Role of Human Teacher in Web-Based Intelligent Tutoring Systems

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INTRODUCTION The research on Intelligent Tutoring Systems (ITSs) has expanded in recent years to new dimensions due to the advent of the Internet as a global communication medium. This brings about a new area of research which was not considered till now due to the localised nature of academic environments. This area is the adaptation to local contexts by the systems while they are being used by students in different parts of the world. These local contexts reflect the distinction between the two roles of ITS designer teacher and ITS implementer teacher which probably are far apart, with different personality attributes, styles, and preferences. This fact develops a concern among teachers who distrust the ITSs as being unable to reflect their own pedagogic aspects, but rather embodying the beliefs of the ITS designer (Major & Reichgelt, 1992). In fact, current research on ITSs has been narrowly focussed only on the interactions between an ITS and a student, largely neglecting the role of the teacher in the design and implementation of such systems. This paper presents the concept of a *Human Teacher Model* in the ITSs which would consider the attributes and role of a human teacher—both as a designing collaborator and a teaching collaborator within a joint cognitive system consisting of the ITS, student and human teacher.

This paper very briefly examines the contexts of an Intelligent Tutoring System (ITS) to encourage a broader perspective in designing ITSs, however, its utility extends to any educational resource. There is a need to consider the environmental contexts of an ITS in addition to the interactional context frequently addressed in the existing research. These contexts are required to address some of the key aspects of any educational system (see Patel, Kinshuk, & Russell, 1999). Two important aspects that need attention are: (i) what are the various *teaching styles* and how is the performance of an educational system affected by the possibly divergent teaching styles of the teachers involved in designing and implementing various educational resources; and (ii) does the nature of a particular domain favour a specific teaching approach or method of knowledge representation, providing points of convergence among the possibly divergent teaching styles.

The environmental contexts are those that surround the design and implementation of an ITS and they significantly help or hinder its acceptability and performance. The paper is based on a broader consideration of contexts that led to the development of *Basic* Intelligent Tutoring Tools (ITTs) for introductory numeric topics by the Byzantium project under the Teaching and Learning Technology Programme of the Higher Education Funding Councils of the United Kingdom (Patel & Kinshuk, 1996b). The internal structure (see Patel & Kinshuk, 1996a) and functionality (see Patel, Kinshuk, & Russell, 2000) of the ITTs have been discussed elsewhere but the following narrative very briefly describes the scope and structure of an ITT and provides a brief development history. A *Basic* ITT has a narrow focus. It encompasses a single topic or a very small cluster of related topics. It is a *mixed-initiative* system with an *overlay* type of student model. Its inference engine processes knowledge rules stored in a two-fold knowledge base, giving it a degree of intelligence.

The scope of an individual ITT can be enlarged by combining various ITTs. An ITT may thus be seen as a building block of a larger and more comprehensive tutoring system. It may also be mixed and matched with other internet-based technologies (e.g., streaming audio/video) or non internet-based technologies (e.g., audio/video CDs) as well as human teachers (Kinshuk & Patel, 1996), in various configurations of Computer Integrated Learning Environments (CILE) to suit classroom based, open and distance learning. The development of the early ITT prototype commenced in 1990 at the De Montfort University, United Kingdom, when the need was established to provide some kind of a tutoring tool to replace at least some aspects of teaching and assessment for introductory level Business Studies. The purpose of such a tool was to release some of a lecturer's time with a view to better utilise it for richer interaction with advanced level students. Four ITTs were developed as fully functional advanced prototype applications for the teaching and learning of different techniques—involving dissimilar domain logic and operations, to provide a better understanding of the critical aspects of the interface and internal structural requirements for these diverse applications. The applications are currently operational and have already been used by student numbers in excess of 7,000 to date at multiple institutions.

