct learning on educational system? 4) Which digital contents should be selected by learner that can do some help to comprehension of learning objects? 5) Which learning object should learners take after current learning object? 6) When learners may need to learn by doing, learn by seeing, learn by reading and learn by testing? 7) How many scores do learner need that learner pass or jump to another cognitive levels of learning object?

In case of access control:

The influences of access control on web-based learning between materials and learners are evident. In other words, the access control will be the main communication channel between materials, learners, tutors, learning strategies and teaching strategies. The vulnerabilities of access control include the following: 1) which methods are adaptive access control for web-based learning? 2) To neglect substantial differences (cognitive level, presentation type, difficult degree, and prior knowledge) of learning materials. 3) To deliver the same teaching materials to heterogeneous learners or send teaching materials without concerning relationships between learners and materials. 4) Whatever linear, net-structured and multi-dimensional educational systems may not the most important issue than suitable access control between learners' characteristics and attributes of learning materials via pedagogy perspectives on web-based educational system. 5) Which are the ways to create adaptive channels to combine the educational system with technology and knowledge construction? 6) Which is the bridge between learner-centered and tutor-centered pedagogical approach?

Cognitive, Object-Oriented Teaching Model

The purposes of web-based adaptively educational system are not merely transplanting materials to the web sites to enhance the accessibility and usability of materials but also to promote learning/teaching efficiency during learning/teaching processes. Learning is a complex task; several

different aspects must be taken into consideration. Cognitive, Object-Oriented Teaching Model will integrate the cognitive psychology perspectives, object-oriented concepts, pedagogical aspects, technologies in digital content development and information management to enhance adaptive web-based learning/teaching environment.

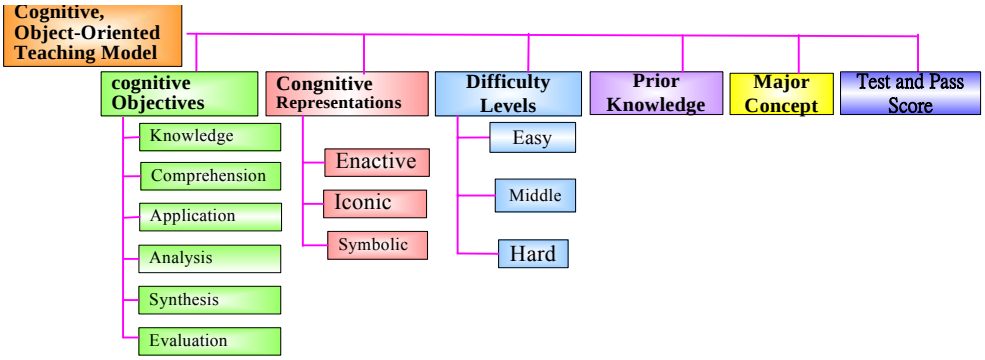

Figure 1, Cognitive Object-Oriented Teaching Model (COOTM)

Cognitive psychology perspective in COOTM

If there are no authentically cognitive representations, learning styles or management of cognitive objectives (Bloom, B.S., Engelhart, M.D., Furst, E. J., Hill, W. H., & Krathwhol, D. R., 1956) involved in web-based learning processes and actives, learners may learn it through rote memorization with learners' customs. A learner comprehends of teaching objects by engaging in web pages of web-based educational systems and interprets teaching concepts in individual experiences. Learners have to construct and comprehend knowledge by themselves, hence educational system need to create adaptive learning environments where learners have opportunities to interpret and construct new concepts of materials via web pages by themselves. COOTM adopts three cognitive psychology perspectives to enhance adaptive mechanisms of web-based educational system.

Cognitive representation

The cognitive representation of Bruner (1966) suggests three modes for processing information allowing human beings to construct their worlds, in the following order: (1) through action → enactive representation (2)through imagery → iconic representation (3)through symbols and language → symbolic representation.

Table1: Cognitive Representation modes of Jerome Bruner

Mode	Representation	Phenomenon
Enactive	Manipulative aid	Represents and understands through actions/ hands-on, concrete operation
Iconic	Imagery/ visual aid	Represents and understands in images that stand for certain objects or evens
Symbolic	Descriptions/ symbols /Text	Represents and understands in abstract ideas, symbols, language, and logic

He also asserts that domain knowledge or problems in that domain can be represented in these representation stages: enactive representation, a set of actions for achieving a certain result; iconic

representation, a set of images for expressing a concept without defining it fully; symbolic representation, a set of symbolic or logical propositions for explaining a certain concept. He suggested that instruction should proceed from enactive representation (direct operate experience) to iconic representation (diagram, pictures and films) to symbolic representation (texts, words and describe sentences). He further stated to follow the above sequence that will effect on achieving mastery of learning effects and this teaching sequence may apply to all learners without ages limit.

