An initial framework of contexts for designing usable intelligent tutoring systems

Ashok Patel, David Russell
CAL Research & Software Engineering Centre, De Montfort University, Leicester, UK
Tel./Fax: +44 116 257 7193; Contact E-mail: apatel@dmu.ac.uk

Kinshuk, Reinhard Oppermann and Rossen Rashev
GMD FIT - National Research Centre for Information Technology, Sankt Augustin, GERMANY
Tel.: +49 2241 14 2144; Fax: +49 2241 14 2065; Contact E-mail: kinshuk@gmd.de

Abstract. The notion of context has been an issue of research in various aspects of intelligent systems such as knowledge management, natural language processing, reasoning and so on. This paper focuses on the various contexts surrounding the design and use of Intelligent Tutoring Systems (ITS) and proposes an initial framework of contexts by classifying them into three major groupings: interactional, environmental and objectival contexts. Interactional contexts are used by the system, environmental contexts surround its design and use while objectival contexts refer to the objectives of an educational system as exhibited by its 'teaching' and 'assessment' practices. A better understanding of these contexts is essential for designing better and more usable intelligent tutoring systems.

1. Introduction

The issue of context has been an important area of research in recent years, however, there is no consensus as yet about what context really means, what are its implications and how it can be generalised. Most of the research so far has concentrated on how the notion of context has been implemented by different systems, the resultant improvement in the quality of human-computer interactions and the pedagogical strategies employed by such systems. The issue of how the various contexts of an intelligent tutoring system (ITS) implementation can affect its design and use has not been studied in a systematic way, except perhaps in relation to the student users (student model).

This paper provides a brief overview of context as currently employed in intelligent systems and proposes an initial framework of contexts for encouraging a broader perspective in relation to ITS, however, its utility extends to any educational system whether technology based or traditional. The framework proposes addition of two new categories to the interaction related context addressed in most of the existing research and enables consideration of some of the key aspects of any educational system, for example: (i) what are the various constituents of knowledge and does any constituent benefit more from the technology employed; (ii) what are the various *teaching styles* and how is the performance of an educational system affected by the possibly divergent teaching styles of the educational designers and implementing teachers; and (iii) does the nature of domain favour a particular teaching approach or knowledge representation, providing points of convergence among the divergent teaching style preferences.

The initial framework categorises the contexts of an ITS into three classifications: *interactional* contexts, *environmental* contexts and *objectival* contexts. The interactional contexts are the contexts within which the interaction between an ITS and a student takes place. The environmental contexts are those that surround the design and implementation of an ITS and they significantly help or hinder in its acceptability and performance. The objectival contexts arise from the educational process itself and are, in the main, concerned with explicit and implicit objectives of the teaching and assessment systems. The listed contexts and their classifications are not intended to be exhaustive and it is hoped that the proposed initial framework will encourage further research into the area, especially in terms of determining the inter-relationship of such contexts.

2. Background

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 [29]. The internal structure and functionality of the ITTs has been discussed elsewhere [30] 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 *overlay* type of student model. Its inference engine processes knowledge rules stored in a two-fold knowledge base, giving it a rudimentary level 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 technologies (e.g. video) as well as human teachers [23], in various configurations of Computer Integrated Learning Environments (CILE) to suit class-room based, open and distance learning.

The development of the early ITT prototype commenced in 1990 when the need was established to provide some kind of a tutoring tool to replace at least some aspects of teaching and assessment at the 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 prototypes 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 different applications. These prototypes are operational and are used by students at multiple institutions. The approach has also been tested theoretically for the Spring Design ITT in Mechanical Engineering [31].

The proposed framework of contexts has evolved from various inter-disciplinary deliberations undertaken during the design, development and implementation of these ITTs. It has also benefited from the ongoing discussions on proposed further developments including implementing the methodology on the World Wide Web with a view to share both the development activities and their outcomes.

3. The meaning of context

There are many definitions of context in use and many researchers have provided in-depth studies of the subject (e.g., [25,26,27]). Brezillon & Abu-Hakima [6] observed that context is what gives meaning to data. Iwanska [21] suggested that the word context itself gains its meaning according to its use. In linguistics, context is recognised as being important to the task of ascertaining 'correct meaning' [32]. Brezillon [5] has reviewed context as used in various disciplines and domains such as artificial intelligence, databases, communication, explanation, knowledge acquisition, machine learning, electronic documentation and vision. Akman & Surav [2] have provided a good overview of the role of context in various disciplines such as natural language, categorisation, intelligent information retrieval as well as knowledge representation and reasoning.

