Integration of Brain Based Learning and Intelligent Tutoring System for Developing Pedagogical Software

تطوير برمجية تعليمية مبنية على التعلم القائم على المخ وأنظمة التعليم الذكية

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ملخص البحث

يعد مجال تطوير أنظمة التعليم الذكية والبيئات التعليمية من المجالات المهمة فى الحاسب الالى والتربية ومن هنا يقدم هذا البحث برمجية تعليمية لتدريس وحدة فى منهج الأحياء لطلبة المرحلة الثانوية. يعتمد النظام المقترح على مفاهيم نظرية التعلم القائم على أسلوب التفكير فى مخ الإنسان وعلى انظمة التدريس الذكية وذلك لتقديم واجهة تفاعل متغيرة لتلائم نمط تفكير المتعلم. فلنفس المحتوى التعليمي وإستراتيجية التعليم يقدم النظام مكونات مختلفة لواجهة التفاعل مع المتعلم طبقا لنمط تفكيره (أيمن –أيسر – متكامل) حيث يفضل الأشخاص ذوى النمط الأيمن للتفكير فى التفاعل مع الصور والألوان والفيديو كمكونات لواجهة التفاعل. ويفضل الأشخاص ذوى النمط الأيسر فى النصوص والصوت بينما يفضل ذوى النمط المتكامل لكل هذه المكونات. يعتبر النظام من الأنظمة الديناميكية حيث انه متغير ومرتبط بنموذج الطالب.

Abstract

The development of intelligent tutoring systems and learning environments has become an important issue in both computer science and education. This paper presents pedagogical software for a secondary school biology course. The proposed system integrates the concepts of Brain Based Learning (BBL) and intelligent tutoring system to adapt the learning interface according to the student thinking style. The system is formalized as finite automata with some attributes that allow learner interaction (image, video, text, color, sound and contents) and some user's brain characteristics (right, left, and integrated thinking style).

For the same contents and strategy the information of the learner thinking style enables the system to adapt a specific learning environment. The initial student model is formed through personal data and thinking style. The thinking style is obtained by a diagnostic activity, based on brain assessment test offered to the students. The system enables an adaptation in the output learning environment where the resulting user interface is highly personalized and dynamical.

KeyWords
Intelligent Tutoring System (ITS), Brain Based Learning (BBL), Thinking Style, Adaptive Interface (AI), Automata Formulation.

١- Introduction

The problem of detecting how students learn and acquire knowledge has gained great interest, where students learn in many different ways. In addition, the problem of how much a given student learns, depends on his characteristics. Many researches show that the best learning may occur when the teaching styles match with the student's learning styles [١].

Individuals favor verbal or visual strategies when they are processing different kinds of information. The left and right thinking styles are distincted by analytic–holistic, sequential-intuitive and verbaliser–visualiser consequently [٢].

The influences of computer-supported learning are proved. Visualisers benefit more than verbalisers from multi media [٣].

Learning styles methods suggest that suitable technological tools can be used to

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alternatives are used for integrated thinking style learner.

Due to this important role of the thinking style in learning, the researchers of the computer in education field have studied techniques of artificial intelligence in order to turn the educational systems more customized also, for the affective states of the student.

The ultimate goal of any Intelligent Tutoring System (ITS) is to make the learning process most effective in the corresponding domain. Careful selection of the contents, kinds and structure of knowledge and information are the extreme importance in achieving that goal.

This paper describes a pedagogical software that integrates concepts of ITS and BBL to learn a unit in secondary school biology course. The paper is organized as following: in Section ٢, brain based learning and thinking styles are introduced. Section ٣ contains the ITS' features, the adaptive interface and the automata formalization of ITS. An illustrative example of ITS is introduced in section ٤.

٢- Brain Based learning

Brain based learning is the informed process of using a group of practical strategies that are driven by sound principles derived from brain research [٤].

