Intelligent Tutoring System: A Tool for Testing the Research Curiosities of Artificial Intelligence Researchers

Asst. Prof. Dr. Huseyin Yaratan

Department of Educational Sciences
Faculty of Education
Eastern Mediterranean University
Gazimagusa, TRNC

ABSTRACT

An ITS (Intelligent Tutoring System) is a teaching-learning medium that uses artificial intelligence (AI) technology for instruction. Roberts and Park (1983) defines AI as the attempt to get computers to perform tasks that if performed by a human-being, intelligence would be required to perform the task. The design of an ITS comprises two distinct features - a sophisticated computer programming feature which has to be programmed by a computer scientist and a comprehensive curriculum design feature which has to be developed by a curriculum specialist. Unfortunately, most of the existing ITS's were designed by AI researchers alone without much involvement of curriculum designers, education psychologists and/or subject specialists. These AI researchers were not primarily concerned about instructional issues and their main concerns were to test their research curiosities in the AI field with minimum involvement of other people.

This paper will analyze both features of an ITS; first, the four components (**problem-solving** or **expertise module, student model, tutoring module** and **the user interface**) of an ITS will be described and then the nine elements (**objectives, content, learning activities, evaluation procedures, materials** or **resources, teaching strategies, time, grouping** and **space**) of a curriculum design will be explained. The paper will end with a discussion of the problems that can arise if both curriculum development and computer programming features of the design of an ITS are not taken into consideration.

I. INTRODUCTION:

Intelligent computer assisted instruction (ICAI) was the name given to Intelligent Tutoring Systems (ITSs) when scientists started to use artificial intelligence (AI) technology in designing computer-based instruction in late 1970s. AI is defined as the attempt to get computers to perform tasks that if performed by a human being, intelligence would be required to perform the task (Roberts and Park, 1983). Although Roberts and Park in 1983 had made the assumption "… that widespread use of true ICAI systems will undoubtedly occur, but not for 15 to 20 years", it is a fact that ICAI (or ITS) is still limited to laboratory studies. Twenty years ago Roberts and Park (1983) specified some of the prominent limitations inherent in existing ICAI of that time. These limitations can be listed as:

- Absence of a natural language dialogue between student and the computer;
- Differences in how people reason restricts the appropriateness of the expertise model for all students;
- The enormous amount of time and effort required to build an ITS which teaches even a small amount of content.
- The restriction of the ITS content domains to highly structured content areas like mathematics, electronics, and games.
- Requirement of very powerful machines with manageable costs for the individual consumer.

There has been some progress towards encountering some of the above limitations, but most of them still exist.
Another significant reason for constraining the effectiveness of computer tutors was specified by Park, Perez, and Seidel in 1986. They stressed that most ITSs were developed by AI researchers alone, without much involvement of curriculum designers, education psychologists, and subject matter specialists. These AI researchers were not primarily concerned of instructional issues and their main concerns were to test their research curiosities in the AI field with minimum involvement of other people. Furthermore, Park, Perez, and Seidel (1986) stressed that AI researchers chose subject matter areas with which they were most familiar and these areas were mainly mathematics and science; (to be specific they can be listed as mathematics, computer programming, medical diagnosis and electronics). A review of recent research in ITSs reveals that the situation

still persists and computer scientists dominate all the other scientists in the development of ITSs. Thus, curriculum for ITSs so far has been limited to relatively well-structured subject areas. But this does not imply that ITS technology cannot be applied to other areas of education. Carbonell's (1970) SCHOLAR system is an ITS program for teaching South American geography and can be considered as a good example of ITS application in social sciences. If the curriculum researchers start taking part in the design of the ITSs, the process of first, choosing AI techniques for exploration and second, selecting subject matter area which is most appropriate for the manipulation of the selected AI techniques and finally, ending up with a random curriculum, will be reversed; i.e. first, the type of curriculum will be chosen at the broad level, second, the area of interest (subject) will be selected and a curriculum relevant to ITSs will be designed at the specific level by considering the nine curricular elements (objectives, content, learning activities, evaluation procedures, teaching strategies, learning materials, grouping, time, and space) proposed by Frances Klein (1985), and finally, appropriate AI techniques will be selected to program the designed curriculum.

This paper will first, give information about the existing four components of most ITSs - **expertise module, student model, tutoring module,** and **user interface**. Then, the design of a curriculum when ITS is used for instruction will be discussed to show that an ITS can be the ideal medium for curriculum implementation.