The definition, best suited to the proposed framework, suggests that the context of something consists of the ideas, situations, events, or information that relate to it and make it possible to understand it fully [2]. It is observed, however, that the practical implementations based on the notion of context differ from each other significantly in terms of their understanding of context and the corresponding functionality provided in an intelligent system [see section 4.1]. None of these efforts address the issue of usability of an ITS in view of the various environmental contexts besides the student user and appear to be concerned only with the interactional contexts. This paper proposes a much broader framework of context to take cognisance of powerful contexts surrounding the implementation of an ITS and to help in developing more purposeful and usable ITSs.

4. An initial framework of contexts for an ITS design

Any tutoring system is designed and used in the context of a wide variety of factors that can be grouped into three categories as shown in Fig. 1. These are discussed in the following sub-sections.

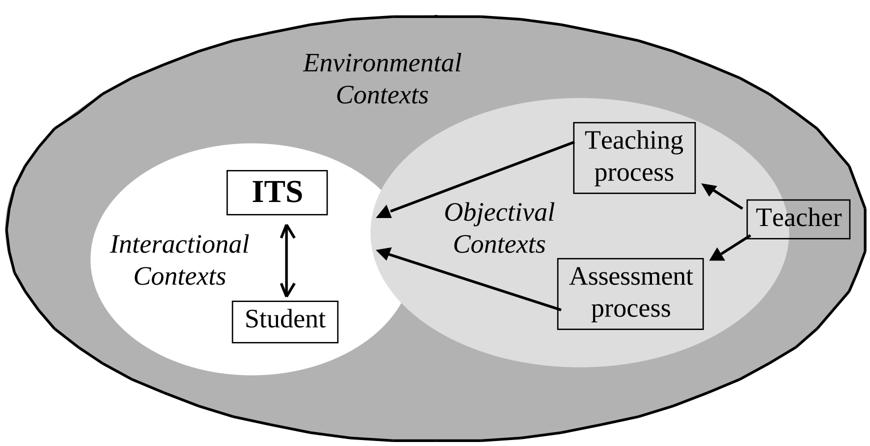

Fig. 1. The contexts of an Intelligent Tutoring System

4.1 Interactional contexts

The need to employ this class of contexts in an intelligent system is the necessity to accommodate the notions of co-operation, explanation and incremental knowledge acquisition [11]. The research so far, 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 more intelligent feedback by the system. Some of the practical implementation of this class of contexts is reviewed below.

Widmer & Kubat [34] 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. Burstein & Kaplan [8] described constructed-response, an innovative way of testing the knowledge acquired by a user. One type of constructed-response elicits spoken or written language. Context is used in processing such responses. Dybkjaer et. al. [17] 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 context for providing better reasoning is found in PROTÉGÉ-II System, a meta-tool for constructing task-specific expert-system shells [33]. The application of context to plan recognition has been explored by Johnson [22] 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 use context as applied to the human-computer interaction, and provide design philosophy accordingly. However, we believe that other classes of contexts are perhaps even more important from the implementation point of view and ITS designers need to look beyond the student-system interaction issues.

4.2 Environmental contexts

The environmental contexts of ITS 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), including *student peers* (ii) *Teacher* (the 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 Fig. 2.

4.2.1 The actors and their interactions

An ITS designer needs to consider two categories of the students: (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.