Stoner and Harvey (1999) carried out an independent evaluation at the University of Glasgow, involving the ITTs and another widely used traditional Computer Based Learning package. They found the results to indicate that student performance had improved significantly over the period since Learning Technology materials were introduced and that this improvement appeared to be mainly reflected in the students' ability to complete the questions in the area of learning covered by the ITTs. Their student feedback focus groups observed:

> *The ITTs were useful because you could go over bits you were unsure about. It was better than a book because it was interactive. With the interactive questions you tend to pay more attention than you would to a book.*
>
> *I prefer the ITTs because the other package waffles on about what you already know and provides no incentives to pay attention to what it says. The ITT offers instant feedback, is more involving and you can do as many questions as you like.*

Of the two tutoring systems, 71% of students showed a preference for the ITTs while 8% indicated no particular preference. The students wanted more tutoring systems, similar to the ITTs, for other topics and were positive about Computer Aided Learning (CAL) in general, observing that it was good to use CAL if the tutoring software was good. They also found that student performance had improved to a greater extent when the ITTs were better integrated into the curriculum. This confirmed the project team's own implementation experience of the test versions, that the implementing teacher/tutor plays a crucial role in the success of a tutoring system.

The idea of the necessity of additional contexts, beyond the interactional contexts normally considered by ITS designers, has emerged from various inter-disciplinary deliberations undertaken during the design, development and implementation of the ITTs. It has also benefited from the on-going discussion on proposed further developments including implementing the methodology on the World Wide Web with a view to sharing both the development activities and their outcomes (see Patel et al., 1999).

THE CONTEXTS OF AN ITS

The need to employ the interactional contexts in an intelligent system arises from the necessity to accommodate the notions of co-operation, explanation and incremental knowledge acquisition (Context-97, 1997). The research as reported in the literature, points to the notion of context being employed primarily with respect to the tasks of plan recognition, knowledge structuring, knowledge representation, reasoning, and discourse management. Employing context in these tasks improves the human-computer interaction and facilitates intelligent feedback by the system. For example, Widmer and Kubat (1993) described a system called FLORA3 that implements incremental concept learning in dynamic environments where the target concepts may be context-dependent and may change drastically over time. Dybkjaer, Bernsen, Dybkjaer, and Papazachariou (1995) reviewed a spoken language dialogue system that uses context to provide system-directed dialogues to enable controlled steps in the direction of mixed-initiative dialogue.

An example of the use of interactional context for providing better reasoning is found in PROTÉGÉ-II System, a meta-tool for constructing task-specific expert-system shells (Walther, Eriksson, & Musen, 1992). The application of context to plan recognition has been explored by Johnson (1995) who presented a system called REACT, used for training operators of the communication links in NASA's Deep Space Network (DSN). The systems described above paint a general picture of the existing research. They all suggest appropriate design philosophy using the notion of context as applied to the human-computer interaction. We suggest, however, that other classes of contexts, in particular the environmental contexts are perhaps even more important from the point of view of wide-spread usability in the actual learning environment and the ITS designers need to look beyond the student-system interaction issues.

Environmental Contexts

The environmental contexts of ITSs are analogous to the contexts of office application systems (such as word processing packages, spreadsheets and so on). While the contexts of office application systems can be defined in terms of the user attributes and nature of the tasks, those of the ITS have to be described by the student, the learning goal, the learning environment, and the practical application environment where the learning results will be employed in due course. Major groupings of the environmental contexts may be listed as (i) *Student* (the student's capabilities, preferences and motivation), also including *student peers* (ii) *Teacher* (the designing and implementing teacher's preferences and outlook) (iii) *Discipline* (the nature of subject discipline) (iv) *Characteristics of knowledge* (the characteristics of the domain knowledge) (v) *Characteristics of the medium* (the capabilities of the computer hardware and software employed as a tutoring medium) and (vi) *Social environment* (the social environment in which the ITS is designed and used). These groups of context and their main constituents are depicted in Figure 1. This paper, in the main, addresses the teacher as an environmental context of an ITS.

