Intelligent tutoring systems have been shown to be highly effective at increasing students' performance and motivation. In this paper, a brief overview of ITS will be provided and then, an overview of the main components of intelligent tutoring systems will be discussed in detail.

1.0 Intelligent Tutoring Systems

Intelligent Tutoring System (ITS) is a computer system that can support and improve learning and teaching process in the domain knowledge. Katie Hafner defined ITS as “an intelligent tutoring system is educational software containing an artificial intelligence component. The software tracks students' work, Tailoring feedback and hints along the way. By collecting information on a particular student’s performance, the software can make inferences about strengths and weaknesses and can suggest additional work.” (Hafner, 2000).

Regarding Bloom’s research the improvement of students’ learning in one-on-one human tutoring is more effective than traditional classroom instruction by two standard deviations (Bloom, 1984). This improvement of two standard deviations shows that the students were taught by one-on-one tutoring, on average, achieves as well as the top (2%) of those were attending classroom instruction. Based on this, the ITSs aim to achieve similar results to those observed when a human tutor teaches a student individually. The goal of ITS is to enable students to acquire deep knowledge, gain skills of problem solving, and work independently.

Computer has been used in education since 1970s. Computer-based training (CBT) and computer aided instruction (CAI) were the first educational systems being designed to be used in teaching (Beck, Stern and Haugsjaa 1996). Instruction in these systems was presented exactly in the same way to all students for all time. On other hand, Intelligent Tutoring Systems (ITSs) go further than training simulations to deal with specific user needs and to tailor Instruction based on the student profile. Unlike other computer-based training technologies, ITSs combine the artificial intelligence, cognitive science and advanced technologies to improve the learning level of students. Additionally, ITSs assess each learner’s behaviour within these interactive environments and enhance a model of their knowledge, skills and expertise. Based on the learner/student model, the ITS tailors instructional strategies, in terms of both the content and style, and provide explanations, hints, examples, demonstrations and practice problems as needed.

1.1 Architecture of Intelligent Tutoring Systems

The first proposed ITS architectures consisted of four main components: a domain module, a student model, a tutor or pedagogical model, and an interface or communication module (Self, 1990). Since then, this basic architecture has been extended upon by many researchers,
Recent systems usually contain a student modeller, domain module, pedagogical module and interface. These modules exchange information between them through a series of linkages. The student modeller stores specific information about each individual learner in the student model database. It gets information from the domain module and then processes this information together with information from the pedagogical module to provide user specific information back to the pedagogical module. Based on this, pedagogical module makes decisions about the tutoring process. The pedagogical module interacts with all components of the system providing the results of teaching decisions to the communication module to present information to the learner including domain content and feedback messages. The discussion of each of these components is presented below in more details.

1.1.1 The student model

The student model contains the diagnostic competence of the ITS and produces the student model with all information about the individual learner. In other word, the student model is a demonstration of some characteristics and attitudes of the learner. These are useful for
achieving the sufficient and individualized interaction established between the computational environment and the learner (Hartley, Paiva and Self, 1995). A student model must contain some characteristics and attitudes of the learner such as what does student know and does not, learning abilities, strengths and weaknesses (Tsybenko 1995). “Building a student model involves defining who the learner is including learner history and physical limitations; what is to be modelled e.g. the goals, plans, attitudes, capabilities, knowledge, and beliefs of the learner; how the model is to be acquired and maintained; and why information is being sought from/about the learner e.g. to give assistance to the learner, to provide feedback to the learner, or to interpret learner behaviour” (Stauffer, 1996). The student model builds and maintains the understanding of the student. Additionally, the student model must keep track of a student’s performance on material being taught, the misconceptions made, the student’s understanding of concepts and their acquisition and retention rate (Pillay, 2003).

1.1.2 The pedagogical module

The pedagogical module, or Tutor Module, is responsible for the instructional competence and provides implementations of different tutoring strategies depending on the pedagogical knowledge and the student’s state and history. ITSs present individual instruction, one-on-one tutoring using teaching strategies and meta-strategies. Teaching strategies can be shown as the individual methods and techniques employed to teach a particular concept. On the other hand, meta-strategies refer to the overall tutoring strategy utilized.

The tutor module includes Decisions making with no limitation of teaching strategy that should be employed at any selected point in the tutoring experience; occurrence of feedback and which task should be presented next. Information from the student model is passed to the pedagogical module as input so that the decisions of the pedagogical module reflect the differing needs of each student effectively tailoring the tutoring experience to the particular student. The pedagogical module uses this information and based on the overall meta-strategy chooses the most appropriate teaching or instructional strategies and actions for the particular student and the topic at hand. Low-level issues the pedagogical module needs to consider as part of the meta-strategy include (Pillay 2003):

- Which topic to present to the student?
- Which problems to present to the student?
- How frequently the student should be provided with feedback such as hints and error listings?