It is a comprehensive approach to instruction based on how current research in neuroscience suggests our brain learns naturally. This theory is based on what we currently know about the actual structure and function of the human brain at varying stages of development. This type of education provides a biologically driven framework for teaching and learning in addition to, it helps explain recurring learning behaviors. BBL is a meta-concept that includes eclectic mix of techniques. Currently, these techniques stress allowing teachers to connect learning with student's real life experiences.

The core principles of brain-based learning state that [٥]:

١. The brain is a parallel processor, meaning it can perform several activities at once.

٢. Learning engages the whole physiology of human.

٣. The search for meaning is innate.

٤. The search for meaning comes through patterning.

٥. Emotions are critical to patterning.

٦. The brain processes wholes and parts simultaneously.

٧. Learning involves both focused attention and peripheral reception.

٨. Learning involves both conscious and unconscious processes.

٩. We have two types of memory: spatial and rote.

١٠. We understand best when facts are embedded in natural, spatial memory.

١١. Learning is enhanced by challenge and inhibited by threat.

١٢. Each brain is unique.

The three instructional techniques associated with brain-based learning are:

١. Orchestrated immersion--Creating learning environments that fully immerse students in an educational experience.

٢. Relaxed alertness--Trying to eliminate fear in learners, while maintaining a highly challenging environment.

٣. Active processing—Allowing the learner to consolidate and internalize information by actively processing it.

The educational tool's designers must be artistic in their creation of brain-friendly environments. Instructors need to realize that the best way to learn is not through lecture but by participation in realistic environments that let learners try new things safely.

Jensen [٦] states several concepts as essentials of brain-based learning such as multi-model input engage as many modalities as possible by providing learners with options and choices. Ensuring learning activities offer auditory and visual components.

Instructional design must include learning principles and conditions that meet the learner's needs. Key elements of instructional models include: learner consideration, learning task, learning content, content organization, instructional strategies, media, learning environment, assessment of instruction, materials for delivery and evaluation/feedback. In brain based learning environments materials and instruction must be learner-centered and delivered in a manner that is fun, meaningful and personally enriching [٧].

Studying of brain cells is needed for understanding brain based learning. The brain consists of many cells such as the neuron which is basic to learning. The learning takes place when two neurons communicate and when the neuron gathers information, it grows appendages called dendrites.

٢-١- The Brain

Human Brain Weighing about of ١.٣ kg and containing ١٠٠ billion neurons. It is a marvel of evolution. Complex interactions between neurons produce psychological processes, including learning, memory, emotion, thinking and perception.

Many motor and sensory functions have been "mapped" to specific areas of the cerebral cortex. In general, these areas exist in both hemispheres of the cerebrum, each serving the opposite side of the body. Less well defined are the areas of association, located mainly in the frontal cortex, operative in functions of thought and emotion and responsible for linking input from different senses. The areas of language are an exception: both Wernicke's area, concerned with the comprehension of spoken language, and Broca's area, governing the production of speech, have been pinpointed on the cortex. Figure ١ represents these areas.

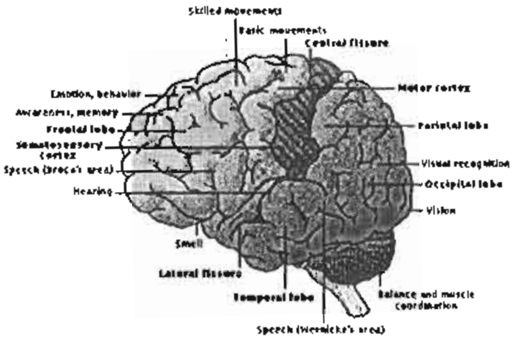

Figure ١ Functions of the Cerebral Cortex

٢-٢ Thinking Styles

Although the cerebrum is symmetrical in structure, with two lobes emerging from the brain stem and matching motor and sensory areas in each, certain intellectual functions are restricted to one hemisphere. A person's dominant hemisphere is usually occupied with language and logical operations, while the other hemisphere controls emotion and artistic and spatial skills. The left hemisphere is better with sequencing, language, parts and creating internal dialogues (interpreting events). The right brain processes spatial information, works randomly and with wholes (the gestalt). None of these attributes guarantee creativity. There are very clear, anatomical and functional differences between the left and right half brain [٨].