Learning style

The index of learning styles questionnaire (ILS) (Felder, R. M. , Soloman, B. A, 1999), is an instrument to identify which tendencies of learning styles belong to learners and which representations of teaching objects are suitable for learners. The ILS results provide an indication of an individual's learning preferences and an even better indication of the preference profile of learners. Over the last two decades, researches on qualitative and quantitative of ILS have indicated several consistency in major dimensions of individual differences (Dunn, DeBello, Brennan, Krimsky, & Murrain, 1981; Riding & Cheema, 1991; Liu & Ginther, 1999). The differences will effect on personal learning process. The ILS used to assess preferences on four dimensions (active/reflective, sensing/intuitive, visual/verbal, and sequential/global) of learning styles. The ILS inventory consists of 44 paired items to detect four dimension learning style profile provides an indication of possible strengths and possible tendencies or habits of learners.

The relations and functionalities between presentation types and learning styles of digital content:

COOTM integrates the ILS and cognitive representations. COOTM maintains mechanisms to direct the multimedia or digital content as materials to enhance adaptive teaching/learning processes, the mechanisms are the follows: 1) Active tendency→ Enactive representation→ Manipulative materials; 2) Visual tendency→ Iconic representation→ Visual aid materials; 3) Verbal tendency→ Symbolic representation→ Text materials; 4) Sequential tendency→ Sequential learning→ Not to jump learning levels; 5) Global tendency→ May non-sequential learning→ If possible then jump learning levels; For the multi-feature of phenomena express each teaching concepts in more than one expression that will benefit on learners' knowledge comprehension, multi-cognitive channels, and plenty descriptions of teaching concept. Each representation types have different functionalities as follows: 1) Guide and mediate the cognitive learning process not to demo or dominate learners' knowledge construct. Enactive material is interactive digital content which maintain concrete operational activities such as simulations, animations, VRML, and 3-D models that can help learners to interpret and construction knowledge by themselves, learning by doing. 2) Iconic material is visual digital content which illustrates theory or concepts in the context such as diagrams, photos, pictures, statistical charts, graphs that can conduct learner via imagery to construct knowledge, learning by seeing. 3) Symbolic material is a descriptive digital content which interpret

learning concepts via symbols, descriptions, text that learners will read through these symbols to interpret their learning concepts, learning by reading.

Pedagogical aspects in COOTM

In web-based educational system, teachers may not act as learning material designers or controllers. They may become the facilitators of students' knowledge construction and managers of information and knowledge. It is observable that the gaps between talented, average, and less able students in teaching mathematics environment, hence COOTM build different difficult levels and presentation types to improve this individual difference and maintain the multiple cognitive channels to enhance the opportunities in knowledge comprehension and construction. Furthermore, many educators believe that students' 'prior knowledge' could highly influence subsequent learning (Ausubel *et al*. 1978, Novak 1977, Wandersee *et al.* 1994, Tsai, C. C., 2000). Learning should not merely take learners to one knowledge level but also assist learners to go further more easily. Accordingly, the prior knowledge and major concept of each learning objects become more essential information for learning and teaching in web-based educational system.

Object-oriented concepts in COOTM

In traditional course model, it will not easy to detect and diagnose the difficulty in learning and teaching processes. As shown in Figure 2 (Tsai, 2002), the goals of object-oriented design are to refine teaching concepts and identify relations between teaching concepts.