The Teacher as an Environmental Context

A pedagogic designer of an ITS needs to consider the categories of the students based on several criteria: (1) the novice and expert users of a tutoring system (prior knowledge of how to use a tutoring system on any particular hardware/software platform), and (2) the novice and experienced students, based on (a) knowledge—due to prior exposure to the subject discipline and (b) learning ability—due to prior exposure to academic instruction. The *user sophistication* (as determined by factors such as age, experience, socio-economic background, prior education and so on) may also be a factor to contend with, for instance, adult learners may be rich in experience but poor in formal education. A much improved appreciation of the complexity of the task undertaken by the traditional ITS designer has brought about increasing recognition of two concepts. The first is the general acceptance that knowledge has a contextual component and that the context provides a systematic way to cluster, partition and organise knowledge and its dimensions (Brezillon & Abu-Hakima, 1995). The second is the acceptance of the role of a student's natural intelligence, i.e., common sense and general problem solving abilities in the learning process, to the extent that some researchers argue that the human tutors virtually never provide the sort of explicit diagnosis of student misconceptions that is sought to be provided in the traditional ITS (Cumming, 1991).

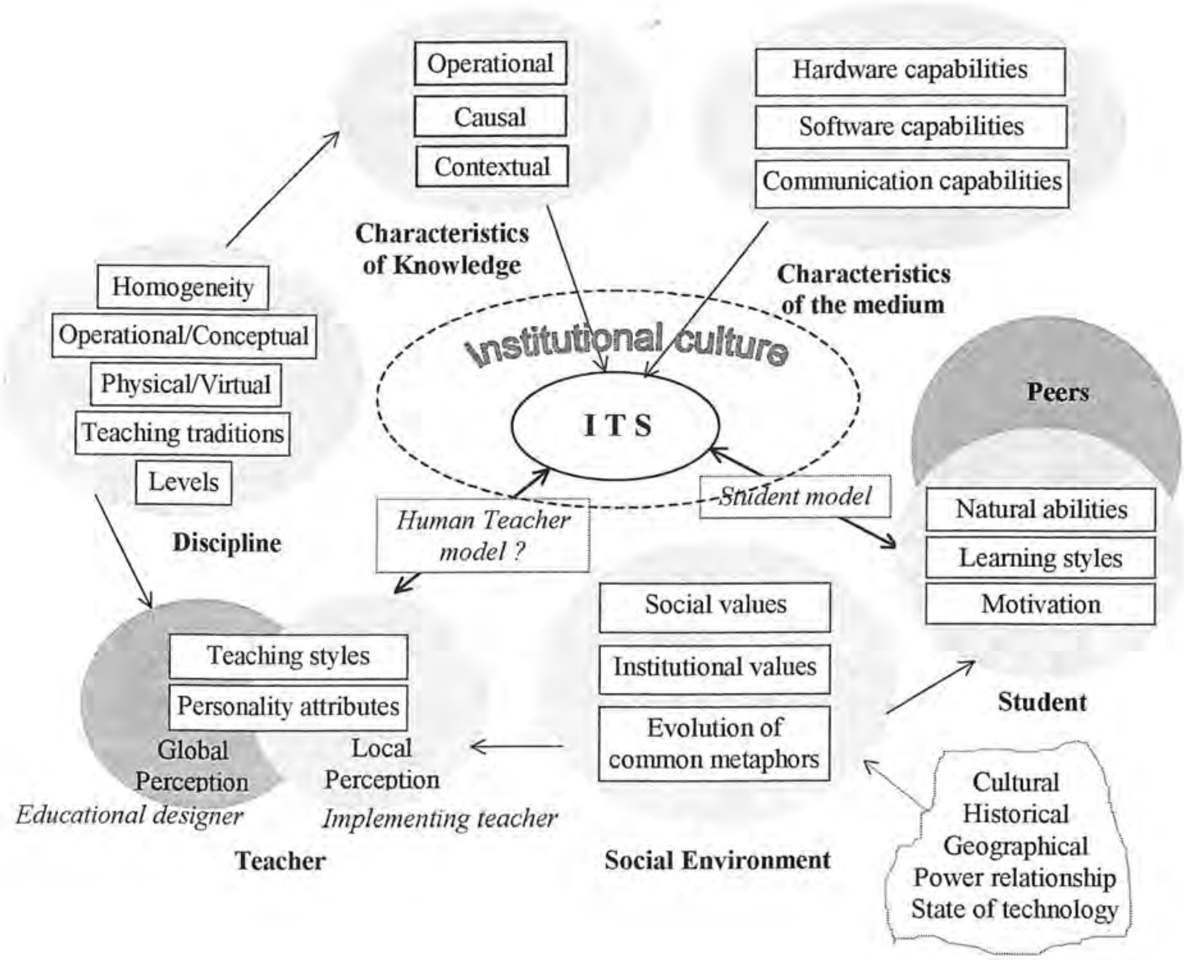

Figure 1: The environmental contexts of an Intelligent Tutoring System

Newman (1992) has noted that the observations of instructional interactions in which a teacher was helping a student or group of students indicated that the teachers often did not have an understanding of exactly how the students were approaching the task. The over ambitious design of traditional ITSs attempted to outperform a human teacher though, as Chen (1995) noted, "The methods currently used in areas pertinent to computer-based learning environments are incomplete in addressing the wide range of cognitive and pedagogical issues involved". Given the natural intelligence of the student, perhaps the endeavour at deep understanding of the student's mental processes, though it may be desirable, does not appear to be very critical and the educational purpose may be better served by providing the teacher with better and more efficient tools for teaching. The attempt at eliminating the teacher from the process has perhaps resulted in many years of research with little to show in terms of tutoring systems that are operationally successful in the real learning environment.

While the idealism provides a good impetus to research in the laboratories, it is essential to grasp the ground reality as expressed by Devlin (1997): "Thousands of hours of effort by brilliant computer scientists, mathematicians, linguists and system engineers have yet to produce an interactive help facility on a photocopier that is even remotely as good as an office junior, just out of high school, who has had an hour's instruction on using the machine." An ITS, realistically, can only be seen as a joint cognitive system (Dalal & Kasper, 1994) comprising not only the tutoring software and a student, but also an implementing teacher and to an extent the peer students. The student-ITS interaction is therefore, a convergence of the human psychology of a student and a teacher, and to the degree to which the tutoring software is "intelligent", the cyber-psychology of an ITS—reflecting the psychology of the ITS designers including their perception of students, teachers and the learning process.