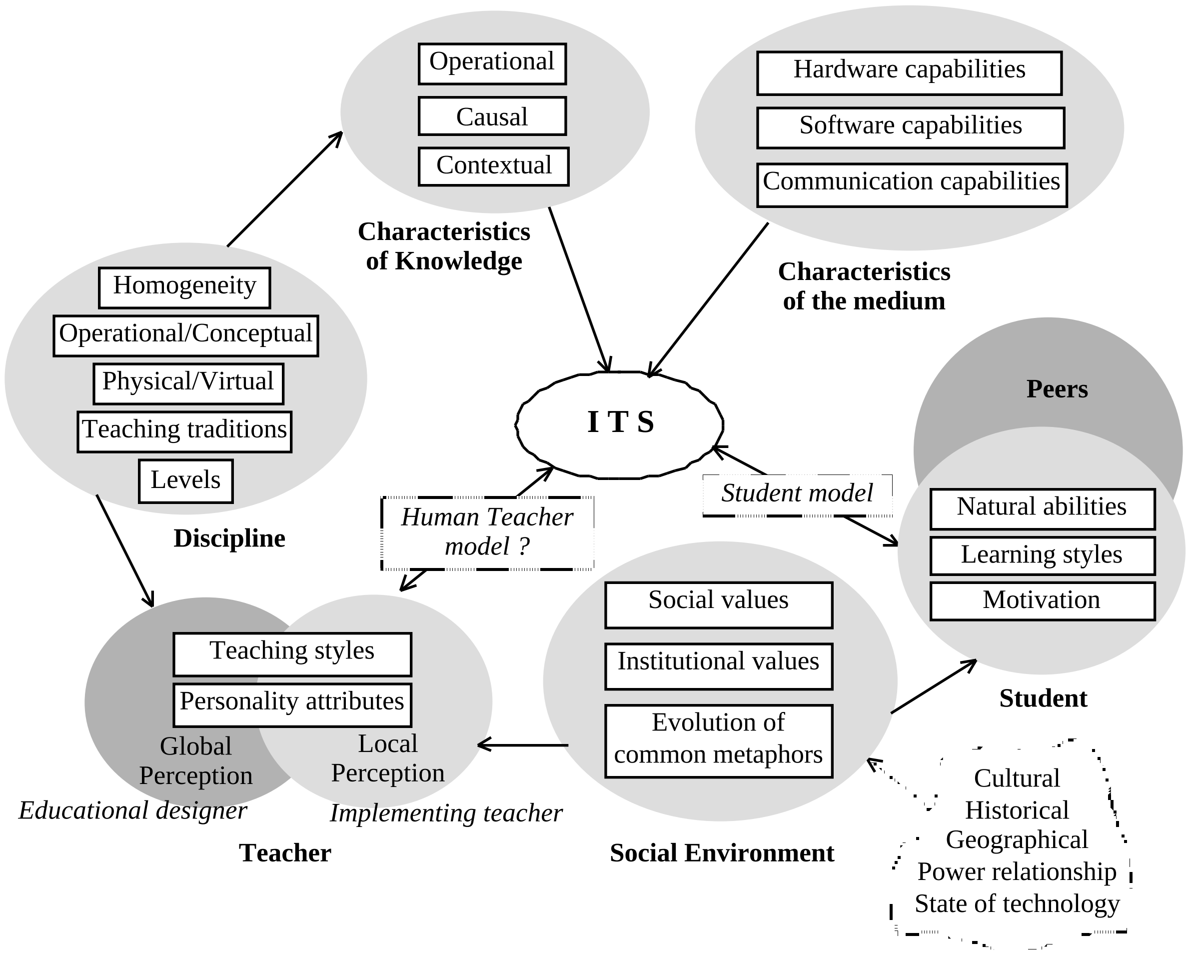

Fig. 2. The environmental contexts of an Intelligent Tutoring System

A greater understanding of the immensity 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 principle way to cluster, partition and organise knowledge and its dimensions [6]. The second is the acceptance of the role of a student's common sense and general problem solving abilities in the learning process, some researchers arguing 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 [12]. Newman [28] 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 ITS attempted to outperform a human teacher though, as Chen [9] noted, "the methods currently used in areas pertinent to computer-based learning environment are incomplete in addressing the wide range of cognitive and pedagogical issues involved".

While such idealism provides a good impetus to research in the laboratories, it is essential to grasp the ground reality as expressed by Devlin [15], "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 [13] 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 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 may be more important than the learning style of a student. Identifying these preferences is a difficult task as each teacher may have a different personality and a different teaching style born out of their traditional, progressive or vocational outlooks and possibly their own learning style [18]. 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 [20]. 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 [20].

This observation obviously leads to the question about how similar conditions of increasing workloads, performance assessment demands and increasing constraints of the work environment affect a teacher's teaching style. If a teacher is forced to adopt a superficial teaching style due to such environmental factors, the situation can be improved by harnessing ITS in a supportive role to free up some of the pressure [23]. However, unless the ITS has some conception of a teacher and enables its configuration to suit the implementing teacher, it will not find easy acceptance. 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, record the teaching style/s adopted in the design and preferably enable 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 [19] arising from any differences in the teaching styles.

4.2.2 Disciplines and the process of education

The process of education involves traversing the granularity of various disciplines to varying extents, from detailed to abstract and from intrinsically simple to complex representations of knowledge - the complexity arising from implicit knowledge, implied context and inferred semantic. It is important in this context to distinguish between the apparent and intrinsic scope of granularity. The apparent scope refers to the representation itself while the intrinsic scope refers to making sense out of the representation. To encounter the ambiguities of the normal language and to avoid excessive use of qualifiers, each discipline creates its own dialect of discourse by adopting a common terminology. To learn a discipline, its students have to learn an appropriate language of technicality and abstraction [14].

