ARTIFICIAL INTELLIGENCE TO SUPPORT TEACHING AND TUTORING PRACTICES
ITS AS A REPLACEMENT FOR THE TEACHER OR AS A TEACHING SUPPORT?

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The analysis of Intelligent Tutoring Systems over the last 20 years has moved on from seeking solutions in which the project design was closely linked to a knowledge of the discipline, to solutions that were more and more focused on emotional factors, on ill-defined problems and domain and, last but not least, on aspects connected to the sustainability of teaching. Equally, if the one-to-one model, typical of the tutor in a classic teaching situation, was initially seen as the reference, the class today is seen more and more not just as a more economical solution, but as a device offering advantages also from an educational point of view. Two further aspects have entered the pedagogical debate and are influencing the project design: a greater attention to the dialectic between teaching and learning, and to in-itinere regulation. Shulman (1987) and the movement promoted by him, teacher thinking, have highlighted the importance of teachers’ thought and have shown how teaching does not derive from learning in a deterministic way. On the other hand research in a Francophone context on practical analysis has underlined how many teachers’ decisions made in itinere cannot be defined during the project design, but may depend on the evolution of the system and on the structural coupling (Varela, 1996; Begg, 2002; Proulx, 2008) between subject and environment, or rather, in the case of education, between teacher, student and class. What guidance can we draw from this for ITSs? Within the perspective described above, the paper analyses the plug-in made in the European project l-TUTOR to support the work of teachers and to foster student’s learning. The plug-in are objects where the presence of the component of artificial intelligence are highlighted. Finally, the first data gathered from the pilot project are also provided.

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1. ITs in the 1990s

The history of ITs started in the 1960s and their evolution went hand-in-hand with that of learning machines and with research into artificial intelligence. In the 1980s there were significant contributions from J. Brown (1982), who first introduced the term ITS, and E. Wenger (1987). In the 1990s many of the products still used today were designed. K. Van Lehn made an important contribution with the creation of ANDES, an ITS dedicated to the learning of classical physics (Schulze, 2000). The characteristics and aims of ANDES are common to many of the ITs worked out in those years. ANDES, still used today in various American colleges and universities, allows the student to acquire the basic elements of classical physics. Its platform is very wide since it includes all those students in the bridging years between high school and college. Worked out on the basis of the cognitive, rule-based model1 it offers the student problems and comments step by step on the student’s activities. If the student is in difficulty, it formulates questions to set him/her on the right track or provides suggestions. The student can insert graphics and algorithms, explaining his/her choices, he/she can dialogue with the system, ask questions and request help. The ITS structure is complex and requires a long time to create.

Many of the characteristics that have favoured the success of ANDES are typical of the ITs at the present time: a well-defined and structured domain, problems with a solution known to the person setting them, and a wide platform of recipients that is stable over time. There are therefore a large number of recipients — students who have yet to enter college or who attend the first years of college and who have to acquire basic knowledge. The presence of a very wide target guarantees a return on the investment, which is necessarily high for creating the device. There are some ITs, similar to ANDES, constructed for other domains. These include Cognitive tutor (Algebra), Wayang (Mathematics), Project Listen (Reading), ASSISTments (Mathematics), Crystal Island (Microbiology), BILAT, Interview (A Military Simulation), and Helicopter Pilot.

2. Advantages and limits in the “well-defined” approach

The strength of ANDES and of similar ITs is also their weakness, since the complexity and the ability to incorporate a wide domain of knowledge have the following corresponding features: (1) the large amount of work to elaborate the products, (2) the one-to-one link between ITS and a specific domain (ITSs are

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1 “The rule-based (RB) model is set on rules that should be followed by the student step by step during the development of the problem. Each action receive a feedback according to the correct modality/ies to execute the task itself, modalities that must be all foreseen, and in the same way possible errors must be foreseen. The model is thus used in the solution of problems that can be structured in well-defined steps provided that those steps also allow solutions to be easily identifiable and verifiable.” (Paviotti et al., 2012)
very rigid) and (3) the structuring of activities around a well-defined problem. By well-defined problems we mean problems in which the choice of the solving process is implicit in the task. Domain and well-defined problems are not connected on a one-to-one basis. Also in well-defined domains (for example, classical physics) it is possible to construct problems that require the students to elaborate heuristic characteristics — ones that can be solved correctly by following different paths, some of which may not have been foreseen by the person setting the problem. However, there are also ill-defined domains and in this case it seems simpler to attribute ill-defined tasks. One might think of law (for example, the preparation of a defence in a court-case). One of the first ITSs in the ill-defined category — CATO [Aleven] — was elaborated for this sector.