The teacher plays various roles including those of providing the context, selecting and scheduling other educational technologies, managing the curriculum and overseeing the learning progression. In the ensuing power relationship, the preferences of a teacher will certainly be more important than the learning style of a student, in gaining wider acceptance of a tutoring system. Identifying these preferences is a difficult task as the teachers may have different personalities and possibly different teaching styles born out of their traditional, progressive or vocational outlooks and their own learning styles (Entwistle, 1981). However, it is recognised that the orientation to teaching strongly influences the teaching methods adopted, learning tasks set, assessment demands made and the overall workload specified (Gow & Kember, 1993). These, in turn, influence the student approaches to learning. High workloads, surface level assessment demands and lack of freedom in the learning environment are the factors that are found to coincide with an extensive use of reproductive approaches by students (Gow & Kember, 1993).

This observation obviously leads to the question about how similar conditions of increasing workloads, performance assessment demands, increasing constraints of the work environment and changes in the "Institutional Culture" as the education sector becomes competitive and commercialised, affect a teacher's teaching style. If a teacher is forced to adopt a superficial teaching style due to one or more of such environmental factors, the situation may be improved by harnessing the ITS in a supportive role to free up some of the pressure (Kinshuk & Patel, 1996). However, unless the ITS has a teacher model and enables its re-configuration to suit the implementing teacher, it will not find easy acceptance as the last thing the harassed teachers would want to do is to fight against their own past practices and invest time in implementing someone else's pedagogy. We suggest that a *human teacher model* should formally be incorporated in the design of an ITS and indeed in any educational system: to recognise the different teaching styles, to put on record the teaching style(s) adopted in the design and enable manual or automatic adaptation to suit the implementing teacher. An explicit explanation of the teaching style adopted in the design not only enables an implementing teacher to understand the designer's rationale but also helps in dealing with the cognitive dissonance arising from any differences in the teaching styles. In fact, this might also contribute to improvements in the student learning in the case of less adaptive systems, as the rationale behind the adopted teaching strategy is made clear.