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 also traverse the aggregation [24] granularity 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. For example, they may first learn about various techniques of evaluation in a discrete fashion and then learn that the individual techniques provide a different perspective on a situation and need to be combined in the presence of some ranking mechanism for a decision making process. 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, contexts and concepts that are later on taken for granted as implicit to an advanced level dialogue. They are also more likely to be learning the *parts* to be able to later combine them into *whole*, within appropriate environmental constraints such as social and behavioural factors.

Similarly the nature of the discipline being taught, in terms of the subject matter being widely homogenous (for example, Law) or a wide collection of discrete concepts (for example, Operations Research) or in terms of dealing with the physical world (for example, the actual measures of Mechanical Engineering) or its virtual representation (for example, the monetary representations used in Accountancy) will determine to a very large degree the teaching methods adopted and technology employed for the purpose of teaching. An ITS, thus, needs to employ appropriate teaching methods and technology as related to the needs of a discipline rather than be driven by some abstract model or emerging technologies. However, as Chen [9] noted, further studies are needed to investigate the effects of different physical attributes (textual and graphical representation, images, animations and speech) of the presentations on students' learning in different domains of subject matter knowledge. These studies are important for designing an ITS that finds ready acceptability among the teachers and students of any discipline. A further 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 teacher and implementing teacher.

4.2.3 The constituents of knowledge

There are many accepted classifications of knowledge in artificial intelligence discipline from the knowledge representation point of view within the system. Winston [35] described two kinds of knowledge from the representation point of view, factual and procedural. Boy [4] provided various dimensions of knowledge based on its representation. He described *shallow* and *deep* knowledge based on the *granularity* of knowledge representation. Chen [9] categorised knowledge displayed by instructional systems as domain knowledge, operating knowledge, affective content and knowledge required for implementation. From the environmental context point of view, knowledge can be classified from the learning perspective [29] as shown in Fig. 3.

