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Where is Education Heading and How About AI?

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Abstract: In this paper we present arguments supported by research examples for a fundamental shift of emphasis in education and its relation to technology, in particular AI-technology. No longer the ITS-paradigm dominates the field of AI and Education. New educational and pedagogic paradigms are being proposed and investigated, stressing the importance of learning how to learn instead of merely learning domain facts and rules of application. New uses of technology accompany this shift. We present trends and issues in this area exemplified by research projects and characterise three pedagogical scenarios in order to situate different modelling options for AI & Education.

INTRODUCTION

For about twenty years the Intelligent Tutoring Systems paradigm has dominated the field of AI and Education. Why? First of all it formed the answer to the supposedly unintelligent Computer Based Learning systems which had prefixed teaching scenarios and no reasoning capacity at all. Secondly ITS systems touched upon all main AI topics: knowledge representation, reasoning, explanation, machine learning, natural language, planning. Thirdly, ITS systems formed an interesting test-bed to formalise cognitive theories and to experiment with their operationalisation.

During the eighties and early nineties the field thrived, more and more became known about in particular the acquisition of procedural skills, about predominant errors and misconceptions in specific domains, about domain viewpoints about the nature of fruitful dialogues between tutor and student (Burton, 1982; Collins & Stevens, 1983; Corbett, Anderson & Petterson, 1990; Elsom-Cook, 1990; Ohlsson, 1987; Sleeman & Brown, 1982). However, despite the successes and this accumulation of knowledge, grumbling voices could be heard saying things like:

- why are we always addressing the easier, well formalisable procedural domains instead of concentrating ourselves on the much harder matter of acquiring conceptual knowledge (Ohlsson, 1993)?
- how old-fashioned ITS's are: the tutor as a know-it-all and the student as a rather passive participant whose knowledge is being assessed without proper consultation with him or her (Tergan, Hron & Mandl, 1992; Katz & Lesgold, 1993);
- why all this student modelling, either it is too difficult or it does not help (Derry & Lajoie, 1993; Laurillard, 1993);
- how about the environment the student finds himself in and the social embeddedness of all ongoing activity (Collins, Brown & Newman, 1989)?

Thus in the course of the nineties many researchers who originally embraced the ITS-paradigm found new ways of looking at AI and at Education and at their possible relationship. New technologies arose and drew the attention of educational researchers: network communication, information databases, and multimedia applications. In this article we are focussing on AI techniques. That does not mean that we do not value the use of new technologies in educational settings. To the contrary, new technologies and AI techniques can fruitfully be combined to create interesting applications. Here we will solely discuss the changing role of AI and the applicability of AI techniques in new educational paradigms.

The nature of the field changed as shown by the declining number of conference contributions presenting ITS research, but its name did not. The list of conference themes of the 1997 AI & Ed's call included themes like collaboration and collaborative learning, educational robotics, intelligent multimedia and hypermedia, learning environments, motivation, social and cultural aspects of learning.

The ITS paradigm started out as a research programme. Its initial aim was to analyse and model students' reasoning during the execution of school tasks in order to use and test these models in a computer program designed to teach students how to perform these tasks. From time to time people mistook such programs as being equally applicable in educational practice as in experimental settings. While insights from cognitive psychology about human problem solving and skill acquisition in some areas looked sufficiently specific to be easily applicable, the status of educational science (especially the implementation and management of computer-supported methods in actual school situations) did not meet the same standards of specification. The actual usefulness of any educational computer program in practice does not solely depend on its excellent cognitive underpinnings, but largely on the organisational context of its use. While positive learning effects of ITS may be established in carefully designed experimental conditions, these conditions bear only an indirect relationship to school contexts. Successful implementation and use of computer programs in practice involves a long-term innovation that cannot be studied in the laboratory.

Instead of criticising the ITS paradigm we should focus on the role AI can play in different educational settings. It is time to consider new educational paradigms in which AI can play a part albeit in a different form than in classical ITS's. New views on education and new technologies offer new challenges for AI. We loosely define AI as a modelling science, developing, applying and investigating formalised models of salient aspects pertaining to learning and instruction, allowing reasoning and derivation of new facts, thereby giving the models in use a dynamic flavour. The dynamic aspect is the most essential feature distinguishing AI from other technologies, e.g. web-based technologies (JAVA applications), hypermedia, multimedia databases, CMC environments. From the vast literature it is not always clear which educational paradigm is advocated or illustrated by a particular research application, nor why certain AI techniques are chosen to support the functioning of an application.

In this article we will outline a framework that serves two purposes:

- it helps to position on-going AI and Education research reported in the literature
- it supports deciding which research questions are relevant and which AI techniques can fruitfully be applied and investigated in which educational context.

What are the requirements for such a framework?

1. It should distinguish fundamentally different educational stances.
2. It should cater for new developments in education as well as in AI.
3. It should classify the prevalent AI techniques in relation to the different foci of the educational stances.

The framework we propose aims to fulfil these requirements in the following way: it links the main trends (requirement 2) apparent in the AI and Education field to three basic, idealised educational scenarios, reflecting different educational stances (requirement 1). These scenarios are called transmission, studio, and negotiation, respectively. For each of these scenarios we discuss the options of AI & Education research (requirement 3). Our main claim will be that AI & Education research should be about analysing the options for modelling and supporting learning processes and that these options are very different for each of the scenarios.

TRENDS AND ISSUES

Although no one would disclaim the value of ITS's for the acquisition of a well-defined and limited skill, ITS's are no longer mainly viewed as stand-alone devices but as embedded in a larger environment which offers the learner additional support for the learning process. Learners do not usually learn in isolation: they may use other sources of information besides the tutoring program, they may ask peers working on the same topic for help, they may address the human teacher for additional information, etc. In this section we will shortly describe some current trends that move away from traditional ITS-research.

Trend 1: More emphasis on open domains

Concerning domain knowledge, we have witnessed a shift in attention towards open domains (writing an essay about constructivism) and conceptual understanding (being able to reason about domain concepts and their relations). This development moves away from traditional ITS-research with its emphasis on tutoring relatively often-procedural tasks in relatively closed domains.