Thinking styles (left, right, and integrated) concern people's habits or tendencies to approach cognitive tasks with a particular attitude, activating a specific set of skills and applying a special kind of strategy [٩]. The learning process is influenced by a learner's style of thinking. So, people who are inclined to apply sequential and analytical strategies (left-thinkers) are thought to learn through a specific way, whereas those who prefer holistic and intuitive strategies (right-thinkers) tend towards another way.

In fact, the left style is associated with logical–analytical thinking and implies preference for sequential processing of information, verbal expression and systematic approach. The right style refers to holistic thinking and implies preference for visual code and parallel processing. The integrated style is used to describe people that show equal amounts of both characteristics [١٠]. The following rules illustrate the Left-thinking and right-thinking features:

Rule for Left-Thinking Style characteristics

If *person is left thinking style*, then the characteristics are: *Analytical, Serial, Sequential, Logical, Oral-abstract, Systematic Realistic, Settled, On purpose learning, Learning in scholastic context, Careful and Planner*

Rule for Right-Thinking Style characteristics

If *person is right thinking style* then the characteristics are: *Holistic, Parallel, Connective, Intuitive, Visual-motional, Pioneering, Imaginative, Enterprising, Inventive, Incidentally learning, Learning in extra-scholastic context, Forgetful and Seeking changes*

If the technological and instructional features of an educational setting are consistent with a learner's style (matching condition), there are better outcomes compared to mismatching conditions. Therefore, the designing of educational systems must adapt learning environment to the students' thinking style by including features that allow them to pursue their preferred way of learning.

٣- Intelligent Tutoring Systems

Intelligent Tutoring Systems are computer programs that use several technological resources to support a teaching–learning process. They use techniques of Artificial Intelligence (AI) to represent domain knowledge module, tutorial module, student module, and user interface module.

The development of ITS is made on the basis of prototypes with consecutive improvements. A modular architecture allows the use of knowledge modules in different applications. Knowledge can be reutilized at different levels, from the knowledge base that stores a given domain, to the whole ITS architecture.

The general systems, ITS shells, are too generic. They demand a considerable effort to carry out an application contrasted to custom made ITS. In between the systems that are domain specific [١١]. In the following part samples of ITS are introduced.

Lisa N.Michaud et al. [١٢] developed an ITS for deaf learners of written English. The system takes a piece of text which is written by a deaf student and analyzes that text for grammatical errors. Then, the system engages that student in a tutorial dialogue, enabling the student to generate appropriate corrections to the text. Ozdemir and Alpaslan presented an intelligent agent for guiding students through on-line course material. This agent can help students to study course concepts by providing navigational support according to their knowledge level [١٣]. Gwo-Jen Hwang proposed a conceptual map model, which provides learning suggestions by analyzing the subject materials and students' test results.

Conventional testing systems simply give students a score and do not give them the opportunity to learn how to improve their learning performance.

Therefore, developing more effective programs to test enhances the learning performance. Students would benefit more if the test results could be analyzed and hence, advice could be provided accordingly [١٤]. Yujian Zhou et al. described a study of the hinting strategies in a corpus of human tutoring transcripts. In additional to the implementation of these strategies in a dialogue-based intelligent tutoring system (Hinting is a general and effective tutoring tactic in one-on-one tutoring when the student has trouble solving a problem or answering a question). They tested their model with two classes totaling ٧٤ medical students [١٥]. Miguel Nussbaum et al. developed a tool for teachers to elaborate tutoring applications for the practice of certain skills related to math in preschool children. The teacher makes use of stored knowledge to choose the required contents so that the system automatically generates exercises. These exercises are completed and evaluated in real time, according to the student's reality, being able to mediate with the pupil to achieve the maximum session utilization [١١]. Sidney K. D'Mello et al. developed a project for integrating affect sensors in an ITS. It augments an existing ITS (AutoTutor) that helps learners construct explanations by interacting with them in natural language and helping them use simulation environments. They aimed to develop an agile learning environment that is sensitive to a learner's affective state. Some of the technologies they were exploring include a video camera that can identify facial features, a posture detector that monitors the learner's position and features of the dialog exhibited while learners are interacting with AutoTutor [١٦]