The ITSs of the ANDS generation have had a lot of success and there is documented research that has proved the advantages in the learning of students who have used the artifacts described, compared with classes that used traditional methods [...].

Certain problems have emerged, however, linked to the following:
- the time and the expenditure required for creating them;
- the difficulty of reusing in other domains objects from an ITS that is strongly rooted in a specific discipline domain; reusing them could enable the resources needed for implementation to be reduced;
- the type of skills and abilities acquired.

The first and second of these problems have been explored by Van Lehn, who tried to use the ANDES objects in a domain, statistics, different from the one for which ANDES was constructed. He has described in various works the advantages and the difficulties encountered in this process (Chi, VanLehn, 2007; Van Lehn, Chi, 2007b).

More generally, various strategies have been worked out to reduce the work needed to construct an ITS (Aleven et al., 2009). We would mention, for example, the use of the constraint model instead of the rule model and the use of author-systems, for example CTAT (Aleven et al., 2009), which allows even those who do not have suitable IT tools to construct ITSs by recording, step by step, the paths created, both correct and incorrect.

The third problem, which relates to the types of skills and abilities promoted by working with classic ITSs, has caused two further issues to emerge: (1) What are the problems underlying students’ difficulties? What is the range of skills that a student should acquire as necessary in the modern world? Are they all promoted by ITSs based on the solving of well-defined problems?

Two paths, essentially, have been explored to find answers to these questions. The first one focuses on problems the students meet in learning, many of which

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2 A cognitive model used frequently in ITSs is the constraint-based model (Mitrovic and Martin, 2007; Mitrovic and Weerasinghe, 2009). “Whereas rule-based models capture the knowledge involved in generating solutions step-by-step, constraint-based models express the requirements that all solutions should satisfy.” (Aleven et al., 2009, 34). Constraint-based modelling (CBM) “consists of specifying sets of constraints on what is a correct behavior or solution rather than to provide an explicit task model. When the learner violates a constraint during a task, the CBM Tutor diagnoses that an error has been made and provides help to the learner regarding the violated constraint.” [Nkambou et al., 2010, 86].
are connected to their motivation, self-confidence, method of study and attention span (and therefore not dependent on the discipline);
The second concerns strategic skills whose development may be promoted by working on ill-defined problems and domains. Ill-defined problems require the student to have skills and abilities that are different from those required by well-defined problems (for example, the skills linked to problem posing, to decision-making, and to the ability to standardize a situation).

3. Paths explored after 2000

From 2000 onwards, designers’ attention therefore moved on to emotional aspects and methods of interaction. Attention to emotional aspects led, on the one hand, to examining the facial reactions and the eye-tracking of students performing a task and, on the other, to developing agents expert in communication and functional in motivating, by supporting, for example, digital tutors with different characteristics. At the same time, studies focused on meta-cognitive components and on self-regulated learning.

A broad line of research also opened up on ill-defined domains and problems. Lynch, Ashley, Aleven and Pinkwart (2006) have highlighted how strategies in the well-defined sector are different from those used in the ill-defined one and have suggested some guidelines for constructing ITSs in ill-defined problems, such as:
– the use of weak methods in which the models function as “a guide but do not require strict adherence to its contents”;
– the use of processes and supports in which “in general, any decision support system could qualify as a discovery support model so long as it helped the users better understand the domain and did not supplant their own actions”. The following belong to this category: (1) the Discovery Support systems that “operate by providing the user with support as they work on a task in an unconstrained domain”; (2) model explorations, and (3) model building;
– the use of case-studies. The authors mention, for example, how this kind of strategy is at the basis of CATO, the ITS mentioned above, used in training law students;
– peer collaboration. “Existing collaborative ITSs have provided this support either by casting the system as collaborator, or by using the system to facilitate interactions among human peers” (Lynch et al, 2006).

As Conati (2009) emphasizes, each ITS has 4 main components: pedagogical model, student model, domain model, communication knowledge. “It should be noted that not all ITS include the four components mentioned above, and that each component can be present at various levels of sophistication” (Conati, 2009). If, in the ITSs based on well-defined problems the domain model has a privileged role, in ITSs based on ill-defined problems the pedagogical aspects have a greater space and the feedbacks place more attention on meta-cognitive processes – a support that “does not require a detailed model of domain expertise” (Conati, 2009).