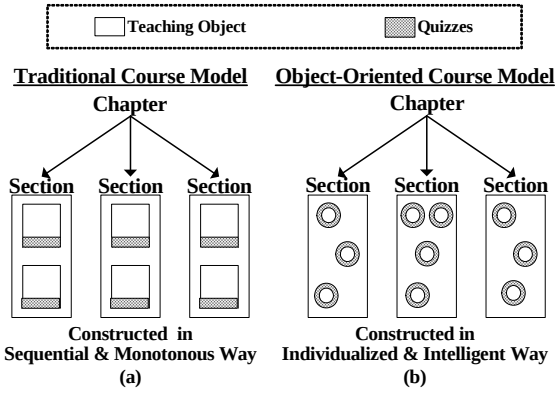

Figure2, the traditional and object-oriented course model (Tsai, 2002)

However, there are some vulnerabilities in this model. 1) It lacks of mechanisms in digital content can direct into adaptive learning or teaching. 2) One presentation type of a teaching material usually has an inflexibility in expressions that sometime cannot adaptively and enough express of teaching concepts. 3) One presentation type of a teaching material, it will lead unique channel for learner to acquisition knowledge. 4) Lack methods to slice cognitive and difficult levels pedagogically. In object-oriented perspectives, we propose a mechanism to refine the teaching materials more appropriate to satisfy the needs of the educational system then it can attach some criteria for users to learn, to teach and to design. And we named the appropriate teaching material as teaching objects. Each of teaching objects will be defined some attributes as

cognitive levels, representation types, major concept, prior knowledge, and score. Object-oriented design in COOTM: To proposes the inheritance of cognitive objectives between parents and child teaching concepts and objects. And the polymorphism supports in different ways, which are multi-orient of model, presentation types of teaching objects, and difficulty levels in each concept hierarchy. We based on the inference DRAMA –an object-oriented inference engine in NORM (new object-oriented model) to construct knowledge base which include factors, rules, and rule classes. As shown in Figure 3, the polymorphisms of teaching objects are constructed in three-tiers: which are cognitive objective class, representation type sub-class, and difficulty level sub-class. The sub-class is inherited from corresponding base-class, and teaching object can be an example from a sub-class. The relationships of inheritance between base-class and sub-class make the sub-class (child) to contain all the attributes of the base-class (parents).

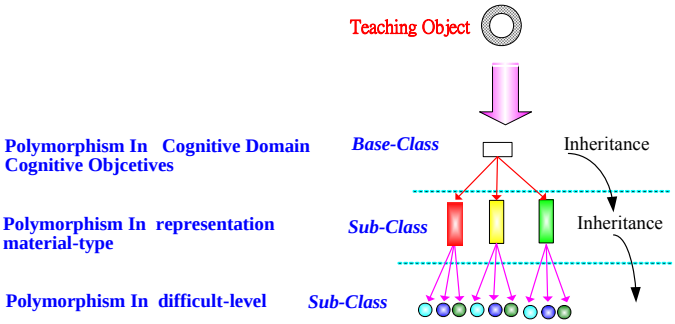

Figure 3: The polymorphism of teaching objects in different classes

Knowledge Management and Information communication in COOTM

What learners know and which their knowledge can support to keep learning to reach teaching objectives is the keystone of knowledge management in web-based educational system. In COOTM, the knowledge management is to determine which information within adaptive web-based educational system qualifies as “valuable”. Information is not knowledge, but meaningful, practical, and purposeful information can be committed as a teaching resource during learning/teaching processes. Learners and Learners’ characteristics in learning will change constantly, then knowledge management is not unchangeable, that is no immutable principle in Knowledge Management. Information communication, it plays roles in teaching/learning access control, it may inform system the status of learning and drive learning directions in adaptive teaching/learning processes.

Access control:

The operations on adaptive mechanisms for web-based educational system in COOTM are Knowledge management and information communication. COOTM must manage both explicit and implicit knowledge and handle the interaction between the above knowledge. There are three bi-directions of information communications as follows: 1) instruction and learning 2) instruction and material 3) material and learning; Then based on the information communications to find out weakness points during learning processes and find some improve methods in knowledge base to

ameliorate learning, teaching, material construction.

Functionality of COOTM

Structure of subject: The obvious problem is how to construct curricula that can be taught and learned by teachers and learners via web-based educational system adaptively. Furthermore, cognitive and pedagogical perspectives need to be involved clearly in system then map out the criteria (cognitive objective levels, representation types, difficulty levels and major concept of materials) to learners who own different abilities at different cognitive properties. Accordingly, the well-defined attributes and values of attribute of related objects will play the important roles to construct subject in COOTM.

Bridge and balance learner-centered and tutor-centered: Information management will bridge and balance learner-centered and tutor-centered in COOTM educational environment. Firstly, COOTM will detect and acquire characteristics and profiles of learners in a bottom up direction, from learners to teachers. Secondly, COOTM will authenticate and map out teaching strategies, teaching objectives and properties of materials in a drill down direction, from teachers to learners. In other words, COOTM will balance and bridge the learner-centered and tutor-centered approach.

