# CONTINUOUS INNOVATION AND EVOLUTION OF THE INTELLIGENT TUTORING SYSTEM TEx-Sys

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**Abstract**. *The structures and functionalities of all developed and implemented intelligent tutoring systems based on the very first TEx-Sys model are presented, and their continuous innovation and evolution are shown. The TEx-Sys is based on the cybernetic model of educational system, which is based on Gordon Pask's statement that teaching is control of learning. The knowledge has a contextual component and creation and design of knowledge bases is emphasised as particularly important. The testing of prototypes has been carried out with students of different ages, from primary education to university level. Based on our experience of designing and implementing intelligent tutoring tools a possible extension of our approach using intelligent tutoring applets is considered.*

**Keywords.** teaching, learning, intelligent tutoring systems, web oriented ITS

## 1. Introduction

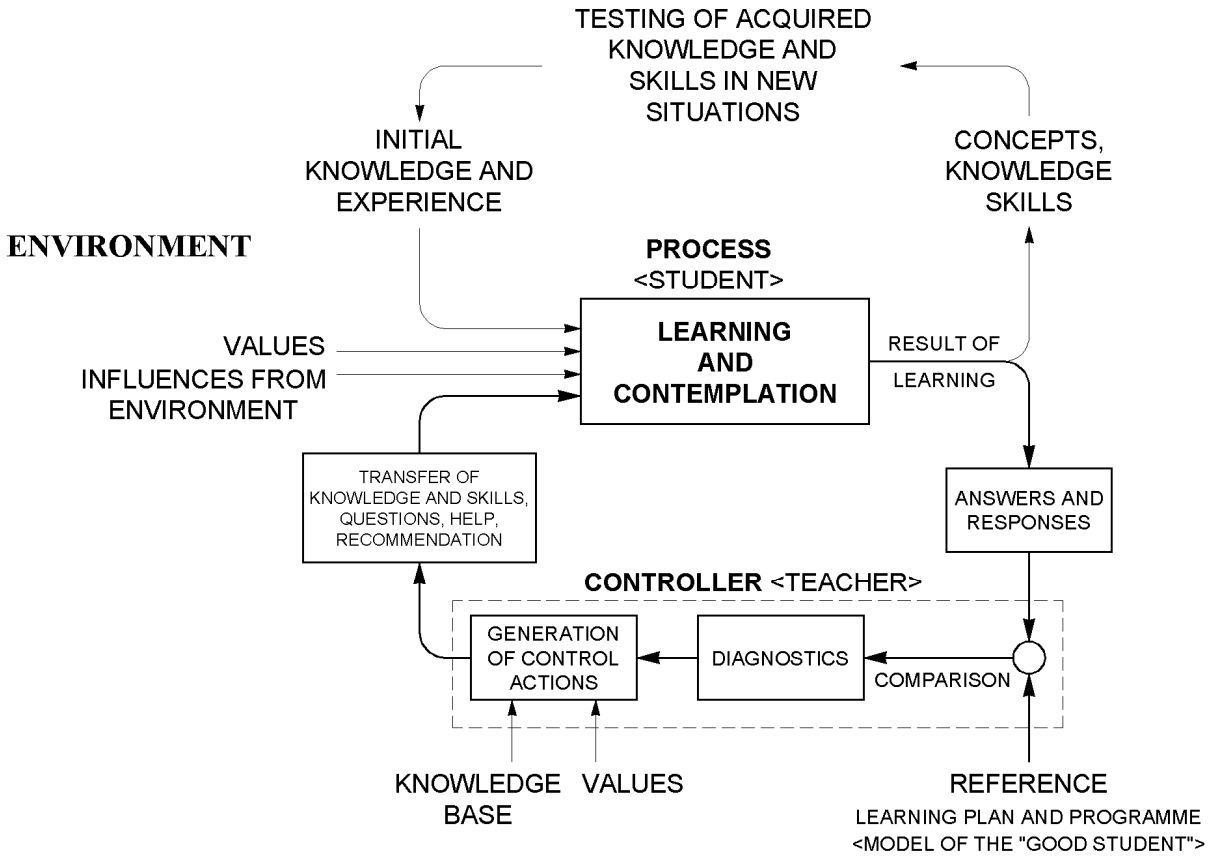
Technological advancement in education has received considerable attention in last two decades and has been explored as a possible substitute for a human teacher. This has proved to be an immense and a very challenging task, particularly having in mind the diversity and richness of the educational environment.

We started our research relying on the traditional intelligent tutoring system and the consideration that "teaching is control of learning" (Pask, 1961) and with the aim to provide tutoring facilities that will satisfy all of the students, the teacher, the curriculum and the institutional needs (Patel et al., 2001).