Most successful computer applications for learning have focused on the learning of procedural knowledge or skills (e.g. Goldstein, 1982; Burton & Brown, 1982; Miller, 1982; Burton, 1982; Anderson, 1988). The student is requested to solve a number of problems and to input intermediate problem solving steps and products. The tutoring system compares the problem-solving path thus generated to an ideal path - based on expert performance. In general, most ITS systems cope well with situations in which the student's answer differs from that of the expert model. If a remediation move is needed, this takes the form of an explanation of what step the expert proposes and why this is considered the right step to take. This approach simplifies the task of providing instruction (Ohlsson, 1993): (1) the learner actions can be relatively easily observed, (2) progress can be measured in terms of correctly solved problems and (3) there exist well founded theoretical notions on skill acquisition. None of these advantages are available in the case of coming to understand something. Understanding is basically expressed in the medium of language and is not intrinsically tied to particular performances. Furthermore there is no sound theory available. Work is needed on the ways computers may support the acquisition of concept knowledge. In this respect, Laurillard (1993) stresses the importance of tutorial dialogues. Ohlsson (1993) suggests the analysis of epistemic activities (arguing, describing, explaining, predicting, etc.) to be more relevant for higher order learning of declarative knowledge than the study of goal-oriented action.

These days, ideas on what should be learned and how it should be acquired are changing. One of the reasons for this is the increasing importance attributed to open learning tasks. Open learning tasks are tasks for which there is a well-defined outcome in abstract terms, but this outcome may be instantiated in many ways. In addition there is no fixed series of steps to reach the outcome. The domains involved are open and often characterised by ill-structuredness, meaning that they invoke a highly variable set of responses concerning referents of attributes, permissible operations and their consequences (Reitman, 1965). Furthermore, in ill-structured problems, there is not even a well defined outcome in abstract terms: there is a wide range of schematic interactions that are simultaneously brought to bear on the problem (Petraglia, 1998), and in addition, "the pattern of conceptual incidence and interaction varies substantially across cases nominally of the same type" (Spiro, Feltovich, Jacobson & Coulson, 1992). Most real world problems are ill structured, and it seems that computational paradigms have largely ignored their importance.

The process of becoming an expert in a certain domain is no longer solely viewed as the acquisition of a representation of correct knowledge. The knowledge to be acquired to flexibly manage open problems is intertwined with aspects of contexts and tasks and may be personal and difficult to model. One of the hard questions to answer is how to support such learning.

Trend 2: Taking into account the learning environment

Not only what people learn is important, but also where and how. Learning does not take place in isolation. Besides interacting with the primary learning material, learners interact with sources of information available in their surroundings. Learners should be provided with different kinds of support so they can choose their own learning route and strategy adapted to their needs, capabilities and preferences. Educational technologists are seeking ways to create pedagogical tools that accommodate ideas of more encompassing environments that offer multiple didactic approaches, multiple representations of learning material and a variety of learner support tools. An open learning environment allows the learner to learn what he or she wants when he or she wants it in the manner of his or her choice (Van den Brande, 1993; Tergan et al., 1992). Open learning environments transfer the responsibility for the learning process from the instructor to the learner. Exploratory learning studies, though, have cast some doubt on the capabilities of students to take on this responsibility (e.g. van Joolingen, 1993).

How much freedom is beneficial for a learner is an unresolved question to date. Besides it is unclear how the learner is best supported in executing the responsibility for an on-going learning process. To describe and represent a learning environment from the point of view of the learner, Barnard and Sandberg (1994) distinguish six entities with which the learner interacts, that characterise an open learning environment: tutor, monitor, fellow learner, learning material, information sources and tools. A truly open environment consists of all these entities. More restricted environments may be characterised by fewer entities. For example, an ITS can be described in terms of just three entities: tutor, monitor and learning material. The entities proposed by Barnard and Sandberg refer to functions supporting learning. They may be realised in many different ways. For example the tutor function may be realised by a human tutor or by a computer tutor, information sources may be found in books and other documentation or in information databases. The realisation of each function can depend heavily on technology but this is not necessarily required. Entities can take the role of agents, especially the tutor, monitor and fellow-learner entities.

It is clear that many characteristics of situations affect learning, but it is less obvious how to arrange situations to affect learning in specific ways. In addition, the question how users should be supported in such cases is hard to answer.

Trend 3: Collaboration as a didactic strategy

According to this trend, decisions in education should be the result of careful negotiation among all participants. Much of education is concerned with enabling the student to acquire knowledge as a result of interaction, with the teacher, a co-learner, or a medium. Increasingly, social and collaborative processes are seen as central to the development of thinking skills. Collaboration is important because it mirrors the dynamics of doing business in the real world (Bruffee, 1993). If only for social reasons, students reflect more effectively on their problems in peer dialogues than in tutorial interactions (Veerman & Andriessen, submitted). Learning companions (Chan & Baskin, 1990) endowed with capabilities comparable to those of the learner are better able to understand the learners' problems. Collaboration not only allows the student the chance to see learning activities modelled, but also provides opportunities to articulate one's thinking to an audience (Petraglia, 1998). Despite large quantities of research on collaborative learning, not much is known about the specific mutual relationships between the nature of interaction on the one hand, and learning and problem solving on the other hand.