In 2011 Joshua Underwood and Rosemary Luckin, of The London Knowledge Lab, drew up the report “What is AIED and why does Education need it?” which aimed at capturing the changes in the ITS sector from 2000 to 2011 (Underwood and Luckin, 2011; Underwood and Luckin, 2011b).
From the report we can deduce the asymptotic process between research in the Artificial Intelligence for Education sector and that in the Education sector (Table 1).

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
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<tbody>
<tr>
<td>• Support for 1-to-1 learning</td>
<td>• Support for personal, collaborative and social learning</td>
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<tr>
<td>• Support for learning in tightly defined domains and educational contexts</td>
<td>• Support for open-ended learning in ill-defined domains across varied physical and social cultural settings and throughout the lifetime</td>
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<tr>
<td>• Support for knowledge acquisition</td>
<td>• Support for knowledge construction, skills acquisition and meta-cognitive, motivational and affective support</td>
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<tr>
<td>• Small-scale systems and laboratory evaluations</td>
<td>• Large-scale deployments, evaluations in real settings and learning analytics</td>
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<td>• Focused analysis of relatively small quantities of experimental data</td>
<td>• Discovery and learning from educational data mining of large amounts of data captured from real use</td>
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<tr>
<td>• Constrictive technologies and Interfaces</td>
<td>• Accessible, ubiquitous, wireless, mobile, tangible and distributed interfaces</td>
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<tr>
<td>• Designing educational software</td>
<td>• Designing technology-enhanced learning experiences</td>
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Table 1 - Movements in focus of AIED research 2000-2010 (Underwood and Luckin, 2011)

4. Teaching sustainability

A careful reading of the table highlights an obvious theme that is present at various points and lies almost right at the bottom of it: the role of the teacher. A deterministic vision of the relationship between teaching and learning is often present in classic ITSs, and reference to the centrality of the student is connected to this. Many studies over the past 30 years have shown how teaching requires the student’s active participation and therefore does not derive mechanically from the teacher’s activity (as instructivist proposals would want), but they have also shown how this autonomous activity can be promoted by the scaffolding role of the expert (Vigotski) and by devices put in place by the teacher. Moreover teaching does not have the student as its sole reference since it is based on processes of mediation between scholarly knowledge and the student. If attention to learning has, rightly, allowed instructionist approaches to be superseded, having the centrality of the student as sole reference may hide either an obvious fact (the aim of school is in any case learning), or a demagogic approach (under-valuing the teacher-student-knowledge triangle and the asymmetry between teacher and student). Many of the operational models, suggested by the adaptive approach and by personalization, take into account this view. Equally, certain research, for example that of Ploetzner (2011), highlight the centrality of the mediation of the teacher.

Another element that has been widely investigated, especially in French research, is in-itinere regulation (Vinatier and Altet, 2008). The dialogue between
a project and an act, and the teacher’s ability/need to reorganize in itinere his or her own project, do not always spring from a lack in the design. Still in relation to in-itinere regulation, a further aspect must be highlighted. While providing, in the design stage, for alternative directions that a problem-solving path might follow, there is nevertheless a point of view at the basis of the various tracks. It identifies a field, in the Gestalt sense – a phenomencic space that starts from certain presuppositions and from a shared language. The student’s difficulties very often arise from not being inside this point of view and this determines why he or she does not empathise with the teacher and with the path, not because of the difficulties connected with the specific theme. The student’s distance depends on his/her history and on his/her experiences and varies from case to case. It cannot be predicted.

Thanks to in-itinere regulation the teacher often perceives the missing links and the obstructions and manages to carry out those changes, even minimal ones, that are necessary so that the proposed activity has “a meaning” for the student. It is not surprising, as Graesser already highlighted in the 1990s, that the more prepared students, those in tune with the teacher’s logic, those who know how to ask “the right questions”, benefit most from classic tutoring (Graesser et al., 1995). One final observation relates to sustainability. Many courses, even university ones, are organized by the teacher in a short period of time preceding the start of the course, during which he/she creates a broad-based design that he/she will then develop during the course. Then, each year, the courses are partly modified and although similar contents are repeated, changes are made because of research carried out. This operational mode does not fit in easily with the classic ITS types.