II. COMPONENTS OF AN ITS:

As in any other instructional system, the components represent the content to be taught, the device to understand the amount of knowledge that the student has, the suitable teaching strategy, and a system for communications issues. In computer assisted instruction (CAI) all these components are in one structure whereas in ITSs they are separated and this gives more flexibility to the student and the machine in a way that they can have a one-to-one interaction just as when student and teacher sit down and attempt to teach and learn together (Park, Perez, and Seidel, 1986). Another advantage of these modules being separated shows itself when one attempt to make changes in the program; change could be done only in one component of the program and the alteration of the whole program is not required. The four components mentioned above are referred to as problem-solving or expertise module, student model, tutoring module, and the user interface.

1. Expertise Module:

An expertise module or a problem-solving module consists of the domain knowledge that the system intends to teach the student. Nature of knowledge is an important factor in answering questions about intelligence. The AI community divided knowledge into three categories, conceptual, procedural, and imaginal; and they worked with all three kinds of knowledge in the design of ITS programs (Halff, 1986).

(a) Conceptual Knowledge: Conceptual knowledge is the knowledge of concepts and facts and the relationships between them. Conceptual knowledge is represented in AI systems by the use of a semantic network device. Semantic networks consist of nodes and links. Each node has a concept in it and the links give the relationships between the nodes. The figure below shows a part of the semantic network describing conceptual knowledge about birds.

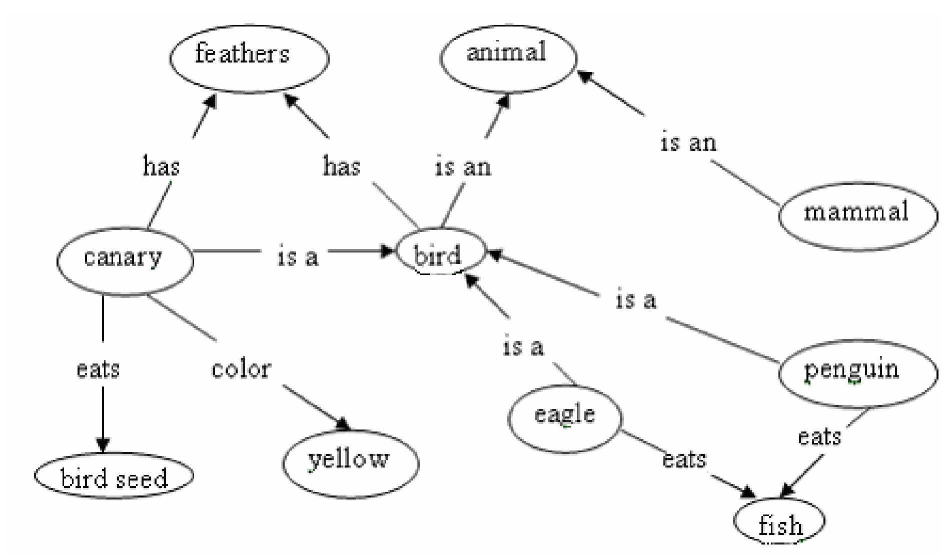

FIGURE: A part of a semantic network (Halff, 1986).

Computer programs can use this network to perform a number of tasks:

(i) They can answer direct questions such as "What does a penguin eat?"
(ii) They can compare and contrast concepts: Penguins and canaries are both birds but penguins eat fish and canaries eat birdseed.
(iii) They can make inferences: Eagles are birds, and birds have feathers; therefore eagles have feathers.

(b) Procedural Knowledge: Procedural knowledge is the kind of knowledge needed to perform tasks such as solving a mathematics problem, understanding a spoken sentence, writing a computer program and so on. Procedural knowledge can be represented by one or both of the following methods:

(i) Procedural experts: These correspond to sub skills that a student must learn in order to acquire the complete skill being taught (Roberts and Park, 1983).
(ii) Production rules: These are used to construct modular representations of skills and problem-solving methods. Each rule has two parts, a condition and an action: "If 'this' condition occurs, then do 'this' action." (Park, Perez, and Seidel, 1986).

(c) Imaginal Knowledge: Imaginal knowledge is obtained by using the ability to produce, in the mind, consequences from some sensory experience. Imaginal knowledge is used extensively in computer-graphics to bring computing power to children. (e.g. Parert's (1980) LOGO project).