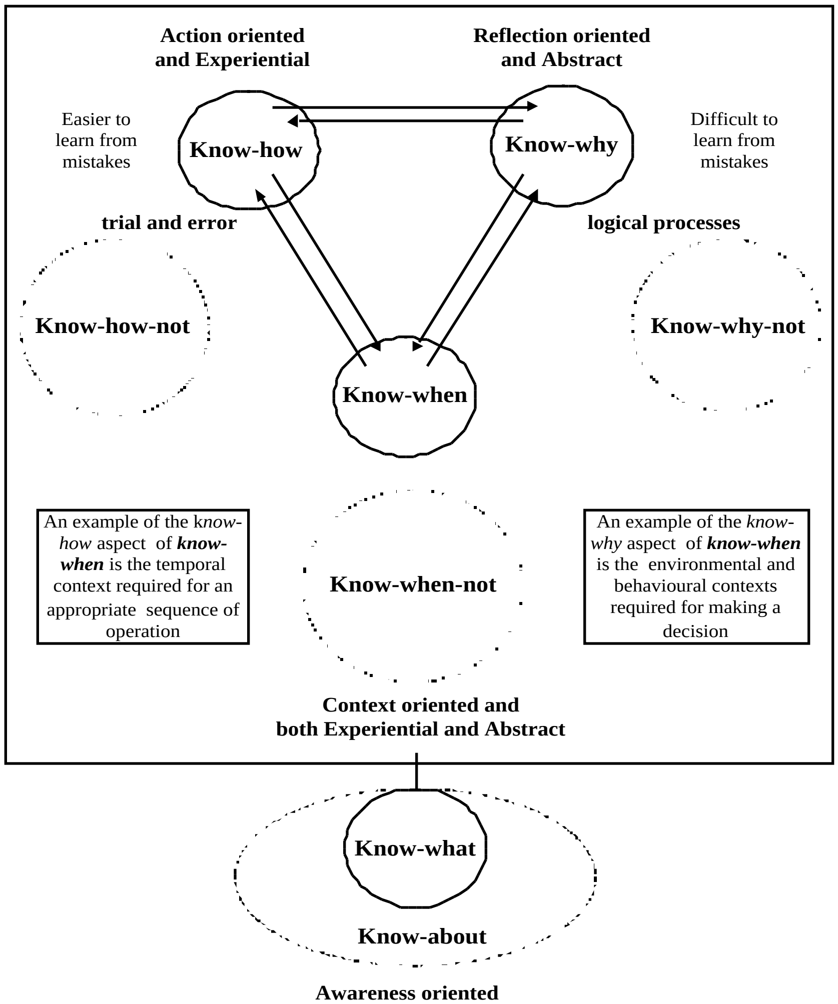

Fig. 3. The constituents of knowledge

The know-how aspect of knowledge is mainly action driven and hence pre-dominantly experiential. It is difficult to inherit this type of knowledge directly from someone else's experience and requires learning by doing (active learning) or by observing someone who is doing (passive learning). The *know-how-not* represents an aspect of experiential learning where a student learns from making mistakes. A large part of *know-how* knowledge may be gained from the *know-how-not* aspect through a trial and error approach. The k*now-why* is mainly reflection driven and based on abstraction. This type of knowledge can be inherited, following someone else's line of reasoning, provided there is effective communication. Unlike the *know-how* aspect of knowledge, the *know-why-not* seems to logically follow from *know-why* rather than the other way round. It is still possible to learn from erroneous conceptions but this requires a deeper reflection. The *know-when* (and -where) has a contextual orientation. It provides the context for both the *know-how* and *know-why*. It is thus both action and/or reflection driven. An example of the action driven *know-when* is the learning of proper sequencing within an operation while the reflection driven *know-when* is seen in appreciating the boundary conditions of a causal relationship.

The *know-about* has an awareness orientation and includes the three types of knowledge discussed above summarised in terms of *know-what*. It also contains information about the general context of this knowledge so that similarity of problems can be perceived and similar problem solving approach be adopted, enabling an extension of understanding from the already known to the hitherto unknown. K*now-about* contains partial and imperfect knowledge arising out of the varying status of the three basic constituents, for example, mankind made productive use of a pulley long before its functioning principles were understood in theoretical terms.

It appears from above discussion that there is an operational aspect of knowledge where a student can learn by doing or by observing without too much reliance on the linguistic expressions. While the ‘observing’ action enables simple acquisition of explanatory representations, there is no mechanism for freely conversing with the system to argue a viewpoint, exchange different perspectives and get the misconceptions pointed out and corrected. These are essential steps to obtain a deeper learning of the reflection oriented *know-why* and *know-why-not* components. However, as the learners are intelligent beings, they can process the acquired explanatory representations more fruitfully if these are multi-sensory, offer flexible navigation between different parts of the information and are rich in the contextual information. Multimedia and virtual reality representations facilitate the way to exploit the benefits of multi-sensory, more realistic domain representation by relying on both multi-sensory input and multi-sensory output, though in current practices, not many examples can be seen which utilise this phenomenon [1].

4.2.4 Characteristics of the medium

While technologies such as hypertext, multimedia, hypermedia and virtual reality offer increasing ease and flexibility in knowledge construction by the learners, they are not an unmixed blessing as they are accompanied by an additional cognitive load and a potential for distractions. Also, two important factors should be noted at this point [10]: (i) it is the instructional methods and not the media that cause learning as demonstrated in hundreds of media comparison studies; and (ii) the human brain, the product of millions of years of evolution, is not changing rapidly and can be overloaded by the sensory output that technology is capable of delivering. To prevent such overloading and to curtail possibilities of distraction, the amount of information and especially the richness of the contextual information may have to be constrained to suit the level at which a discipline is learnt.

The situation, however, is not straight forward. It is the novice learners of a discipline who are likely to benefit from richer representations as they provide multiple stimulus but it is also the same group of learners who are most likely to get distracted in absence of directed learning as they may not have developed adequate metacognitive skills of setting learning goals, selecting effective learning techniques, monitoring progress towards goal, and adjusting strategies as needed [10]. Different teachers would therefore constrain the learning process 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. Even at the level of instructional design theory, the arguments for and against Cognitive Apprenticeship [10] are indicative of this situation.

The ongoing debates suggest that it might not be possible to identify a best way of designing learning resources in terms of an abstract educational theory, especially the various strategies adopted for sequencing and therefore constraining student actions. However, we believe that the problem should be addressed in the context of the nature of the discipline and the level at which it is learnt, since they determine the mix of conceptual and procedural knowledge to be learnt by a student. The choice of suitable representations is guided by whether the learning is conceptual or procedural. For example, Dentistry students learning diagnoses of a malformed jaw, may benefit conceptually from a moving sequence depicting the progress of the malformation, but need to learn to evaluate static x-ray pictures as diagnosis relates to evaluating a given state at a given time. It is important to realise that a representation that is efficient from the learning point of view may be inefficient for a performance task and the optimisation of efficiency and expressiveness is often mutually exclusive requiring a trade-off, possibly per domain [16].