Although there are variations of ITS in their domains, features, size, and applications, they must have a suitable user interface module. The interface module allows communication between the student and the system. Recently, the interface has acquired greater importance, enriching interactivity between students and system. Interface became the learning environment and its adaptation is fundamental to improve system efficiency.

٣-١ Adaptive Interface

A key function of any ITS is the ability to adapt, as closely as possible, pedagogical activities to individual learner needs. So, they try to identify some student's characteristics that allow obtaining criterions to propose activities, as well as to know how to react to some actions. Adapting tutoring to individual students significantly increases the speed of learning. Therefore adaptability can be observed as a common goal in all the systems developed.

A great variety of techniques to facilitate and increase flexibility of interface construction have been developed in the last years. Also several studies are being developed in the domain of the cognitive sciences to understand learning. Some of these studies identified relationships between students' characteristics and environments that facilitate their learning processes [١٧, ١٨].

Two types of variables have been defined to represent the variables of learning process: characteristics and attributes. The first is a set of variables that identifies the student. Each student model is formed by the characteristics values. On the other hand, the attributes identify the interface.

The characteristics include: age, sex, interests, learning styles, cultural and socio-economical information, etc. The attributes include content, form (strategy, media, context, etc.) and interactivity (number of links, navigation availability, etc.).

The interface of pedagogical software must be configured in function of two axes: the learner's axis and the pedagogical axis. It emphasizes that the interactions between the learner and the object under study must be facilitated. The interface must be highly adapted to the student, and its aim is not to facilitate the use of the system, but to propitiate learning [١٩].

٣-٢ Automata Definition

Formalization of the ITS as automata can facilitate the integration of the knowledge areas involved in their development [٢٠]. The ITS can be defined formally as finite automata. It can be represented or defined by a set of six elements:

S (U; Y ; X; x.; λ; η) where:

U as the unite set formed by the attributes that allow learner interaction (image, video, text, color, sound, content).

Y as the unite set formed by the attributes that establishes the interface configuration.

X as the unite set formed by the user's characteristics (right, left, integrated thinking style, content). Each model implies a specific planning of the activities. For example, for the same content and strategy, the information of the learner thinking style enables the system to select a specific learning environment.

x. the initial student model is obtained by a diagnostic activity, based on tests which are offered to the students at their first interaction with the system.

λ the transition state function, it represents knowledge of the relationship between attributes and Characteristics (A→C). It enables an update in the student model.

η the output function, it represents knowledge of relationship between Characteristics and attributes (C→A). It enables an update in the output (for example: if the student is verbal, text attribute must be activated).

The behavior of ITS can be modeled by means of the automata, each components of the ITS defines a specific part: the inputs and outputs occur at the interface. The student module stores system states, which correspond to the apprentice identification. λ and η belong to the tutorial module, which stores pedagogical knowledge that enables the system to update the output according to the input. In the following section an illustrative example of ITS is introduced, the system is formalized as automata.

٤- An Illustrative Example

The proposed example is ITS for learning a unit of biology course containing seven lessons for secondary school students. Figure ٢ represents the system architecture. Four modules are presented: the domain module, the tutorial module, the student module and the user interface module.

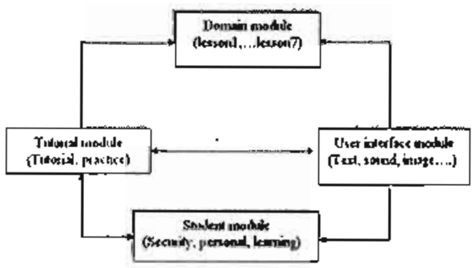

Figure ٢ system architecture

The student module is formed by the learner's characteristics and subject contents, the students' data tables and relations between them are stored in a database file. Figure ٣ represents relationship between student table and results table.

