CHAPTER 2

Literature Review

To set the context of ITS in mathematics education, literature concerning various issues in developing ITS was examined. One of those is the use of multimedia in ITS. Normally, multimedia concept is used in Computer Assisted Instruction (CAI) and the enhancement of CAI is ITS which is currently used in medical field, mathematics and so on.

2.1 Multimedia in ITS

Multimedia can be a very effective teaching tool for making learning experience authentic and relevant to the learner's life [Woolf and Hall, 1995]. Multimedia can be an effective intermediate way to attract students using the ITSs. For example, by using graphics or animation the system will be more attractive compared to text based system. Animation has been shown to be a very powerful tool in teaching mathematics [Kaljumi, 1992]. Multimedia provides increased flexibility in hint presentation. We can move types of hints rather than just static text [Joseph Beck and Mia Stern]. Animation can show how to reach the situation of the problem step by step. The system will help students the way to get a correct answer using the right intermediate steps.

Another aspect of multimedia is hypertext or hypermedia. It is likely to remain the principle means by which information to assist the student will be presented, although the links that are embedded may take the user to graphical or pictorial formats as well as text (hypermedia). In other words, it provides an additional note from the particular texts or graphics. It may help students to gain an additional knowledge from the words or terms they do not understand. Color pictures, either from real life (photographs) or drawing, have great potential to illustrate many of the important concepts that need to be understood to solve the problem successfully.

In addition, sound can be used to provide information to the user and may be useful in conjunction with any kind of visual image.

2.2 Computer Assisted Instruction versus Intelligent Tutoring System

ITS and CAI provide instructional materials to the user and test for user knowledge, but their approach differs greatly. CAI systems allow experts to create instructional interactions by representing their decisions and problems in the form of programs. Thereby, instruction is typically delivered in a rigid and structured manner, much the same for all users. ITS on the other hand provides a means to capture expert knowledge which the system then uses to compose dynamic instructional interactions. These systems then allow the expert to program the knowledge used to make their decisions rather than simply the decision itself devoid of context.

2.2.1 What is Computer Assisted Instruction

Computer Assisted Instruction, sometimes called Computer Aided Instruction is the term used to describe a learning system that is usually interactive, self-paced, comprehensive software programs that offer instruction and testing. It is an educational medium in which instructional content or activities are delivered by a computer. Students learn by interacting with the computer and appropriate feedback is provided. Several acronyms represent the use of computers in educating students. These are:[Lurain, M.U]

CAI: Computer Assisted Instruction
CAL: Computer Assisted Learning
CaI: Computer Aided Instruction
CaL: Computer Aided Learning
CBI: Computer Based Instruction
CBL: Computer Based Learning

Most of the software was designed linearly and incorporates the uses of behavior modification principles such as:

- applying appropriate reinforcers such as text, audio or video.
- shaping, chaining, modeling, punishment and rewards.
- scoring and/or monitoring system
- status of progress.

CAI comes in various forms such as Drill and Practice, Simulations, Tutorial and game.

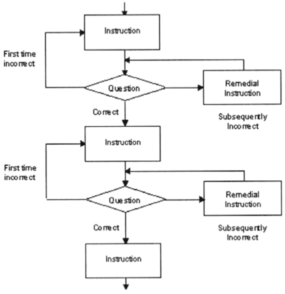

Figure 2.1: Routing within a CAI system

The structure of the system can be seen in Figure 2.1 above. The information will be presented to the user after a series of questions are asked. If the correct answers are detected, the next phase of instruction is entered. If the incorrect answers are detected, the instructional material which has been presented may be in the different format. If, after the material has been repeated, the student again answers incorrectly then remedial instruction may be presented. But the disadvantage of this kind of system is, it will never be able to provide an explanation that will help resolve the misunderstanding of the problem. The system generates a certain response to a particular situation as a human tutor would be able to do.