The computer can support collaborative learning in several ways. Erkens (1997) distinguishes four different types of use: (1) Computer-based collaborative tasks (CBCT), (2) Co-operative tools (CT), (3) Computer mediated communication (CMC), and (4) Intelligent Co-operative Systems (ICS). In CBCT (1) the computer presents a task environment to foster student collaboration. The extra advantages of the medium (compared to collaborating without it) may be the shared problem representation, that may function as a joint problem space, the ease of data-access, and, in some cases, intelligent coaching. Examples are Sherlock (Katz &

Lesgold, 1993) and the Envisioning Machine by Roschelle & Teasley (1995). A computer used as a co-operative tool (2) is a partner that may take over some of the burden of lower-order tasks, while functioning as a (non-intelligent) tool to work with during higher-order activities, such as in the case of a Writing Partner (Salomon, 1993), CSILE (Scardamalia, Bereiter & Lamon, 1994), or a Case-based Reasoning tool (Kolodner, 1993). CSCL (3) involves collaborating over electronic networks. The computer serves as the communication interface, which allows interaction and collaboration between several students at the same time or spread out asynchronously over a specific period. Email conferencing (Henri, 1995) and Groupware systems (Mitchell & Posner, 1996) fall into this category. In addition, representations and interfaces that support problem solving and communication are sometimes provided, such as in Chene (Baker & Bielaczyc, 1995), Belvedere (Suthers & Weiner, 1995), or the Collaborative Text Production Tool (Andriessen, Erkens, Overeem & Jaspers, 1996). Finally, in ICS (4) the computer functions as an intelligent co-operative partner (DSA: Erkens, 1997), a co-learner (People Power: Dillenbourg & Self, 1992) or learning companion (Integration-Kid: Chan & Baskin, 1990).

Obviously, different uses of the computer parallel different views on collaborative learning and different goals for using computers in collaborative learning research. In this research area probably more than anywhere else, answers to questions about what to support and how to support it depend on often-implicit pedagogical goals. In addition, new research topics arise when aspects of collaborating with computers are analysed with respect to social and linguistic issues.

Trend 4: Use of information databases

Real life requires people to cope with large amounts of information. One of the greatest assets of the computer is its boundless potential to store information, and in addition, to create some more. The use of this potential in educational settings raises serious questions concerning (1) the didactics: thinking about worthwhile tasks to make use of databases and to teach users how to do it, (2) knowledge management: how to organize, index and maintain such information, (3) user strategies: how to find relevant information, and how to evaluate the information encountered.

As many have experienced, searching information on Internet may well turn into a cumbersome task. One either fails to get the material altogether, or the information is there, but embedded in a vast amount of facts and figures not of interest at all. Effective use of hypermedia environments necessarily involves search and retrieval skills not typically associated with comprehension tasks (Goldman, 1996). Computers and the Internet make life more complex, for some adding to the already apparent chaos, lack of censorship, and the absence of formal authority, for others an opportunity to discover what a teacher has to offer that a computer cannot (Rushkoff, 1997).

The way information is represented and indexed in most databases hardly corresponds to the way in which people naturally view and try to carry out a ’search for information’ task. The terminology through which the indexing takes place not necessarily matches the terminology the users are familiar with. Moreover, people like to pose questions in natural language, and have difficulties to comply with the grammar of formal query languages. Databases are accessed with different goals in mind, and some of these may require different organisations of the same information. Learners are to acquire adequate search strategies both in terms of defining what they need to know and in really accessing the right information. Besides the problem of accessing and finding the right information there exists the accompanying difficulty of what to do with the information, once found.

Recently, educational environments have been developed that not only include the use of large amounts of data, but also have the goal of acquiring the flexibility of finding and using information. The CSILE environment (Scardamalia & Bereiter, 1991) consists of a hypermedia system built around a student-generated database. It provides the students with the opportunity to insert topic-specific notes, to inspect one another’s notes and to comment on one another’s notes. The database is accessed via networked microcomputers present in each classroom. Text and graphical notes in all curriculum areas go into the same database, from which they can be retrieved by pseudo-natural language searches involving topics, key words, authors, and status.

DesignMuse (Domeshek, Kolodner & Zimring, 1994), is a case library authoring tool that allows construction of structured, indexed and searchable databases of analysed case studies for students to learn from. DesignMuse builds functionality for indexing, organising and presenting case information into the case libraries created from it. It also provides graphical user interfaces for specifying search probes, for presenting case information and for modifying and extending the case library. Cases are structured in terms of stories, problems, responses and design overviews.

Databases used for education are no static piles of data. There is the obvious issue of allowing users and/or developers to add information to the database. We could end up with many intranets containing senseless amounts of useless information, repeated at different locations. Although it seems that computer tools could do a good job at helping users to find and store information, there is a more principled question: should users be supported in finding and evaluating (correct) information, or should we teach students the skills to find and evaluate information by themselves? Do both solutions require the same type of indexing? And what about managing the increasing amount of information? Is there any educational objective served by data-mining, where information is filtered and indexed for users in a world where we know this information to change all the time, new information to be added constantly, and old information to disappear regularly?

TRENDS IN RELATION TO AI: WHAT IS THE EDUCATIONAL PERSPECTIVE?

New trends in education offer new challenges for the AI & Education community, which has traditionally been associated with the ITS paradigm. It seems that this paradigm, for example as it is described in Wenger (1987) cannot cope with many of the previously described trends. We have to agree with Laurillard's (1993) criticism that AI & Education research (or ITS research, as she calls it) does not provide education a clear pedagogical alternative, besides individual tutoring. The volume edited by Derry & Lajoie (1993) contains many chapters in which the roles of the tutor, student modeling and that of AI in educational computer programs are challenged. The proposed alternative there is not a new model, but a specific view on the role of the computer in education: as a cognitive tool. A tool should take over the burden of lower order tasks, while allowing the user to concentrate on the more important higher order thinking (Salomon, 1993). We do not think that a tool-building perspective is a fruitful perspective for AI & Education, as it seems to ignore the importance of AI altogether. Taking over the lower-order tasks does not necessarily require any intelligence at all. Of course freeing students from these often cumbersome tasks may be pedagogically sound, however it does not shed any light on the role of AI.