2. **Student Model**:
The student model is used to assess the amount of knowledge that the student has in the material that is intended to be taught, to predict the learning behavior of the individual user and to diagnose the causes of errors (Dede, 1986). To assess the student model there are four information sources:

(i) implicit (problem solving behavior of the student),
(ii) explicit (direct questions asked to the student),
(iii) historical (assumptions based on the student's experience),
(iv) structural (assumptions based on the difficulty of the subject-material).

This sophisticated procedure of creating a student model can be resolved to some extend by considering the student as a subset, simplification, or deviation of the expert's (computer's) knowledge. This technique was named as the **overlay model** by Carr and Goldstein (1977).

To model the student's knowledge, learning behavior, and causes of errors, basically two procedures are used:

(i) Simple pattern recognition is applied to student's response history for making inferences about his understanding of the skill and his reasoning process used to derive the response.
(ii) Charting within the subject matter semantic network (or the rule base) to represent the areas that the student has mastered.

3. **Tutoring Module**:
Once the student model has been selected and the expertise in the subject domain is given, the expert tutor selects an initial efficient teaching strategy based on the student's previous performance. This teaching strategy is modified as the student model evolves and the pedagogical strategies used may include presenting increasingly complex concepts or problems. The fundamental issues for a tutor as listed by Dede (1986) are:

(i) whether to intervene in the information flow,
(ii) what to discuss,
(iii) which presentation strategy to use,
(iv) how much to say.

The presentation of learning materials is based on three methods in the existing ITSs: The Socratic method, the diagnostic or debugging method, and the coaching method.

(a) The Socratic Method: This method provides the student with questions to guide him to find out his own mistakes and thereby modify his conceptions.

(b) The Diagnostic or Debugging Method: In this method the computer debugs the student's misconceptions and explains why the student is making that mistake. The BUGGY program developed by Brown and Burton (1978) which uses a diagnostic method allows teachers to practice diagnosing the underlying causes of student's errors, by prescribing examples of systematic, incorrect behaviors of students in basic mathematical problem-solving skills.

(c) The Coaching Method: In this method the student is provided an environment in which he can enjoy and learn as a consequence of fun. In this kind of environment the student gets engaged in activities such as computer games in order to learn related skills and general problem-solving skills.

4. **The User Interface**:
A user interface is developed to provide communications between the student and the ITS. Natural language is used as the means by which information is exchanged between student and computer. Unfortunately most programs use non-vocal techniques (typing and reading from the screen), but in the near future vocal techniques will become feasible. While voice output seems to be easy, voice input, i.e. making the machine understand spoken language is still a major technical challenge (Dede, 1986). The development of natural language techniques has a vital importance in the instructional systems. A machine that can converse with students are clearly more flexible than those supporting more restrictive interaction (Halff, 1986).

III. CURRICULUM DESIGN WHEN AN ITS IS USED FOR INSTRUCTION:
There are two different levels of decision making when designing a curriculum (Klein, 1985).

(i) A broad level, which involves the basic value choices of the designer.
(ii) A specific level which involves the technical planning of curricular elements.

At the broad level, decision is based on three data sources - organized subject matter, the students, and the society. Any one of the three data sources can be used when designing an ITS. However, as Tyler (1949) suggests, a combination of all three sources would be most appropriate. A review of the literature on ITSs reveals that the present ITS programs consider organized subject matter as a data source more than the other two data sources. As mentioned earlier, the main reason for this choice, is that most ITSs are being developed by AI researchers alone, without much involvement of curriculum designers, education psychologist, and subject matter specialists.

The purpose of this section is to discuss the factors that affect the technical planning and implementation of curricular elements when ITSs are used for teaching. The curricular elements used in the design of a curriculum are objectives, content, learning materials and resources, learning activities, teaching strategies, evaluation procedures, grouping, time, and space and environment (Klein, 1985).

Each of these elements will be examined from an ITS design perspective and the necessity of the involvement of the curriculum designers will be stressed.

1. **Objectives**:
Objectives provide directions in learning, they give the specific aims of education. There are several types of objectives, such as behavioral objectives, instructional objectives, general objectives, problem-solving objectives, expressive outcomes... The more sophisticated and complex the statements of objectives are, the harder the task of programming the materials to be taught. If the outcomes or the behavioral changes that are expected from the learners are stated in a very specific manner then programming of an ITS becomes easier. The most suitable objectives for the ITSs are Mager’s instructional objectives, because of their strict, well-defined structures (Mager, 1962). These objectives have three major components:

(i) The behavioral term which expresses the type of task required by the student. This term also specifies the level of the objective in the cognitive domain (Bloom, 1956) or in the affective domain (Krathwohl, 1964).
(ii) The condition or the situation under which the behavior is to be performed.
(iii) The criterion or the level of performance which will be used to evaluate whether the behavioral change has been achieved.