In the 1960's, researchers created a number of CAI system that were generative [Uhr,1969]. The programs are generated sets of problems designed to enhance student's performance in skill-based domains, primarily arithmetic and vocabulary recall. It was an automated flash card system, designed to present the student with a problem, receive and record the student's response, and tabulate the student's overall performance on the task. These CAI systems did not explicitly address the issues of how people learn, with an implicit behaviorist and transmission model of teaching and learning. They assumed that if systems presented information to the learner, the learner would absorb it.

2.2.2 What is Intelligent Tutoring System

Intelligent Tutoring System is similar to a CAI system but more intelligent in giving guidelines and tutoring. ITS assists students to master the material they have chosen to learn. Students can use the intelligent tutorial to evaluate their understanding of the subject, reviewing only those sections, which need additional study. The hint and guideline for solving the problem will direct and help them to master the particular topics. [Serengul Smith]

ITSs are able to know what to teach, how to teach and any relevant teaching information which is related to the student being taught. This requires the representation of domain expert knowledge (Expert Model), an instructor's knowledge (Instructional Model), and the particular student that is being taught (Student Model). Through the interaction of these models, ITSs are able to make judgments about what the student knows, and how well the student needs to know without the intervention of a human instructor.

All of these components are called Model of ITSs. Through the interaction of these models, ITS are able to make judgement about what the student knows, and how well the student is progressing.

2.2.2.1 Expert Model

Expert Model contains sources of knowledge that can be conveyed to the student. In an expert model, there are various types of knowledge architecture, such as Black Box Model [Anderson, 1988], cognitive knowledge in simulating human problem solving skills, Issue-based model, and knowledge structure.

Black Box Model

The Black Box model establishes a criterion referenced knowledge base. The content domain is naturally organized in a domain expert who is understood by the computer. The computer can assess student performance without the need of human intelligence. The criterion for acceptable performance is clearly identified by the system. Thus, if the input does not meet the criterion, which has been identified earlier, the system will inform the student the performance error and recommend possible solutions.

Cognitive Model

Cognitive models will simulate the human problem solving realistically. There are three levels of cognitive knowledge. It is known as Procedural knowledge which relates how a task is performed, a Declarative knowledge which is a set of facts organized to permit reasoning and a Qualitative knowledge which uses the model of the system that involves causal understanding which allows humans to reason about behavior. The expert model consists of the correct, expert-like knowledge that is to be transferred and learned.

Issue-based Model

This model compares the input to the expert model and the student model. Instructions are programmed to specific issues, which are observable in the behavior of the expert model and the student model. The immediate feedback will be given to the student if his performance fails to meet the prescribed behavior criterion. This feedback includes an explanation of the rule. The dialogue can be very simple feedback with the correct action or very complex by providing detailed reasoning behind the behavioral rule.

Knowledge Structures

Knowledge is structured in a rule-based system or known as Production System. A Production System analyzes and synthesizes large quantities of knowledge to solve problems. The examples of knowledge, which are integrated in this Production System, are declarative and procedural knowledge. The declarative knowledge formulates a database of facts where the procedural knowledge provides the rule base in an IF-THEN or WHEN-THEN relationships.

The aim of the expert model is to provide knowledge or information for students in problem solving. It may convey the source of knowledge to students and will be compared to the student's knowledge.

2.2.2.2 User Interface Model

Interface is the form of communication between the system and the student. It will translate the system's internal representation and an interface language, which is understandable to the student. For example, the standard form of the square root function cannot be represented in the system. In order to solve this problem, student can use the '^" instead of '^{2}'. Example, 3^2 is typed as 3^2. In VECITS, the system informs the student to use '^' symbol instead of square root. The system will accept this kind of symbol as the square root.

2.2.2.3 Student Model

The student model consists of the incorrect and incomplete knowledge that a student begins with. It also consists of a database that stores the student's misconception and missing conception. This database is known as the "bug library". Misconception is an item of knowledge that the student has but the system does not [VanLehn, 1988]. Missing conception is the opposite of this. Bugs are identified from the literature, observation of student behavior and learning theory of the content domain [VanLehn, 1988].