It is also important to recognize two facts (Clark, in press): (i) it is the instructional method and not the media that causes learning as has been demonstrated in many media comparison studies; and (ii) the human brain, that has evolved over millions of years, does not change rapidly and can be overloaded by the sensory output that the technology is capable of delivering. To prevent such cognitive overload, the amount of information and in particular, the richness of some of the contextual information may need to be constrained in early stages of learning. The situation, however, is quite complex. It is the novice learners who benefit more from richer representations as these provide multiple stimuli. It is also the same group of learners who are more likely to get distracted in the absence of directed learning since they may still be developing adequate meta-cognitive skills of setting learning goals, selecting effective learning techniques, monitoring progress towards the goals and adjusting strategies as needed. Different teachers would direct the learning process by constraining it in different ways, including defining an appropriate grain size of learning, learning in a situational context or abstract learning that is applied to problems of varied context. An ITS therefore needs some mechanism for adapting to the teaching style of an implementer teacher.

The need for such adaptation to the implementing teacher is even more critical in the case of tutoring systems that are implemented in far away places or are run on the Internet and are accessed at long distances. The wide cultural differences may make some of the representations difficult to comprehend. Similarly, the teaching style adopted at the design stage may turn out to be unproductive in a different cultural setting. The implementing teachers, in such cases need some way to access a localized ITS.

Domains and the Process of Education

The process of education involves traversing the granularity within various domains to varying extents, from detailed to abstract and from intrinsically simple to complex representations of knowledge—the complexity generally arising from implicit knowledge, implied context and inferred semantic. It is observed in current educational practices that learning takes place over a number of topics in a number of subjects over a period of time with progressively increasing depth and/or breadth. This practice indicates that there are levels in the learning process at which knowledge is instructed and the students advance in the process of an educational model progression along the part-whole dimension. They first learn about each component of an ultimate framework and then learn how they combine in the framework. It follows from the above discussion that the type of teaching and learning at an introductory level is likely to be qualitatively different from that at an advanced level. At the introductory level, the students are more likely to be learning the details that are later taken for granted as implicit to an advanced level dialogue.

Similarly the nature of the discipline being taught, in terms of the subject matter being widely homogenous (e.g., Law) or a wide collection of discrete concepts (e.g., Operations Research) or in terms of dealing with the physical world (e.g., the actual measures of Mechanical Engineering) or its virtual representation (e.g., the monetary representations in Accountancy) is very likely to determine to a very large degree the teaching methods adopted and the technology employed for the purpose of teaching. An advantage of systematically considering the nature of discipline and the level at which it is instructed lies in the possibility that it may provide points of convergence while the preferred teaching styles may create points of divergence between the designing and implementing teachers.

Incrementally Growing More Successful ITSs

While the effort put into developing very intelligent ITSs, that can entirely replace all the functions of human teachers and provide a much enhanced level of adaptivity to student needs, is laudable, it may be more productive to adopt the approach that was successfully implemented in the development of office applications. The first word processor did not aim to eliminate the steno-typist. It aimed at making the steno-typist more productive by providing more efficient ways of working. Over the years, word processors have improved in terms of functionality through inclusion of a spell checker, a grammar checker, ready made templates, an improved help facility, wizards and the integration of speech interface. It is now possible to replace the steno-typist with a computer system. Similar incremental growth has been seen in all office applications. The advantage of this approach is that it rapidly brings the technology into the workplace, improves the performance and comfort level of the humans who use the technology and encourages the humans to harness the technology more productively.

Adopting this approach, that has already been proven in the case of the development of Office Applications, the ITS designers should design the system with the Human Teacher in mind and as the target user. The ITS designers should try to make the Human Teachers more productive and increase their comfort level while gradually improve the functionality.

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