With these three components in the statement of the objectives the computer scientist will know what the specific aims of the instruction are and he/she will be able to write the ITS program with greater ease and less hesitation.

2. **Content**:
It is obvious that the type of structure of an ITS program is dependent on the subject matter to be taught. Although at the present highly structured subjects are programmable, programming other subjects will be possible in the future, by improving the AI techniques and computer hardware. First, content to be taught will be selected by the curriculum specialist and then it must be organized according to scope and sequence (Klein, 1985). Scope is related to the horizontal arrangement and sequence to the vertical organization of the content. Careful consideration must be given to the scope and sequencing of the content so that programming will be easy for the computer scientist and the content will be manageable and meaningful to the student.

3. **Materials and Resources**:
In an organized subject matter based curriculum design the most commonly used learning material is the textbook. When ITS is used for teaching no textbooks or even no paper or pencil are required. The textbook of the student may be a CD or a diskette, his paper may be a screen, and his pencil the pointer device (mouse) or a keyboard. In the future there will be no need for the latter when full vocal communications with the machine will be achieved. Students will not have to learn how to type or even how to read or write! Interaction with the intelligent tutor (computer) will be based on oral and/or visual communications only.

4. **Learning Activities**:
The curriculum designer must carefully state learning activities in relation to the explicit and implicit objectives. Learning activities in the ITSs are based on one-to-one interaction of the student and the computer. At the present, there are two types of learning activities in most ITSs - tutorials and games (Park, Perez, and Seidel, 1986). A tutorial is basically a series of question-response processes. By trying to answer the questions asked by the computer the student focuses his attention on the intended directions of the learning process. These activities must be set up to foster the behavioral changes of the student as stated in the objectives. The student must be motivated to learn and the best method to acquire motivation is the use of games as learning activities. Another purpose of using games as learning activities in ITSs is to provide a reactive learning environment (Park, Perez, and Seidel, 1986) in which the student explores his own interest (e.g. WEST program written by Burton and Brown, 1979 and WUMPUS program written by Goldstein and Carr, 1977). Reactive learning environment is also created by having the student try his own ideas rather than by having him receive instruction from the system, so that he acquires problem-solving skills. SOPHIE program written by Brown and Burton (1978) is an example, which uses this type of learning activity. Of course, these two types of learning activities are not enough to foster the behavioral changes as stated in all the objectives. Hence, several other appropriate types of learning activities must be carefully considered when designing an ITS.

5. **Teaching Strategies**:
Selection of the teaching strategies is very important in the design of the tutorial module of an ITS. Not only one but several teaching strategies must be programmed into the tutorial module and the ITS will be able to make a choice of the teaching method according to the content to be taught and to the student background and learning style. Even when teaching a particular content the ITS must be able to switch from one teaching strategy to another according to the progress acquired by the student. For lower levels of Bloom's Taxonomy (Bloom, et. al., 1956) which are knowledge, comprehension, and application levels, a particular teaching strategy might be very productive, but it might not be adequate for higher levels of the taxonomy which are analysis, synthesis and evaluation levels. One commonly used strategy in organized subject matter based curriculum designs is the diagnostic-prescriptive-evaluative one (Klein, 1985). This strategy has been used in many of the existing ITS programs such as BUGGY developed by Brown and Burton (1978), GUIDON developed by Clancey (1979), and NEOMYCIN developed by Clancey and Letsing (1981). Learning-by-doing (Bruner's discovery learning) is another important teaching strategy employed by many ITSs. Also Bloom's mastery learning strategy can be employed in ITSs since teaching may proceed on a one-to-one basis.

6. **Evaluation Procedures**:
Evaluation procedures are the techniques that are used to assess the amount of achievement the student has acquired in the behavioral objectives and the content. In classroom situations only periodic determinations are possible. But with an ITS continuous evaluation of the student response is possible which can also be accompanied with an immediate feedback. Whenever a student makes a mistake he is immediately notified and also an explanation of why he is doing the mistake is given. Under this type of evaluation the student is

constantly tested and no mid-term or final exams are required. When the student completes the program (i.e. goes to the end of the content) he will be evaluated as a student who has mastered the particular content.