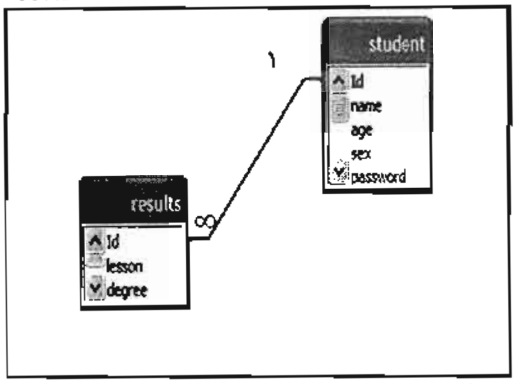

Figure ٣ the relationship between student table and results table.

Students attributes categorized into: security data (ID and Password); personal data (name, age and gender); and learning data (thinking style, contents, and scores).

The Initial Student Model is obtained at the first interaction with the system. The student fills his personal data and his thinking style is assigned through a diagnostic activity, based on brain assessment test which is offered to the students [٢١].

The test is employed to identify students' thinking styles. It contains ٦١ questions. Each new student is given randomly ٢٠ questions from them. Each question has three answers; one referring to the left-style thinking, the other referring to the right and the remaining answer referring to the integrated style. The learner is asked to choose the answer that agrees with him. Samples of these questions are shown in appendix A.

The system computes the number of answers that represent the left style, the right style and the integrated to identify the student thinking style. The resulted style is assessed and shown to the student. It is then stored in his record that found in students' table in the database file.

The interface module is produced according to the student attributes. Table ١ illustrates the inputs that contain media (color, text, image, sound and video) for representing a specific topic (for example cont١ or cont٢).

Symbol	Input
A	Color
B	Image
C	Sound
D	Text
E	Video
F	Cont١
G	Cont٢

Table ١ system inputs

The student is modeled by his thinking style and topic. Table ٢ represents some possible states.

State	Definition
$X_{١}$	right thinking style, interested in cont١
$X_{٢}$	left thinking style, interested in cont١
$X_{٣}$	integrated thinking style, interested in cont١
$X_{٤}$	right thinking style, interested in cont٢
$X_{٥}$	left thinking style, interested in cont٢
$X_{٦}$	integrated thinking style, interested in cont٢

Table ٢ Space of states

The left style thinking implies preference for verbal and systematic approach; the right style thinking implies preference for visual processing. Integrated style describes people having amounts of both characteristics. Therefore contents are presented by images, video, color for the right thinking style students or text and sound for the left thinking style students. Mix of the previous media is presented for the integrated thinking style students. The following diagram represents the transition state diagram. Table ٣ illustrates the outputs corresponding to students input.

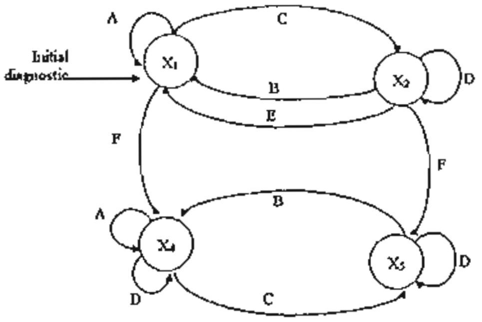

Figure ٤ states transition diagram

	A	B	C	D	E	F
X1	Color cont1	Image cont1	Speech cont1	Text cont1	Video cont1	Color or image or video cont2
X2	Color cont1	Image cont1	Speech cont1	Text cont1	Video cont1	Speech or text cont2
X3	Color cont1	Image cont1	Speech cont1	Text cont1	Video cont1	Any media cont2
X4	Color cont2	Image cont2	Speech cont2	Text cont2	Video cont2	Color or image or video cont2
X5	Color cont2	Image cont2	Speech cont2	Text cont2	Video cont2	Speech or text cont2
X6	Color cont 2	Image cont2	Speech cont2	Text cont2	Video cont2	Any media cont2

Table ٣ illustrates the output according to each state.