The cybernetic model of the education presented in Figure 1 has been considered as a basis for the development of our very first version of the intelligent tutoring system (Stankov, 1997, Božičević, 1998, Stankov & Božičević, 1997). It is composed of the student model, which represents student's learning process and student interface. The teacher model describes teacher's control actions based on the information on students' knowledge and serves as a tool for managing communication of knowledge, the examination, the questions and tests given to student.

The achieved knowledge (result of the learning process) of a certain domain serves as a controlled variable, while the reference value is defined: a) through the "good" student model based on the cognition of defined level of knowledge or competence and b) by means of the facts that have to be understood. The difference between the actual student knowledge and the reference knowledge defines

managing activities: transfer of knowledge, asking questions, recommendation, helping etc.




The units of the conceptual model presented in Figure 1 have been transferred in the modular computer models and an intelligent authoring shell has been composed. Basic application has been concentrated on the teaching of the isomorphic model of the system, the control mechanism and their application in technical, natural and social whole. The students have a possibility to choose between several options: to learn directly from the knowledge base, to be questioned and assessed or to create a certain knowledge base. The tutor has the following options: implementing his/her own teaching scenario, creating various questions and tasks for students as well as reviewing student's learning progress. Diagnostics and evaluation of students' knowledge are also considered, and marking is made by an expert system with production rules, which is being continuously improved.

Knowledge in the TEx-Sys is presented by semantic networks with frames. Basic components of semantic networks are nodes and links. Nodes are used for presentation of domain knowledge objects, while links show relations between objects. Nodes have different meaning and significance, such as: understanding of an entity, attributes event description and entity state. Besides nodes and links, the system also supports properties and frames (attributes and their respective values), along with property inheritance. The system relies heavily on modern supporting technologies, such as multimedia, with the following structure attributes: picture, animation, slides, hypertextual description and URL address.

TEx-Sys uses the following predefined semantic primitives: IS_A, SUBCLASS, A_KIND_OF and PART_OF. In addition, TEx-Sys uses semantic primitive labelled PROPERTY for showing properties, as well as Minsky diagram that encodes knowledge in the packages, so called FRAMES, which are incorporated in the network with search capability. The system is then accordingly called "frame based system". Frame is usually assigned to an object, which can have optional number of slots, i.e. attribute sets and their values.

## 2. Implementation of the TEx-Sys

Initially the TEx-Sys was developed and implemented as an on-site computer system. Then, it was followed by research, development and, finally, implementation of a distributed version Distributed Tutor-Expert System, DTEx-Sys (Rosić, 2000). The TEx-Sys and the DTEx-Sys have been used in selected courses (Stankov et al., 2003) at our university. The achieved results have been used for further research that relies on Bloom's experiment (Bloom, 1984) using our own research methodology. A prototype of an extended version of the TEx-Sys *eXtended Tutor-Expert System*, xTEx-Sys (Stankov, 2005), called *Web oriented intelligent authoring shell* has also been developed as a result. LabTEx-Sys, *Laboratory Tutor-Expert System* is designed too. It serves for teaching based on laboratory experiments.

### 2.1. On-site TEx-Sys

On-site version of TEx-Sys has a modular structure with the following main functionalities:

- *Login* for work legalization on the system;
- *Developing module* for building the base of freely chosen domain knowledge (for experts, for teachers, and, in particular cases, for students, too);
- *Learning and Teaching* (Learning &Teaching module) of freely chosen domain knowledge (for students);
- *Testing* (Testing module) evaluation of a student's knowledge within a teaching scenario, according to Piaget's theory of "guided free play" (Sugerman, 1978) and combinations of teaching scenarios by "articulated experts" and "dialogues of divided initiatives" (Carbonell, 1970);
- *Evaluation* (Evaluation module) access to the results achieved in learning and teaching (for teachers and students too);
- *Quiz* (Quiz module) implementation of the test, in which a student is given a set of questions with attached answers, which can be correct or incorrect. Student solves the test by marking the answers he assumes to be correct. After the student solves the test, he gets a mark (according to his answers) and, perhaps, a recommendation for learning more about some entities of domain knowledge, if the system concludes that he/she isn't acquainted with them by evaluating his/her answers (for students).

The on-site version of TEx-Sys has been actively used in the learning and teaching process at the Faculty of Natural Science, Mathematics and Education at the University of Split since 1997.

TEx-Sys implements data storage using database with no support for network-based application usage. Owing to this shell's weakness, the complete system is designed as a standalone application, without connections and data interchange with

the environment. Modules are single executable files without intercommunication and rely on Windows operational system application programming interface.