7. **Grouping**:
There is no grouping. The student is alone with the tutor. All teaching is done on a one-to-one basis. Each student progresses through the learning process at his own pace. The teaching strategies, and learning activities must all be chosen to fit the learning style of the individual student. Bloom (1984) compared individualized instruction with classroom instruction in the fields of pre-college probability and cartography. 98% of the students who were taught by individualized instruction did better than the average classroom student. Students who were struggling had the highest benefit from the individualized instruction. Bloom's research proves that ITSs with their individualized teaching strategies will be powerful educational tools to help many students easily attain the specified objectives.

8. **Time**:
There are so many subjects that the educators want the students to learn to cope with their constantly developing environments. Hence, time is a limited resource and students and instructors are expected to make full use of it in a regular classroom setting. When ITSs are used, however, time may be used as a flexible resource because of the individualized nature of the teaching-learning situation. Slow learners will simply have to sit by the computer tutor for a longer time.

9. **Space and Environment**:
When most students afford to own an ITS and the use of ITSs broadens, the learning environment of an individual student will no longer have to be the classroom, but instead, it may be the bedroom of the student or a study-room in his home. When ITSs aare designed to use the internet for connections to libraries, archives or anywhere on earth where the necessary information exists, the learning environment of the individual student will expand beyond the boundaries of the environment where he/she lives. Learning will tremendously be enhanced and the time spent for obtaining information helpful for learning will be a lot shorter.

10. **Communications**
Communications can be an important addition to the existing nine curricular elements proposed by Frances Klein (1985). Type of communication between the students and the teacher in the traditional classroom depends on the capability of the individual teacher; neither the students nor the curriculum designers can participate in choosing the type of communications. But, in an ITS many alternative communication types can be designed for the **user interface** to use according to the choice of the learner. The tutor (computer) may use different accents or even decide whether to use a male or female voice to have the strongest influence on the learner. Communications may also be designed to be symbolic, figural, or semantic, or a combination of these three types.

IV. **Conclusion**:
True learning occurs when one digests the new material, makes it his own by reorganizing his cognitive structure and uses it in new applications. Interaction with a computer that provides immediate feedback and individual guidance is particularly appropriate for the process of true learning. Furthermore, someday machines will be able to learn throughout their lifetime. They will build up their knowledge and will be able to do advance reasoning. They will be able to acquire knowledge by reading natural language materials and best of all they may be able to make conclusions from examination of their existing knowledge to extract new knowledge (Gevartor, 1983).
No matter how advanced the ITSs become, responsibilities and roles of teachers in education will extend far beyond the capabilities of the most advanced ITSs and computers will never replace teachers (Halff, 1986), but the role of teacher will have to be restructured for sure.

REFERENCES:

Bloom, B.S., *The 2 Sigma Problem: The Research for Methods of Group Instruction as Affective as One-to-one Tutoring*. Educational Researcher, 13, 3-16. 1984.

Bloom, B.S., et. al. *Taxonomy of Educational Objectives: Cognitive Domain*. David McKay Co.: New York, 1956.

Carr, B., and I.P. Goldstein. *Overlays: A Theory or Modeling for Computer-Assisted Instruction* (MIT AI Lab Memo No. 406). Cambridge, MA: MIT, 1977.

Dede, C. *A Review and Synthesis of Recent Research in Intelligent Computer-Assisted Instruction*. Int. J. Man-Machine Studies 24, 329-353. Academic Press Inc. (London) Limited, 1986.

Gevartor, W.B. *An Overview of Artificial Intelligence and Robotics*. Volume I - Artificial Intelligence, Part A – The Core Ingredients. NASA Technical Memorandum 85836.

June, 1983.
Halff, H.M. *Instructional Applications of Artificial Intelligence*. Educational Leadership. Volume 43, Number 6. March, 1986.
Klein, M.F. *Curriculum Design*. International Encyclopedia of Education: Curriculum Studies. Volume II. Husen, T. and Postlethwaite editors, Pergamon Press: Oxford England, 1985, pp. 1163-1170.
Krathwohl, D.R., B.S. Bloom, and B.B. Masia. *Taxonomy of Educational Objectives: Affective Domain*. David McKay: New York, 1964.
Mager, R.F. *Preparing Instructional Objectives*. Palo Alto, California: Fearon Publishers, 1962.
Park, O., R.S. Perez, and R.J.Seidel. *Intelligent CAI: Old Wine in New Bottles - Or Is It Just Vinegar?* U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, Virginia. January, 1986.
Roberts, F.C., and O. Park. *Intelligent Computer Assisted Instruction: An Explanation and Overview.* Educational Technology. Volume 23, No. 12. December, 1983.