Multiple cognitive channels: The adaptive mechanism of multiple cognitive representation types of each teaching concepts that have fourfold benefits: first, which supports multiple learning styles and multiple intelligence of heterogeneous learners; second, which can provide the mechanisms to diverse and direct multimedia teaching materials to enhance adaptive teaching or learning processes; third, the progress of web technologies improve rapidly, these are the channels to perform the technologies take effect or enhance the efficacy of educational system; fourth, the multiple representation and interpretations of teaching objects that will benefit for learners in knowledge acquisition and comprehension via multi-cognitive channels.

Logical architecture for teaching, learning, materials construction, and information communication: 1) Teaching objectives/designs architecture: Taxonomy of Bloom et al. identifies and evaluates different kinds of thinking while offering a framework for cognitive domain. By reflecting in the quality of materials and quizzes could be used in web-based educational system. 2) Learning scaffold/objectives/profile architecture**:** Maintain more precise and correct learner profile and learners' characteristics base on COOTM. Correspondingly, COOTM scaffolds the learners in presentation mechanisms, cognitive objectives, and degrees of difficulty. 3) Architecture for refinement/construction/sequence of materials: The Methods can refine and slice teaching materials and teaching concepts. It maintains some channels to refine & slice teaching materials and teaching concepts under cognitive objectives, representation types, and object-oriented concepts in COOTM.4) Information acquisition/management/communication architecture: There are well-defined strategies and processes for improving the effectiveness of information communication across teaching/learning processes. COOTM, a well-architected information structure makes the

information is available in a consistent and integrated form, by integrating educational framework, covering a wild range of different types of information and the relationships between them.

Conclusion

The adaptive strategies for a web-based educational environment are more effective when learning is directed by more than one layer of adaptive mechanisms. In COOTM, **Adaptation-In-Depth (AID)** strategies utilize multiple layers of adaptations. The AID strategies increase the performance of learning/teaching processes and reduce vulnerabilities of web-based educational system. The multilayer、multifactor authentication of the adaptation-in-depth strategies are the follows: 1) **Detection Layer:** To detect learner's characteristics within learning styles via ILS. 2) **Initial Authentication Layer:** To authenticate which cognitive levels and prior knowledge do learners have via the well-defined pretest. 3) **Abstraction Layer:** To abstract the knowledge acquisition from the learning styles and pretest score into knowledge base. 4) **Inference Layer:** To infer from these factors which attach to the learner and acquire the teaching strategies from knowledge base in COOTM. 5) **Acquisition Layer:** Base on the teaching strategies to find which material object is suitable for the current statuses for learner to learn. The object which learner obtains will keep several attributes and values of attribute to assist knowledge management and information communication. 6) **Integrate authentication Layer:** The purposes of integrate authentication layer are authentic characteristics collection. To mediator evaluates the learner's cognitive competencies and seeks to develop any that are weak that will benefit to the availabilities of the knowledge base to take affect accurately. 7) **Information Gathering Layer:** Whatever direction of information network is bottom up, drill up, hierarchy or cross information network may not more important than to gather and manage related information in adaptive educational system. Interventions might create to respond to any perceived cognitive competencies or weakness. COOTM gather information from all well-defined attributes. 8) **Access Gaining Layer:** Inference agent may choose from among the numerous information processes then infer a suggestion from knowledge base and adapt one that might encourage learning an adaptive learning material within COOTM. 9) **Escalating layer:** Cognitive, Object-Oriented Teaching Model is a well-defined architecture that depends on the constituents not to imitate directly. Accordingly, COOTM constructs behaviors from already mastered constituents to match features selection of the model. COOTM can elicit higher level thinking by posing questions intentionally from each cognitive domain of Bloom et al. then escalating cognitive objective levels. The teaching scenario and empirical evaluation have been conducted using COOTM. The mean values (dependent sample t-test) for the pre-test reveal that control group (60.08) performed better than experimental group (56.36). The independent sample t-test for pretest and post-test implies no significant difference in pretest ($0.164>0.05$) but significant difference in post-test ($0.000<0.05$) between experiment and control groups. The results expressly show the model is available and effective in improving learning performance.

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