4.2.5 Social environment

Now that the Internet can offer a potentially global scope for an educational system, problems arising from the heterogeneity of target population have to be addressed. As Bourges-Waldegg & Scrivner [7] noted, "Designing interfaces for culturally diverse users is fundamentally a problem of communicating the intended meaning of representations ... in every culturally determined usability problem a divergence between the target meaning and the interpreted meaning of representations was present." Their study found, however, that intercultural communications between users are less problematic since the users develop jointly a communication space in order to succeed in their task, despite differences in culture and language. These observations suggest two important considerations: (i) the selection of representations need a great care and multiple representations are necessary, and (ii) synchronous or asynchronous communications based on video conferencing, web meetings, electronic white boards or discussion forums enable the explanation and negotiation of *meaning*. Such communications should be systematically integrated in the learning environments.

Communication breakdowns do not require wide cultural differences. Differences in backgrounds, goals, or outlooks on life can be problematic in communication between two people every bit as much as their not speaking the same language [15]. The diverse social environments can affect the usability of a tutoring system differently between a suburban school and an inner city school! Anderson [3] has observed, "So far in the research literature, little attention has been given to the effect of class or socio-economic differences upon variations in learning style." It should be noted, however, that the entertainment industry has created a sub-culture so that the 'MTV generation' may share common metaphors. To what extent can this commonality transfer to educational processes is a matter of research.

4.3 Objectival contexts

The purpose of an educational system is not only to assist in the teaching and learning of a subject discipline but also to assess the acquisition of knowledge gained through these activities. It is interesting to observe the traditional teaching practices of planning for teaching and the methods of assessment. For planning the teaching, a syllabus is drawn up consisting of all the subject knowledge that is considered essential. This syllabus acts as an indicative teaching plan and though there may be small variations, a teacher endeavours to cover as much of the syllabus as possible. The teaching is thus implicitly based on a model of 'perfect' knowledge of the discipline's subject matter. On the other hand, the assessment methods employed may only cover 30% to 60% of the syllabus. Student performance in a typical assessment may be distributed across a range of, say, 20% to 80%, where a 50% score may indicate a pass mark. Thus, for an assessment based on say 40% of the syllabus, a student needs to achieve a 50% performance, i.e. a 20% proven knowledge of the whole syllabus to pass, raising some interesting issues about the knowledge which is sought to be acquired and tested.

If such low overall performance is acceptable, it implies that ‘imperfect’ knowledge of a discipline is acceptable for assessment purpose. This raises interesting questions about the overall objectives of the educational system. Is it to encourage acquisition of the facts and rules constituting the knowledge of a discipline or is it to encourage acquisition of meta-learning abilities? Is a student encouraged to be exposed to various subject disciplines with a view to experience different types of situations, different types of priorities, different considerations, different types of problems and different ways to solve these problems? Is a student supposed to learn how to appreciate a situation, order the priorities, become aware of and take cognisance of various considerations, identify the class of problem and form a judgement about a possible strategy to solve the problem - not in a perfect way but at least in an acceptable way?

While a comparison of the implicit objectives of the teaching and assessment methods may raise questions about the quality of assessments, it may also raise questions about what and how much of it is being taught. The body of knowledge is growing in all disciplines. Does this mean that the syllabus coverage keeps on increasing for each of the subjects studied by a student and possibly result in the overworked student adopting surface learning methods? Is there a need to look at the combination of subjects studied by the students in an integrated fashion and build each syllabus to provide complementary skills? Looking solely at the objectives of a teaching and learning system does not reveal the real objectives of an educational system. Since the acquired knowledge can only be demonstrated through assessment, the assessment strategy strongly influences a student’s learning activities and provides an overriding objectival context that can undermine the stated objectives of a teaching and learning system. As the assessment practices discussed above are widely accepted and practised, they are ingrained in the educational system and provide a powerful context within which the whole educational system operates. It is important therefore that the objectival contexts are studied well and taken into consideration when an educational system is designed, whether it is a traditional system or an ITS.