### 2.2. Distributed Tutor Expert System (DTEx-Sys)

Distributed Tutor Expert System is a Web oriented intelligent tutoring systems that has been developed by keeping in mind issues like (i) accessibility for a large number of potential users and (ii) learning and teaching in arbitrary domains. The system functionality comprehends knowledge base access for arbitrary domain knowledge, along with testing, diagnosing and evaluation of students' work. DTEx-Sys features Web-based tutoring by means of standard browsers and an interactive hypermedia learning environment (picture, animation, slides, URL addresses and hypertextual descriptions), and enables an incredibly easy two-way communication between students and teachers, as well as the student – student communication. The pedagogical paradigm of DTEx-Sys is based on the testing module adaptability and a high level of interaction between this module and the learning one. Adaptability of testing is supported by evaluating every step in student testing along with measurement and diagnostics of student knowledge. After each step, the system generates new questions depending on student's partial results. This phase ends with students' recommendations for further work, thus "closing the loop" by starting another learning cycle. After he has logged in, the actor can select the following system functionalities: (i) access to domain knowledge base in learning and teaching option, (ii) quiz for domain knowledge testing and (iv) option result for viewing your past quiz results.

DTEx-Sys is implemented as a 3-tier client-server architecture. The presentation tier comprises user interfaces individual users use to access system services. The application logic tier comprises ITS functions such as test generation, student rating, student progress observation etc. The data tier comprises domain knowledge bases along with system users' databases.

The creation of intelligent tutoring applets is now being studied with the idea to build up a large inventory of accessible knowledge that can be utilized by all teachers (Brusilovsky et al., 1996, Patel & Kinshuk, 1997).

### 2.3. Extended Tutor – Expert System (xTEx-Sys)

xTEx-Sys takes advantage of new technology which promotes construction of Web oriented system. It is an intelligent authoring shell designed as a Web service. Web services as a standard for describing, publishing, discovering and binding application interfaces could raise e-learning systems into a higher level enabling communication between learning systems regardless of application platforms used. Generally, Web services facilitate application-to-application communication making heterogeneous Web-enabled learning systems cooperative. xTEx-Sys enhanced by some extended functions for courseware development and learning management. Students and teachers work in virtual classroom; students learn individually and teachers prepare courses for students.

Web oriented intelligent authoring shell has the following actors and functionalities:

- *expert* to design domain knowledge on specially defined ontology for knowledge design and representation,
- *teacher* to design courseware using defined ontology for hierarchical organization of course content - units, lessons, topics and instructional items for student

learning and teaching process as well as tests of quiz type for student knowledge evaluation (courseware structure elements)
- *student* to select course and navigate trough domain knowledge content via didactically prepared course content, and finally
- *administrator* for system supervision.

xTEx-Sys architecture incorporates advanced technologies to gain interoperability and reusability of other educational systems. Apart from that, xTEx-Sys merges technical and functional benefits of previous version of the authoring shell TEx-Sys and DTEx-Sys. Its service-oriented architecture provides functionalities to other platform independent systems. Such interoperability can take content developed in one location with one set of tools and use them in another location with a different set of tools.

## 3. Conclusion

Prototype tests on the TEx-Sys, DTEx-Sys i xTEx-Sys have been carried out with students of different ages, from primary education to university, using designed knowledge bases and on the courses with educational contents in developed knowledge bases. Results of the tests are advantageous, according to surveys; and implemented and deployed software satisfies functionalities and actors' demands. Domain knowledge bases design has enabled expert environment testing, while course educational content design has enabled teacher's environment testing. Teachers and students from the Faculty of Natural Science, Mathematics and Education, University of Split, the Faculty of Chemical Engineering and Technology, University of Zagreb, and the Faculty of Philosophy, University of Split performed roles of the experts and teachers. Student environment has been tested to determine system's usability and students' achievements in learning and teaching process. During the second half of 2004 and during 2005 we have conducted 14 tests with 36 domain knowledge bases, with 245 pupils from three elementary schools in Split, 25 students from a secondary school in Šibenik and 344 students from the Faculties mentioned above (Stankov, 2005).

The results have inspired us to investigate learning styles and study approaches, and now we are devoted to the examination of relationship between personality, motivation and study method and to contributing to further improvement of the system by creating a better match between teaching and learning styles.

The results we have achieved are very promising, pupils and students manifest real satisfaction and are motivated to learn while their teachers are challenged to generate new ideas and innovate. On the other side, our very good communication with students and teachers is a continuous motivation for our team to design even better, more student-friendly TEx-Sys.

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