Different pedagogical approaches imply different decisions about the roles of AI and the computer in the learning process. The ITS-model was clear about this, but does not cover new trends. We feel it is due time to propose some basic pedagogic scenarios that together represent the most important dimensions of pedagogic stances and choices. We use the term scenario as denoting a description of an educational arrangement in which the roles of the participants are defined with respect to the underlying educational paradigm. The scenarios we are about to introduce sketch an idealized abstraction. In practice many educational situations reflect a mixture of elements taken from different scenarios. We hope, however that the abstracted scenarios will help in positioning ongoing research in the AI and Education field. The three scenarios proposed are based on principled, albeit general pedagogical perspectives. Individual tutoring by a classical ITS seems to be a clear case of knowledge transmission, for example. In what follows we propose three such perspectives, in which most of the trends described in Section 2 can find their proper place, or can be filled in with a somewhat different didactical focus. The purpose is not to evaluate the state of the art, but to provide some frame of reference to be used by scholars, which may help them to place the research that is going on and to decide on what AI techniques can be fruitfully applied or investigated in particular educational settings.

We will describe three pedagogic scenarios that reflect different educational stands: what knowledge is taken to be, what learning is taken to be, what would be the goal of education, and how the learning process should be mediated by instructional intervention. The scenarios discussed reflect the trends identified above in various ways. The presentation of the three scenarios will be followed by a discussion of the different options for the use and investigation of AI- principles and techniques in AI and Education research.

Scenario 1: Transmission

This is the view that knowledge can be more or less directly transmitted to students through a system of lectures, textbooks and testing. Transmission generally views representation of knowledge to be unproblematic. Scientific knowledge has to be discovered (rather than constructed), and once 'facts' have been proven, they are treated as accurate representations of reality, in fact they are equated with reality. At the individual level, personal knowledge can also be an exact replica of scientific knowledge. The student is capable of assimilating new knowledge in a fairly direct manner. The biases of students however may be problematic and lead to misconceptions that need remediation. At the process level, learning is equated with memorising, and the teacher is responsible for implementing the correct knowledge in the students' mind.

This scenario reflects the production and transmission of universal, objective knowledge, and the diminishing of local, subjective, and personal knowledge. Facts are strictly segregated from opinions. This characterisation is admittedly extreme; the actual opinions of individual scientists and educators hardly ever mirror these positions exactly. However, western culture and the heritage of 20th century education still although tacitly mirrors this view. The system of knowledge transmission through learning by being told (verbally or text-form) which characterises most schooling, adheres to a worldview in which knowledge is perceived as clear-cut and easily transferable. This view of what knowledge is, is interwoven with the prescriptions for how to teach.

The transmission view most closely matches traditional education. The most important didactical approaches in education within this scenario are listening to lectures and studying texts. Students have to be able to listen to the instructor and structure and integrate the information received with their own conceptions. This requires preparation, the better prepared a student is, the more he will take in of what the instructor has to say. The main objections students have against this form of education are related to the rhetorical skills or lack thereof of individual instructors. They do not mind to be taught in groups and they are used to remaining anonymous. In practice, at least in our experience, students do not prepare very well and still manage to pass exams. In part they manage because they have become skilled at inferring what the instructor wants them to know at the exam, and partly because many exams do not test real understanding. The transmission scenario, with its dominant role of the tutor, is not challenged by most students, nor by managers or policy makers, only by some educational scientists. These days, some form of the transmission scenario characterises the education of most people that had any schooling. Hence, it presents a strong case to comply with or to compete against.

In this scenario, media can serve to accompany the lectures, by providing demonstrations and (remedial) exercises. The ITS-model as we know it forms an operationalisation of the transmission model. The innovation ITS was supposed to bring here was individual tutoring. The wisdom of the expert is used as the norm against which a student has to compete. This usually requires extensive modelling of domain and student at a very detailed level, which is only feasible for closed domains with preferably a procedural nature, and no differences of opinion among experts. Development of useful media applications within the transmission perspective is extremely expensive, and limited to very specific application in practice. Furthermore, development of computer programs suffers from the accompanying idea that education should be efficient, and accordingly, the development of computer applications for education is only supported if there is the promise of higher output against lower costs. Finally, the view on the role of expertise is authoritarian and rather outdated, in the sense that new views on learning have emerged that raise serious doubts about the validity of expert norms and expert behaviour as standards for learning.

The transmission view exemplifies none of the identified trends. Transmission scenarios favour closed assignments with criteria determined by the instructor. Learning by being taught, by examples and demonstrations, by drill & practice, or even by discovery all should lead to the attainment of fixed learning goals. Students should learn facts and skills. Conceptual knowledge (see trend 1) is acquired by processes of assimilation and adaptation, not by open tasks or discussion. The ideal environment (trend 2) is one with an inspiring tutor teaching with clear demonstrations, expositions, narratives, arguments and examples. Collaboration between students (trend 3) is motivated by efficiency criteria: it will be used if a learning result is attained faster or cheaper. The tutor should control access to databases (trend 4).

Scenario 2: Studio

The main idea here is that responsibility for learning should reside more with the student. The more constructive efforts are undertaken by a student, the more he will learn. This still can be reconciled within the transmission view, in the sense that one may claim that students should study more actively. The problem here is that when the learner becomes an active processor of knowledge no two processors take the same routes to incorporate new knowledge. Learning becomes very contingent and dependent upon existing knowledge and metacognitive skills. Because students differ in many respects, in order to be effective, education should deal with these differences. Not by imposing an expert model, but by allowing students to proceed in their own way, at their own pace. The role of instruction in this scenario is to provide tools and opportunities for learning, commenting and coaching, creating room for collaborative learning, interactive learning, providing feedback, supporting finding and evaluating information, creating flexible environments, and so on.

This is rather a lot to support, and hence the studio-model reflects all identified trends: more room for open domains, moving towards more encompassing learner environments, more collaboration between students and technical agents and finally, broadened access to information databases. Students should not merely learn facts and skills, more than anything, they should learn how to learn. They should be able to apply what they have learned in practice, and should be able to flexibly adapt to new situations. Obviously, learning by being told does not suffice here. In the abstract, learning in a studio setting requires development of metacognitive knowledge and domain-independent skills. The student should be able to plan, monitor and evaluate the ongoing learning process.