5. Conclusion

The success of an ITS depends on adequate consideration of the various contexts encompassing its design and implementation. While there is an increasing recognition of context in the 'Intelligent' aspect of an ITS, there is a need for recognition that context affects the 'Tutoring' and 'System' aspects as well. The roles of the teacher as an educational designer and as an ITS implementer have not received adequate attention. The power relationship between a teacher and the students and the wide pattern of teaching and learning styles existing in the traditional educational systems need to be recognised. The teacher-student interaction is a very complex phenomenon affected by personality, background, motivation and host of other factors and the same is also true for the peer-to-peer interaction [23]. Daniels [14] observed that the educationally significant human interactions do not merely involve abstract bearers of cognitive structures but real people who develop diverse interpersonal relationships through shared activities in an institutional context. An ITS that intervenes in this rich environment need to demonstrate intelligent behaviour, not only in its interactions with a student but also in its interactions with a teacher.

The 'System' aspects of an ITS require that the attributes of the technology employed, nature of the discipline taught and the type of knowledge addressed in the ITS are well considered and suitable type and multiplicity of representations are provided. It is also necessary to examine the objectives, not only of a tutoring system but also the educational process within which the system operates as it might reveal, for example, that under the traditional system, learning the facts and rules of a discipline may have secondary importance to the learning process itself. The ‘System’ aspects also require that the stand alone 'module' perspective is replaced by a 'computer integrated learning environments' perspective that supports a variety of performance needs. They may also lead us to question the emphasis placed on adjusting to the individual student's learning styles, since the exposure to different teaching may in itself be valuable in enhancing social skills through the development of a versatile style of interaction [23].

The purpose of this paper is to present an initial broad framework of contexts for designing and implementing ITSs. The discussion on the contexts and their relationships have been indicative rather than exhaustive. However, the role of the teacher stands out as a partner within the 'joint-educational system'. An ITS should understand this role and help a teacher rather than prematurely attempt to act as a replacement. As Devlin [15] cautions, "... don't try to mimic the way people communicate, just try to design the system so it complements human communicative skills". While it is worthwhile within the design laboratories to integrate advanced pedagogical strategies [9] of modelling, coaching, reflection, articulation, scaffolding and fading as well as exploration within an ITS, it is also practically worthwhile for an ITS to support a teacher in adopting these strategies in a limited way but with a degree of 'intelligence.'

References

[1] E. S. Adams, L. Carswell, A. Ellis, P. Hall, A. Kumar, J. Meyer & J. Motil, Interactive multimedia pedagogies: Report of the working group on interactive multimedia pedagogy, *Sigcue Outlook*, 24 (1, 2 & 3), 1996, pp. 182-191.

[2] V. Akman & M. Surav, Step towards formalizing context, *AI Magazine*, Fall 1996, pp. 55-72.

[3] J. A. Anderson, Towards a framework for matching teaching and learning styles for diverse populations. The importance of learning styles, R. R. Sims & S. J. Sims, eds, Greenwood Press, Connecticut, 1995, pp. 68-78.

[4] G. Boy, *Intelligent Assistant Systems*, Academic Press Limited, London, 1991.

[5] P. Brezillon, Context in human-machine problem solving: A survey, *Research Report 96/29*, October, LAFORIA, Paris, 1996).

[6] P. Brezillon & S. Abu-Hakima, Using knowledge in its context: Report on the IJCAI-93 workshop, *AI Magazine*, Spring 1995, pp. 87-91.

[7] P. Bourges-Waldegg & S. A. R. Scrivener, Meaning, the central issue in cross-cultural HCI design, *Interacting with Computers*, Vol. 9, 1998, pp. 287-309.

[8] J. Burstein & R. M. Kaplan, On the application of context to natural language processing applied to the analysis of test responses, *Paper presented in the IJCAI-95 Workshop on Context in Natural Language Processing*, August 19, Montreal, Canada, 1995).

[9] M. Chen, A methodology for characterising computer-based learning environments, *Instructional Science*, 23 1995, pp. 183-220.

[10] R. Clark, *Handbook of performance technology*, H. Stolovitch & E. Keeps, eds, Ch. 2, (in press).

[11] Context-97, *Call for papers*, http://www-laforia.ibp.fr/, 1997.

[12] G. Cumming, Using artificial intelligence to achieve natural learning, In: *Advance Research on Computers in Education*, R. Lewis & S. Otsuki, eds, Elsevier, North-Holland, 1991, pp. 51-62.

[13] N. P. Dalal & G. M. Kasper, The design of joint cognitive systems: the effect of cognitive coupling on performance, *International Journal of Human-Computer Studies*, 40 1994, pp. 677-702.

[14] H. Daniels, Pedagogic Practices, Tacit Knowledge and Discursive Discrimination: Bernstein and post-Vygotskian research, *British Journal of Sociology of Education*, 16 (4) 1995, pp. 517-532.