It is important to underline that the advantage of student internal states, based on the student preferences, is subsequent presentations that corresponding to the states (characteristics). This makes the system outputs, all the time, depend on the knowledge, which the system has on the student's characteristics.

Once the system identifies the student, the tutorial module introduces two methods for teaching (tutorial and practice) as shown in figure ٥. The system sets the interface attributes that specify exactly the screen components of each pedagogical activity (content, form and interactivity).

Figure ٥ teaching methods

The second method of learning is the practice where the students answer some questions as training, sample of the questions database is shown in figure ٦.

رقم معرف	السؤال	اجابة١	اجابة٢	اجابة٣	اجابة صحيحة
٢٨	[illegible]	[illegible]	بيومفلاريا	كبد الإنسان	بولنس
٢٩	[illegible]		الكبد	التجويف التنفسي	التجويف التنفسي
٣٠	[illegible]	قوقع بيومفلاريا	الاسبوروسيست	قوقع بولنس	قوقع بولنس
٣١	[illegible]	الميراسيديوم	السركاريا	الاسبوروسيست	الاسبوروسيست
٣٢	[illegible]	السركاريا	الميراسيديوم	قوقع بيومفلاريا	السركاريا
٣٣	[illegible]	الميراسيديوم	قوقع بولنس	الاسبوروسيست	الميراسيديوم

Figure ٦ Questions records

Each environment is considered as output of the system. The interface offers action possibilities to the user, through controls (icons, menus, and buttons). Figure ٧ shows sample of the introduced screen for left thinking style student in the tutorial method. Background is filled with black in addition to grey. The written tutorial context in each frame is colored in white in order not to move the student's attention to any colored item. As this style depends on the audible way of learning rather than the visual one, the screen contains a button for hearing the lesson. The button can repeat reading the written tutorial context. The learners of left thinking style are sequential, analytical and logic, so each screen is containing a button named scientific rule for explain the screen characteristics.

Figure ٧ sample of the introduced screen for left thinking style student

Figure ٨ presents a sample of the integrated thinking style screen where it contains all media components (text, color, image, speech.)

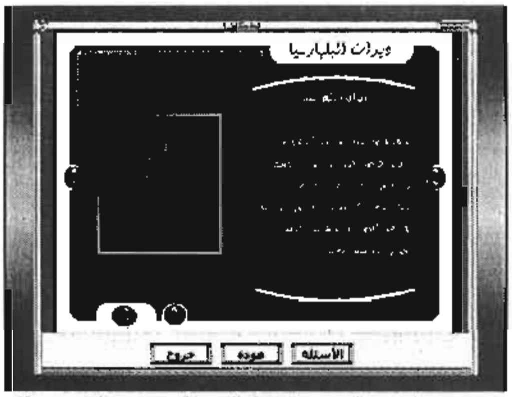

Figure ٨ sample of the introduced screen for integrated thinking style student

Figure ٩ represents a sample of the screen of right thinking style. It contains color, image and video.

Figure ٩ sample of the introduced screen for right thinking style student

As illustrated the resulting user interface is highly personalized and dynamical.

٥- Conclusion

In this paper, pedagogical software for biology course with adaptive user interface is introduced. The system is formalized as finite automata. The main importance of this formalization is that, it describes each component, contributing to a common language to represent the system. In addition, it facilitates the integration of the pedagogical, the domain and the computational areas. The formalization was focused on interface configuration. The system stores knowledge about students' characteristics and takes decisions on how to configure the interface (output) and how to modify the student model (state). Once the initial student model is established, the tutorial module configures a specific learning environment with the suitable interface attributes. The system proposes student oriented activities, it administrate the resources, strategies, and student modules to build the activities. So, each activity responds to specific user's needs.

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Appendix A

Sample of brain assessment test