Currently, the main obstacles to implementing the studio scenario are situated in education itself. Students and teachers will have to change their respective roles in adapting to the studio scenario: students need to be more active and be able to initiate new learning on their own, teachers are expected to coach instead of teach. When confronted with the studio model, students tend to experience vagueness, asking for more feedback and guidance. Tutors have to decide how much feedback and guidance are necessary for each student or each group of students. However, learning goals are still assumed to be fixed and well-defined. Only the way to reach the learning goal is flexible and allows for student initiative in determining through which means the goal is to be reached. This eventually should lead to a student having acquired the flexibility of knowing how to learn in new situations.

Scenario 3: Negotiation

No instructor is expected to possess full knowledge of a domain. In addition, the nature of some domains is such that no correct knowledge is supposed to exist. Especially in social sciences many conflicting points of view about the world seem to co-exist. Open problems such as writing an argumentative essay on the prohibition of smoking appear to have more than one acceptable solution. The goal of education is not knowledge acquisition per se, but to acquire the flexibility to participate in the discourses of several communities of practice, that is, specific groups of professionals acting and communicating in specific ways. All such practices have found their current shape by long-term interaction and negotiation processes. Expertise and authority are socially accorded, and within most academic spheres it is typically given to those occupying a given discursive position (Gergen, 1995). Negotiating implies individuals communicating and debating points of view in order to reach agreement or understanding.

The knowledge negotiation approach in AI & Education (Moyse & Elsom-Cook, 1992; Baker, 1994) holds similar ideas. For some domains, teachers should not aim to simply transmit their own knowledge to the student, should not have complete control over the interactions with the students, and, most importantly, the representation of the domain and the problem solutions themselves should be jointly constructed by teacher and learner. A negotiative technological environment must be capable of distinguishing between those aspects of arguments on which it is appropriate to negotiate with a given learner and those that are not (Baker, 1994).

Participating in professional groups implies the ability to understand the important debates and problems and to use the right language to examine and influence ongoing debate. Learning in the negotiation scenario is learning to produce and comprehend discourse. Participating in dialogues and discussions, with real people can do this: students, teachers and other professionals. In this scenario students collaborate in projects, formulated as open problems by instructors, and they need to discuss extensively to arrive at a product that is the result of this debate. Gradually, these debates become more like those by professionals. The instructor may provide initial source texts, but the main task of students is to look for their own material, based on their current frame of reference and interest. The results of these discussions should be open for inspection to other students and be become the source of further discussion. This way of working is similar to knowledge management scenarios in some professional institutions, but may lack the hierarchical structure of such organisations.

This scenario seems very suitable to be acted out in electronic environments. While face to face (F2F) meetings may be a better solution when quick decision making is asked for, electronic meetings are more convenient to support ongoing dialogue and debate in long term learning processes. Apart from the obvious independence of time and place, electronic environments offer an 'interpretative' zone that allows participants to share multiple perspectives or attitudes relative to a particular topic or issue (Petraglia, 1998). The electronic environment is provided by professional CMC (Computer Mediated Communication)-software, requiring also document management facilities and supporting various forms of communication and discussion (including non-verbal communication, e.g. diagrams).

This scenario reflects the identified trends in a different way than does the studio scenario. In the studio scenario, the learning goal is given and well defined. Students are provided with the means to realise the learning goals in different ways and they are expected to be able to design their own learning routes, with help from a coach. In the negotiation model, the learning goal, in terms of domain knowledge or skills to operate on domain knowledge, may be even lacking. The initial learning goal that forms the starting point for discussion and negotiation may itself become subject of the negotiation process.

The main obstacle is the lack of precise knowledge concerning the pros and cons of electronic discussions, especially for educational purposes. It seems electronic discussions require very motivated users and a very specific and dedicated role for the tutor, who often should behave more like an expert group-therapist than like a know-it-all expert (Mason, 1992). Several studies (Baker, 1996; Pilkington & Mallen, 1996; Veerman & Andriessen, submitted) have shown that whether or not students start critical discussions depends on task characteristics, including the domain, the learning goals, the instructions and the expected product. The meaning of an utterance in F2F communication can be conveyed by use of visual and inflective cues, such as face expression and intonation (Mason, 1992). Most CMC systems do not enable these multi-modal forms of communication and hence there is an increased risk of misinterpretation (Moore, 1993). Printed text appears to encourage a sense of closure. A printed text is often assumed to have reached a state of completion. Subjects are seduced into believing and accepting ideas and statements which they see in print as true, simply because they are in written form (Mason, 1992). It is not clear whether students treat text in a CMC environment in the same manner as printed text or whether it is regarded as an on-going dialogue. Although students share the same communicational context, they might be not as critical of new information or possible problem solutions as they would be in F2F settings (Veerman & Treasure-Jones, in press).

In the negotiation scenario, students have to learn how to participate in communities of practitioners. How this goal should be reached, however, is not very clear. The medium of discourse is presented as its main vehicle. Discourse can often be imprecise, and can be used to hide rather than to convey meaning. Meanings and intentions are often inferred rather than explicitly stated. It seems that for the development of adequate negotiation scenarios, more insight in the educational pros and cons of the use of oral, written, and electronic discourse is crucial.

DIFFERENCES BETWEEN SCENARIOS

The most important differences between the scenarios, in our opinion, concern their conceptions of the purpose of education. In *the transmission scenario*, education should strive for the acquisition of knowledge and skills. This is mainly done by lectures, drills and practice, and reading texts. By generalizing between domains, students acquire the competence to apply knowledge in different situations. The main source of knowledge is the instructor, and negotiation mainly involves dealing with the norms and values of the tutor. *The studio scenario* upholds crucially different conceptions concerning the goals of education. Students should acquire the ability to learn in different situations, by participating in collaborative activities in project-based educational settings that have common characteristics of settings in the real world in which the knowledge is to be applicable. Instead of developing the ability to generalize over tasks, students should acquire metacognitive knowledge and skills, which allows them to reflect on what they are doing. This requires (among other things) the proficiency to interact, involving the social and practical skills to collaborate with peers as well as with tutors. In *the negotiation scenario*, students learn by becoming enculturated into a group of practitioners. These groups are communities of people, which are involved in the activities that characterize their practice, in school often represented by the instructor. This is not the traditional, authoritarian instructor, acting as a guardian of school knowledge, but a mentor and coach who gradually introduces the students into increasingly specialized and theoretical communities of practice, resembling a process called legitimate peripheral participation by Lave & Wenger (1991). In the negotiation scenario, this is essentially a matter of accurately employing the discourse of such communities. This requires, among many other things, sufficient knowledge of relevant facts and concepts, norms and values, and the facility to use argument and counterargument in order to participate in ongoing debates. In the negotiation scenario, learning to participate involves careful negotiation, being absorbed in the process of co-construction of knowledge, by mindful and responsible use of discourse. Table 1 shows the concepts discussed in their relation.