The students' actual knowledge is matched with prediction set by the system. The system will determine the source of deficiency either due to misconception or missing conception if the prediction does not match. The structure of the student model can be derived from

1) the problem solving behavior of the student
2) direct questions asked from the student
3) the difficulty level of the content domain. [Barr & Feigenbaum, 1982].

2.2.2.4 Instructional Model

Instructional model in ITS interacts with students to determine the level of understanding and misunderstanding of a particular domain. It is also known as pedagogical knowledge, which allow ITS to decide what to teach and when to teach it. It gives an immediate response to the student's input and determines the type of help required and the sequence that have to be followed pertaining to the kind of help. The system is able to detect the input line by line and returning the immediate response either by assessing the correct or incorrect answer or an acknowledgement in the feedback.

All of these components can be simplified as in the figure below.

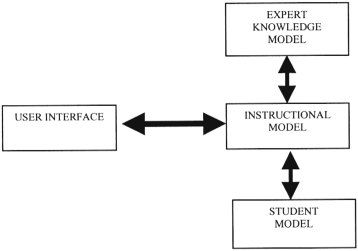

Figure 2.2: Components of ITS

2.3 Feedback Features in ITS

Feedback increases the rate of acquisitions as well as retention of learned behaviors [Williams & Reynolds, 1990]. The feedback has the capability to provide immediate knowledge of results. [Burton, 1988] has identified six formats for structuring instructional feedback to the student which are:

2.3.1 Hint Format.

Hint format has an important role in order to give students a particular guideline to solve the problems. Hint can be defined as a theoretical device that is intended to either: [Hume et al, 1993].

1) provide the student with a piece of information that the tutor hopes will stimulate the student's recall of the facts needed to answer a question, or
2) provide a piece of information that can facilitate the student's making an inference that is needed to arrive at an answer to a question or the prediction of system behavior.

Hint is basically used when the student needs an overview of how to start solving the problem. The most striking phenomenon observed from these transcripts is our tutor's frequent use of hints [Hume et. al, 1993,1996]. Basically, hints allow students to involve in cognitive activity. The activity of students modeling causes a human tutor to monitor the progress of their students. When the student gives a faulty solution to the problem, a hint is presented [Corbet et. al., 1990]. Hints will help students to conclude the answer of the problem. This allows them to answer the question quickly and accurately.

There are two categories of hints: point-to hints (PT-Hints) and convey-information hints (CI-Hints). A PT-Hints alludes to information presumed to be available to the student. The information provides information that should enable the student to proceed solving the problem. CI-Hints explicitly conveys information in the form of an explanation or summary and is followed by a question.

2.3.2 Help Format

In this format, the tutor assumes some of the responsibility for problem solving tasks and allows the student to concentrate on specific areas. The ITS instructs the task by presenting task's operational sequence. The student is provided an opportunity to apply that operation and eventually generalize the operations in solving similar problems. This format facilities the development of conceptual understanding and encourages higher-order thinking skills which are involved in problem solving [Burton,1988].

2.3.3 Empowering Format

This format provides students the tools to review their own decision-making processes. The system will capture the student's performance decisions and their impact, and provides a visual representation of the student's problem–solving ability. The student travels through his or her own decision tree to identify the error made. Problem-solving behavior is acquired in a "risk-free" environment. "Risk-free" environment means the student feel free from doing mistake during solving the problem. This makes them enjoy in solving that particular problem.

2.3.4 Reactive Learning Format

In this format, ITS will respond to the student's actions in a manner that extends the student's understanding of their own action in the context of a specific situation [Burton,1988]. The student establishes a hypothesis, which the computer challenges. The hypothesis is challenged on the basis of its logic, its compatibility with the information the student has previously learned and its consistency with the knowledge base. The student is required to articulate and justify his or her reasoning.

2.3.5 Coaching Format

This format simulates the human coach. It monitors student's performance to identify suboptimal performance. ITS will provide an advise to the student and will immediately interrupt the interaction between the student and the computer. The system compares the student's performance to its expert model. If the student's performance deviates from the expert, the coach redirects the student towards the expert. The coaching format is not concerned with the student completing a predetermined lesson. The primary emphasis is on skill acquisition and general problem solving through computer games [Barr & Feigenbaum, 1982].