[15] Devlin, *Goodbye Descartes: The end of logic and the search for a new cosmology of mind*, John Wiley & Sons, New York, 1997).

[16] D. M. Dutton & G. V. Conroy, A review of machine learning, *The Knowledge Engineering Review*, Vol. 12:4, 1996, pp. 341-367.

[17] L. Dybkjaer, N. O. Bernsen, H. Dybkaejr & D. Papazachariou, On the use of context in building language dialogue systems for large tasks, *Paper presented in the IJCAI-95 Workshop on Context in Natural Language Processing*, August 19, Montreal, Canada, 1995.

[18] N. Entwistel, Teaching Styles, Learning and Curricular Choice, *Styles of Learning and Teaching*, John Wiley & Sons, 1981, pp. 225-242.
[19] L. Festinger, A Theory of Cognitive Dissonance, *Stanford University Press*, Stanford, CA, 1957.
[20] L. Gow & D. Kember, Conceptions of teaching and their relationship to student learning, *British Journal of Educational Psychology*, 63 1993, pp. 20-33.
[21] L. Iwanska, *Summary of the IJCAI-95 workshop on context in natural language processing*, August 19, Montreal, Canada, 1995, http://www.cs.wayne.edu:80/summary/index.html.
[22] W. L. Johnson, Plan recognition in a situational context, *Paper presented at the 1995 IJCAI Workshop on The Next Generation of Plan Recognition Systems*, Montreal, Canada, 1995.
[23] Kinshuk & A. Patel, Intelligent Tutoring Tools - Redesigning ITSs for adequate knowledge transfer emphasis, In: *Proceedings of 1996 International Conference on Intelligent and Cognitive Systems,* C. Lucas, ed., IPM, Tehran, 1996, pp. 221-226.
[24 G. I. McCalla, J. E. Greer, B. Barrie & P. Pospisil, Granularity Hierarchies, *International Journal of Computers and Mathematics with Applications*, 23 1992, pp. 363-375.
[25] J. McCarthy, Some expert systems need common sense, In: *Computer Culture: The Scientific, Intellectual, and Social Impact of the Computer,* H. Pagels, ed., New York Academy of Sciences, New York, 1984, pp. 129-137.
[26] J. McCarthy, Generality in Artificial Intelligence, *Communications of the ACM*, 30(12) 1987, pp. 1030-1035.
[27] J. McCarthy, Notes on Formalizing Context, *Proceedings of the Thirteenth International Joint Conference on Artificial Intelligence*, Menlo Park, California, 1993, pp. 555-560.
[28] D. Newman, Formative Experiments on the Coevolution of Technology and the Educational Environment, In: *New Directions in Educational Technology,* E. Scanlon & T. O'Shea, eds., Spinger Verlag, NATO ARW, 1992, pp. 61-70.
[29] A. Patel & Kinshuk, Knowledge Characteristics: Reconsidering the design of Intelligent Tutoring Systems, In: *Knowledge Transfer,* A. Behrooz, ed., pAce, London, 1996a, pp. 190-197.
[30] A. Patel & Kinshuk, Applied Artificial Intelligence for Teaching Numeric Topics in Engineering Disciplines, *Lecture Notes in Computer Science*, 1108, 1996b, pp. 132-140.
[31] A. Patel & Kinshuk, Intelligent Tutoring Tools - A problem solving framework for learning and assessment, In: *Proceedings of 1996 Frontiers in Education Conference - Technology-Based Re-Engineering Engineering Education,* M. F. Iskander, M. J. Gonzalez, G. L. Engel, C. K. Rushforth M. A. Yoder, R. W. Grow & C. H. Durney, eds, University of Utah, Utah, 1996c, pp. 140-144.
[32] D. A. Schulenburg, Learning and Using Context in a Connectionist Model of NLU, *IJCAI-95 Workshop on Context in Natural Language Processing*, August 19, Montreal, Canada, 1995.
[33] E. Walther, H. Eriksson & M. A. Musen, Plug-and-Play : Construction of task-specific expert-system shells using sharable context ontologies, *Proceedings of the AAAI Workshop on Knowledge Representation Aspects of Knowledge Acquisition*, San Jose, CA, AAAI, 1992, pp. 191-198.
[34] G. Widmer & M. Kubat, Effective learning in dynamic environments by explicit context tracking, *Lecture Notes in Artificial Intelligence*, 667, 1993, pp. 227-243.
[35] P. H. Winston, *Artificial Intelligence*, Addison-Wesley Publishing Company, Reading, Massachusetts, 1977, pp. 236.