Table 1: Scenarios and their missions

Mission	Transmission	Studio	Negotiation
Acquisition of knowledge and skills	Drill & practice, lectures and reading	Collaborative, project-based learning	Legitimate peripheral participation
Learning to learn	Generalization	Metacognition & reflection	Discursive practice
Learning to participate	Acquiring expertise	Social & practical skills	Negotiate and be responsible

These differences can be illustrated by their consequences at the level of assignments. Table 2 defines the three scenario's in terms of the general type of domain typically used for assignments, the extent to which the learning goal is well defined and stable during the learning process, and the extent to which the way the learning goal has to be reached is entirely predetermined, flexible or open.

The *transmission scenario* is meant to operate in an educational setting where the domain is closed, the learning goal fixed in advance and stable over time, and where the route to obtaining the learning goal is well established and can be therefore prescribed. This scenario is clearly operationalised by the classic ITS-model.

The *studio scenario* reflects an educational setting in which the domain may be closed as well as open, the learning goal however is fixed and stable, but the way in which the goal is reached is flexible. This scenario can be operationalised by a learning environment, which offers the learner different tools and sources of knowledge, which may be of use to the learner in reaching the goal. Which tools and which sources are to be used is not pre-specified, but is up to the learner. Of course, the issue is not that interaction should be promoted by offering the user as much opportunities as possible, but by offering the 'right' tools, allowing the user to express himself.

The third scenario, the *negotiation scenario* is characterized by an educational setting in which an open domain is object of study, in which the learning goal is not fixed but may change during the course of the negotiation process and in which the learning route is completely open. In some domains, like the humanities or the domain of musical composition, knowledge is essentially problematic: it is not just a question of solving a problem, it is more a question of seeking out the nature of the problem and then devising an approach to solving it (Cook, 1998). The negotiation scenario is operationalised best in terms of an open discourse situation in which the participating agents come to a shared understanding of the goal they strive to attain and for which they negotiate the appropriate issues to resolve in order to reach that aim.

Table 2: Scenarios and assignment characteristics

	Transmission	**Studio**	**Negotiation**
Domain	Closed	Mixed	Open
Learning Goal	Well-defined, static	Well-defined, static	Ill-defined, dynamic
Learning route	Fixed	Flexible	Open

THE ROLE OF AI IN THE DIFFERENT SCENARIOS

The final and main point, to be examined here in more detail, is what the three scenarios imply for the potential roles of AI. In the present section we discuss which AI techniques can be fruitfully applied or investigated in the three different scenarios.

It is evident that computer mediated education may benefit from the use of AI-techniques. We view AI as a modeling science, which develops, applies and investigates formalized models of some aspects of the world. AI-techniques serve to model specific aspects (both static and dynamic) of human or agent reasoning and problem solving relevant for learning. Broadly speaking, intelligent educational technology requires models of knowledge and models of processes to be used during the execution of instructional assignments. These models no longer need always to include a tutor role or detailed student model, but instead may often need to reflect several partner roles.

However, we do not think everything needs to be modelled in every case. The decision on what kinds of user activities need to take place and which ones call for support is a matter of pedagogical point of view, in our case coarsely represented in terms of three basic scenarios. A scenario focuses on and sets boundaries to the salient aspects that can be considered for modelling. Table 3 presents basic modelling choices, for each of the four trends in relation to the three scenarios, expressed in a in a vocabulary devised to represent the necessary distinctions. That provides us with a tentative ontology providing a meta-view on the AI techniques relevant for education (Appendix A provides the vocabulary as a classification of terms; Appendix B provides a glossary of these terms).

As a general division, table 3 presents a distinction between knowledge and process. Models of knowledge involve the information to be retrieved, organised or updated during the execution of a task. Because such models often imply meta-representations reflecting different viewpoints on one and the same knowledge domain we speak of ontologies (Schreiber, Wielinga & Jansweijer, 1995**)** or ontological modelling. An ontology is an explicit specification of a conceptualisation and as such provides a consistent vocabulary (Appendix A provides the basic vocabulary introduced in this article). Models of processes involve task execution, the use of discourse, interaction between agents and individual learning. Task execution subsumes processes such as planning, monitoring, storing, updating, generating, presenting, etc. Discourse processing concerns the generation and production of language, especially in dialogue. Interaction involves the co-ordination and tuning of actions between multiple agents, with similar or different roles in a specific situation. Such activities may result in learning, and in some situations it may be desirable to monitor individual learning processes. We will shortly explain the information provided by the table, without going into detail concerning each and every cell. Instead we will just describe the salient features for the different scenarios.

Table 3: Modelling choices for scenarios and trends

ONTOLOGIES			
Trends	**Transmission**	**Studio**	**Negotiation**
Open problems/ Conceptual knowledge	Domain Models	Multiple Task Models	Multiple User Models
Learning environment	Task Models	Agent Models; Multiple Representations	Agent Models
Collaboration	Cognitive State Models	Multiple Agents	Interaction Models; Multiple Cognitive States
Information	Conceptual Indexing	Multiple Sources	Conceptual Indexing; Knowledge Infrastructure Models
PROCESSES			
Trends	**Transmission**	**Studio**	**Negotiation**
Open problems/ Conceptual knowledge	Model Tracing	Agent Interaction	Issue Tracing
Learning environment	Expert Reasoning	Agents & Tools	Student/Tutor/ Partner
Collaboration	Student/Tutor	Procedural Facilitation	Interaction; Negotiation
Information	Monitoring	Reflection	Reflection; Management

As a general point of departure for decisions on what needs to be modelled and to what extent we propose that for *transmission*, what has to be modelled can be represented as the classical ITS-model, details and grain size depend on the required *domain expertise*. For *studio*, it is the expected *interaction* of the students with entities in the environment which determines the nature and grain size of modelling, while in *negotiation*, essentially the *student characteristics* with respect to the specific learning situation determine the need for monitoring and modelling. We review these points at the end of this section.