Because the tutor needs to know information about the student to be able to make these decisions, the pedagogical module relies heavily on the student modelling module.

1.1.3 The domain module

The domain module contains the knowledge and skills to be tutored. Generally, it requires significant knowledge engineering to represent a domain so that other parts of the tutor can access it. One related research issue is how to represent knowledge so that it easily scales up
to larger domains (Pillay 2003). Approaches to the problem of knowledge representation include production rules which are a set of rules which match a student’s steps in a traced performance of some task. These can be used to represent both correct and incorrect knowledge and provide increased modularity (single rules instead of entire procedures) and decreased grain size (single problem solving steps versus entire paths). ANDES, physics tutor is one example of such a system and contains approximately 600 rules (Schulze, et al., 2000). Constraint-based modelling based on Ohlsson’s theory of learning from performance errors (Ohlsson, 1996) uses the notion of state constraints to represent knowledge. Each constraint specifies a property of the domain that must be shared by all correct solutions and by so doing models correct knowledge explicitly and incorrect knowledge implicitly. A violated constraint signals an error caused by incomplete and incorrect knowledge. SQL-Tutor, an ITS for creation of SQL queries is an example of such a tutor and consists of 650 constraints dealing with syntactic and semantic errors (Mitrovic et al. 2001).

1.1.4 The communication module

The communication module contains both the interface and optionally, a stored representation of the communication knowledge. The general goal of the user interface is to use the available devices, usually keyboard, mouse, monitor, etc., to display to the student the necessary information, and use these devices to obtain student responses. Like the pedagogical module, the communication module deals with strategies. However these strategies are about the ways in which the system can communicate knowledge, primarily in the form of feedback to the student. It is charged with controlling interactions between the student and the system. Communication with the student must be engaged in a manner that reduces cognitive load while simultaneously providing the student with all information necessary for effective learning. The interface must clearly indicate to the student where s/he is in a problem and errors made must be clearly visible to the student. Student history, learning style and other factors should influence the manner in which information is rendered for the student. The communication module is also responsible for informing the pedagogical module of the student’s actions as s/he progresses through the course. Without this type of information it would be impossible to make decisions regarding the student’s interaction with the system and as such provide individualized tutoring. Richard Mayer in his paper “Cognitive theory and the design of Multimedia Instruction” (Mayer, 2002) notes that at the centre of Cognitive theory lies three theory-based assumptions about how people learn from words and pictures. These are the Dual channel assumption, Limited capacity assumption and Active processing assumption.

According to dual-channel theory, the mind processes visual and auditory content in separate memory systems. Text is initially processed visually, but it becomes an auditory element as the mind eventually hears the word (Mayer, 2002). The human cognitive system is seen as consisting of two distinct channels responsible for representing and manipulating knowledge: a visual-pictorial channel and an auditory-verbal channel. Pictures enter the cognitive system through the eyes and may be processed as pictorial representations in the visual-pictorial channel. Spoken words enter the cognitive system through the ears and may be processed as verbal representations in the auditory-verbal channel. When auditory and pictorial
information are simultaneously presented, processing occurs independently and channels like highways, allow these two lanes of information into the brain. It is therefore better to present an explanation in words and pictures than solely in words (Mayer, 2001). Student with high spatial ability for instance have been shown to benefit from communication which includes pictorial representations. The second assumption is related to the limited capacity to remember.

Each channel in the human cognitive system has a limited capacity for holding and manipulating knowledge. When a lot of pictures (or other visual materials) are presented at one time, the visual-pictorial channel can become overloaded. When a lot of spoken words (and other sounds) are presented at one time, the auditory-verbal channel can become overloaded. The final assumption is that meaningful learning occurs when learners engage in active processing within the channels, including selecting relevant words and pictures, organizing them into coherent pictorial and verbal models, and integrating them with each other and appropriate prior knowledge. These active learning processes are more likely to occur when corresponding verbal and pictorial representations are in working memory at the same time. The Cognitive Theory of Multimedia Learning is important to ITS development because most ITSs are deployed as multimedia applications using multiple forms of media for both input and output. The theory suggests several design principles to improve multimedia instructional design. These are as follow: Multimedia Principle, Contiguity Principle, Coherence Principle, Modality Principle, Redundancy Principle, Personalization Principle, Interactivity Principle and the Signalling Principle. These principles can be used in designing effective interfaces for ITSs, reducing cognitive load while allowing students to process as much information as possible.
References


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