2.3.6 Tutor Format

This format will identify the deficiencies in skill performance. The automatic instructional capability of ITS provides an environment to enhance learning. The instructional tutor will identify errors of commission, omission and bugs in student performance. ITS communicate through natural dialogue and provides remediation when necessary. The Tutor must determine when to interrupt and how often. This is because, too little feedback or too much feedback can hinder the learning process. ITS constantly analyzes the student's performance to ensure the learning process of the knowledge domain is being mastered.

2.4 Why Questions are Needed?

Question is important in developing ITS because, based on the question provided, tutor may know either the student understand what has been taught. Questions may elicit knowledge or information by checking the understanding of students. It also encourages students to think of how to solve the problem and encourage the communication skills in a discussion room.

2.5 The Existing Intelligent Tutoring Systems

2.5.1 ANDES: An Intelligent Tutoring System for Physics

This system was developed for physics tutoring where students usually find difficult to learn Newtonian Physics which is a prerequisite for virtually all advanced study of science and technology. This project started in September 1995. The system has been used in university classes at the U.S. Naval Academy and secondary school classes in the U.S Department of Defense Dependent school. The components of the system consist of [Gertner, A.S].

- The Homework Assignment Editor. This program is used by instructors to create homework assignments.
- The Tutor. This program is used by students to do their homework. It consists of the following modules:

    - ♦ The workbench.

      The student selects activities and does them. The workbench includes tools, such as a calculator and an algebraic equation solver. It can give simple right or wrong feedback on both final answers and intermediate results.

    - ♦ The helper.

      This module tries to understand what plan or goals the student is pursuing as the student does an activity. It offers help when asked, and may sometimes offer unsolicited help. It can explain the feedback given by the workbench. If it detects an important physics misconception or a bad learning habit, it may engage the student in extensive multimedia instructional activities.

- The assessor.

  This module uses Bayesian reasoning to maintain a long term model of the student's level of mastery of the individual physics concepts and the student's preferred methods of problem solving and learning.

2.5.2 ITS for Mathematics

There are two examples of ITS designed for mathematics which are

The *Aplusix* System

Apluxis [J.F. Nicaud and M.Saidi], tries to deal with the difficulties of factorization of polynomials and polynomial-equation solving. *Apluxis* can be either example-driven or reasoning-driven. In the first case, the problem is solved by the system. However, the student may ask for explanation concerning facts or strategic knowledge. In the second case, the problem is solved by the student. He chooses among the possible transformations and the system performs the necessary computations.

The goal of the *Apluxis* is to help the student to discover how to perform the necessary matching operations and to develop efficient strategies. In order to do so, the system shows all the operations performed, including backtracking, when presenting the examples. When solving the equations with the help of the system, the student is relieved of the burden of computation. He can therefore use all his resources on the task reasoning. The problem solving components of the system is an expert system that uses explicitly encoded (declarative) strategic knowledge. It attempts to simulate the way humans reason, by adapting the level of reasoning according to the needs.

The Trigonometry Tutor

This system teaches students trigonometric problem solving [Rajan, P., et. al]. It will help students improve their skills in solving trigonometry problems. The aims of the system is helping students to strengthen their understanding of the various fundamental ideas such as concepts of angles and triangles, properties of right-angled triangles, as well as the concepts covered in trigonometry. The system attempts to reinforce student's learning by providing the right type of exercises and when necessary, helping the student solve them. It leads the instruction, and the student is able to get help. The tutor attempts to:

- Present appropriate problems and guide the student solving it.
- Provide students help or advice (possibly request).
- Provide a learning environment that is individualized to the needs of the student, depending on his understanding.

The strong points of the system are the provision of a user-friendly interface, bug identification and providing appropriate remedial instruction. The system uses a black-box expert to solve problems and the student has the option to ask the system to solve a problem.