Transmission scenarios are based on models of expert reasoning, and require detailed monitoring of problem-solving steps (model tracing) to be able to diagnose user behaviour. Keeping users on the right track requires detailed student/tutor modelling. In transmission, the environment is limited to the task and the information (*domain and task models*) required to execute the task. The domain at hand is closed or made to look as if it were. All information used should be available for modelling and control (*monitoring*) by the tutor. In a transmission perspective, an intelligent collaborative system (ICS, see above) could be designed, in which there is an expert solution (*expert reasoning*) and the collaborating agent may provide the information to keep the student on the right track (*monitoring).* What should be designed here is the strategy of how to react to problems, questions or misconceptions of the student (*cognitive state models*) as they may occur during collaboration. In transmission, information is used to solve problems, and should be adequately structured for this purpose (*domain* and *task models*). In addition, information indexing and retrieval in transmission is under the control *(monitoring*) of the database-manager, maybe an agent, who filters and updates the information and provides user support according to specific scripts (*conceptual indexing*).

Concerning the studio scenario, it seems that the modelling issue moves away from modelling the cognitive states of individual learners to supporting the ongoing interactions between users, tools and tasks in the environment. The focus of the designer of a studio scenario is on the situation in which users are confronted with several tasks (*multiple task models*), which allow them lots of opportunities to interact with other agents and tools (*models of agents and tools*) and to use multiple sources of information. In the studio scenario learner products are at the core of evaluation, not the process. Processes should be supported – but this does not necessarily mean modelling at a very detailed level. The support can often be implemented in the way the interfaces between student(s) and entities in the environment are designed with respect to task execution (*task models*), and with respect to the interaction between agents in the situation (*multiple agents*). For example, *multiple representations* should be available for users at different levels of abstraction or grain size to accommodate users with different characteristics. To produce richness in the interaction possibilities there are encompassing environments being created (e.g. Mühlenbrock, Tewissen, and Hoppe, 1998), comprising multiple domains, representations, assignments, and accommodating a wide variety of users. Generally speaking, *reflection* is to be promoted, besides acquisition of skill or domain knowledge. This implies more emphasis on modelling of the outer layers of the Dormorbile model (Self, 1995; Sandberg & Andriessen, 1997; Cook, 1998). Collaborative learning in the studio scenario may take the form of CBCT (Computer Based Collaborative Tasks) or ICS (see above), in which, ideally, there should be several agents to collaborate with and to choose from (*multiple agents*). Because problems here tend to be open-ended, these agents cannot (and should not) operate at the fine-grained level of problem-solving steps. In addition, several agents should take care of providing support at lower-order tasks (*agent models*), which are not crucial for learning (*agents & tools modelling*). The focus is on self-directed search and evaluation of solutions and information from different sources, and comes in the form of *procedural facilitation* of solution steps (Bereiter & Scardamalia, 1983). *Information indexing and retrieval* in a studio is user driven and users may need support in managing the excessive information flow from *multiple sources*.

In *negotiation* scenarios, only open domains and ill-structured tasks are put to use, making detailed domain and user modelling impossible to achieve. The exchange of information along with discussing its interpretation are the crucial activities to be undertaken by users. Users not only have to become skilled at negotiating knowledge, but also at finding and disclosing the necessary information. Scrutinising information at several grain sizes of abstraction requires precise discourse comprehension and argumentative reasoning. Is support required on all aspects? What intelligence is required for all this? What representations and mechanisms support negotiation? Baker (1994) reviews results on negotiation in distributed artificial intelligence, agent theory and language sciences. Negotia (the elements of negotiation) involve knowledge (beliefs, goals, solutions, viewpoints) as well as interaction (shared resources, agreement, and management). Negotiation processes involve making offers and accepting or rejecting them. In addition, goals may be refined, attempts to persuade others may be undertaken, which may include threats, argumentation or attempts to change the other's perception of the desirability of the offer (Baker, 1994, p. 216).

In addition to ontologies that allow flexible retrieval and use of knowledge (*conceptual indexing* and *knowledge infrastructure models*), interfaces should provide users with easy access to activities of other agents (*interaction models* and *multiple agent models*). Beliefs and goals of participants have to be disclosed (*multiple user models*) as well as their pertinence to the issue under scrutiny (*reflection* and *management*) needs to be computed. Some sort of *issue-tracing*, at the level of topics and opinions and their state of being discussed may be mandated. It seems that providing feedback (by people with different roles) should be made easy by the interface (*interaction models*). Most importantly, supporting successful or less successful negotiation in certain phases of learning may require a system to have access to user argumentation and the refinement of offers, bids and proposals (*negotiation*).

Knowledge management should result in rich data-bases (*conceptual indexing* and *knowledge infrastructure models*) which can answer students questions and are updated when new insights have been arrived at for later use by students with similar characteristics (*user models*). Also, several types of help or advice may be required, for lower as well as higher order tasks (*agent models*, *student/tutor/partner modelling and monitoring*). In this case again, help needs to be found by accessing information on the characteristics of available helpers, humans or artificial (*agent models*). Also, help may be needed by users to find people (and agents) to collaborate with (*management*) (e.g., Greer, McCalla, Collins, Kumar, Meagher & Vassileva, 1998).

CONCLUSIONS

This article sketches a framework to support the research community in positioning on-going research and in determining what AI modeling techniques can be most fruitfully applied and investigated in which context as provided by the basic scenarios. We believe that in many cases it is difficult to derive from the research literature in which educational paradigm the research is conducted and why. We may divide the research community in two broad strands:

- the educationalists who take a stand and investigate how well an educational paradigm could function and how AI techniques could support or even realize such functioning
- the AI-researchers who use the educational context as a test-bed for the construction and evaluation of new AI insights and techniques

In many cases, although both strands are well represented in the AI and Education community, there appears a large gap in understanding and incorporating one another's insights. We hope our framework will help to bridge this gap by providing a more general outlook on educational contexts and processes in relation to the AI modeling field.

Both these strands should be aware and explicit about the choices made in either direction: concerning the construction of an educational context, as well as the AI techniques considered. Why this educational context? And what are its implications? And why these techniques, what are they hypothesized to support or to realize?

By further concentrating on the applicability and potential usefulness of AI modeling techniques in different educational settings we wish to contribute to the research agenda of the community. What is important or potentially worthwhile to model in different settings, at what level of detail and with what expected outcome for the educational process as a whole?

From the classification of modelling techniques in relation to the scenarios various interesting research questions can be derived. Instead of prescribing which questions should be asked, our framework is meant to support the researcher in deriving these questions and in clarifying the nature of the relation between educational goals and the techniques that are used to support the attainment of these goals.

One of the interesting research questions which could be part of the current AI and Education research agenda is if and how the different scenarios differentiate between various subjects, domains or even parts, or phases in the learning of the same subject. At first glance, it might appear that the transmission scenario is in particular suited for the acquisition of basic domain facts, the studio scenario for acquiring skills in operating on such facts, and the negotiation scenario in acquiring a deep understanding of the principles underlying the domain at hand. However, this may turn out to be an overly simplified view of the differential impact of the three scenarios. We have as yet no systematic long-term research results concerning the use of both the studio- and the negotiation scenario.

Of course, many variants of the sketched scenarios can be thought of, already in existence or to be developed in the future. But even in the case of mixed scenarios it can be of a great help to explain the educational stance taken and to consider the options for AI techniques in a more systematic fashion.

Though this article focuses on the role of AI in Education, we are supportive of many of the new technologies that are currently applied to educational settings. We believe, however that these new technologies may well profit from the use of AI techniques, even if these are no longer to be viewed as the core techniques of educational applications, but as complementary support.

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APPENDIX A: BASIC VOCABULARY FOR THE USE OF ODELING TECHNIQUES IN AN EDUCATIONAL CONTEXT

Ontologies

- Knowledge Representation
    - Domain Models
        - Multiple representations
    - Task Models
        - Multiple Tasks
    - Cognitive State Models
        - Multiple Cognitive States
    - Interaction Models
        - Multiple Agents
- Information Indexing and Retrieval
    - Conceptual Indexing
    - Agent Models
- Knowledge Management
    - Knowledge Infrastructure Models
        - Multiple sources
    - User Models

Processes

- Discourse
    - Argumentation
- Agent Interaction
    - Negotiation
    - Agents and Tools Modelling
- Individual learning processes

Student/Tutor/Partner Modelling

- Problem Solving
    - Expert Reasoning
    - Model Tracing

Issue Tracing

- Monitoring
    - Reflection
    - Management
- Procedural Facilitation

APPENDIX B: GLOSSARY OF TERMS

Ontologies	**Description**
Agent Models	Capturing the salient features of agents executing (low-level) tasks in support of the user
Cognitive State Models	Capturing the state of knowledge of an individual with respect to the execution of a (problem solving) task
Conceptual Indexing	Organising database information with semantically based indexing features and mechanisms for retrieval
Domain Models	Capturing the concepts, relations and facts pertaining to a particular domain
Information Indexing and Retrieval	Organising database information with particular indexing features and mechanisms for retrieval
Interaction Models	Capturing the communication structure between entities in the learning environment
Knowledge Infrastructure Models	The identification, representation and classification of knowledge in relation to the group processes and the roles represented within the group
Knowledge Management	The collection of those processes that describe and administrate the knowledge assets of a group and that guide the conservation and enlargement of those assets
Knowledge Representation	All intelligent activity presupposes knowledge. Knowledge is represented in a knowledge base, which consists of knowledge structures.
Multiple Agents	Capturing the communication relations and dependencies between differently equipped agents
Multiple Cognitive States	Capturing the relations and dependencies between two or more cognitive states
Multiple representations	Capturing multiple views on one and the same underlying domain
Multiple Sources	Capturing the relations and dependencies between different sources of knowledge and information
Multiple Tasks	Capturing the relations and dependencies between more two or more tasks
Ontologies	Explicit specification of a conceptualisation. The conceptualisation provides a structured, consistent viewpoint on the subject at hand, which concepts are distinguished and how they relate. An ontology is expressed in a standardised vocabulary.
Task Models	Capturing the decomposition of a task into its sub-tasks with a specification of the in- and output between the subtasks
User Models	Capturing potentially relevant characteristics of users

Processes	**Description**
Agent Interaction	Modelling the ongoing communication and exchange of information between agents
Agents and Tools	Capturing the ongoing communicative actions between differently equipped agents and tools
Argumentation	Modelling the usage of argumentative discourse
Discourse	Modelling the exchange of verbal expressions stating facts, views, opinions etc.
Expert Reasoning	Modelling reasoning steps during expert problem solving
Individual learning processes	Modelling relatively stable transitions between cognitive states of individual learners
Interaction	Capturing the communication structure between entities in the learning environment
Issue Tracing	Modelling the change history of critical issues
Management	Modelling the management strategies employed during negotiation
Model Tracing	Modelling reasoning steps during problem solving in terms of a reference model
Monitoring	Modelling reasoning strategies employed during problem solving
Negotiation	Modelling the unfolding arrangements between agents during a discussion
Problem Solving	Modelling reasoning steps during problem solving
Procedural Facilitation	Providing on-line support for strategic decisions in the learning environment
Processes (modelling)	Modelling connected series of actions, changes, or operations over time
Reflection	Modelling meta-cognitive strategies employed during problem solving
Student/Tutor/Partner	Modelling the ongoing reasoning processes of students/tutors/partners