Does it make sense to organize “intelligent” tutoring in a situation that provides for in-itinere regulation, where a limited time is allotted to the course design, and in which the teacher modifies his/her own course each year?

5. A project proposal

There are two motivations spurring us on to give a positive response:

- it is now the practice to structure courses, both in universities and in schools, by setting up different devices, structured and synergetic, and even face-to-face courses make use of online activities and learning environments. It is not always easy, however, for the teacher to create environments that are not simply repositories or spaces of information. If one wants to perform more complex activities, the problem of sustainability arises, meaning that the teacher’s work increases and he/she does not always have the necessary time;

- in online courses the tutors’ work is wide-ranging and differentiated and we move from routine activities (reminding students of due dates and replying to requests of a bureaucratic nature) to supporting the various students with personalized actions;

- online environments, both in face-to-face and distance learning courses, allow an amount of data on students’ behaviour to be collected, but this mass of information is not always manageable and usable by the teacher and by the student. The data is there, but for it to be used, it must be elaborated and analyzed.
The I-Tutor, for intelligent tutoring of online courses, was born out of these considerations. Financed by the European Union, its aim is to construct artifacts that will support the work of physical tutors, in some cases interacting directly with the student, and in others supplying representations or sending notifications to the tutor and to the student to highlight critical situations or to suggest perspectives for intervention. In particular, the activities carried out by plug-ins are as follows:

1. mapping the concepts present in the environment writings. A second plug-in constructs a two-dimensional map of the main themes dealt with in the course. The words are distributed on the map according to a logical proximity logic, always deduced from the text and the position of the concepts on the map suggests the relationship between these. Identification of the concepts emerges from the automatic analysis carried out with statistical algorithms of the texts present in the environment and of a database hidden to the students and prepared by the teacher. In addition, the map has a depth, meaning that it is structured in four levels. By clicking on each area of the map, that is, on a keyword, the keywords connected to it that specify its territory emerge, going deeper and deeper and analyzing the various aspects of the concept. The fourth level, on the other hand, enables you to read directly the texts relating to the conceptual space of the relative area. The map (Fig. 1) is intended both for the student and for the teacher/tutor. Using the map, the student can go through the themes of the course with a different perspective from that of the curriculum and going over them again and again can suggest relationships between concepts. The teacher/tutor, on the other hand, can check, from reading the map, the completeness of the course that has been designed. As well as the general map of the course, the plug-in creates a personalized map of each individual student. The areas where students’ productions may be located are coloured on the general map, so that the way in which his/her writings are distributed can be viewed.

![Figure 1. Conceptual Map](image)
2. analyzing the tracking data with Education Data Mining techniques, to compare the behaviour of the individual with that of the class. As previously stated, a lot of data is supplied by an LMS tracking system but it is not always usable and does not always supply information, if it is not compared with reference values. In the project we decided to analyze tracking data relating to 22 variables. The system calculates 4 clusters for each variable, which contain groups of students with similar characteristics in relation to the variable analyzed. The highlighted clusters become references for the student (which cluster they belong to) and for the teacher/tutor who can thus understand the structure of the class and the positioning of each student (Fig. 2). Multiple displays of the graphics are shown. There is an overall view (the position of the various intervals, their minimum, maximum and median value, and the number of students associated to each cluster), a timed view to see how the class evolves in relation to the specific variable, and a radar-type graph display allowing many variables of the same student to be associated in one single view, and linking them. If the system highlights behaviours that are lower or higher than defined targets it sends an alert to the teacher and, in some cases, to the student.
3. automatically sending to the student explanations and instructions about routine aspects. The plug-in analyzes the student’s question and searches in the environment for the answer. From the analysis of student-tutor interactions in 8 Master’s courses, with over 700 students, activated by the University of Macerata between 2008 and 2011, it emerged that 58% of requests to the tutor are related to information already present in the environment. Inserting faqs does not solve the problem since the student “does not trust the machine” and wants direct information. Therefore a system that sends the student personalized replies may reduce the tutor’s workload so that he/she can dedicate his/her time to tutorial activities of more importance to the learning path.

The plug-ins comply with the following constraints:
- they do not require intervention from the teacher during the project, nor do they require an activity linked to the domain, but they operate automatically and with a content-free logic;
- they supply updated information in real time and therefore follow dynamically the course as it evolves, thus responding to the in-itinere regulation requirement;
- for textual analysis, they do not use semantic tools, but only statistical ones. In this way one is not linked to specific languages and the plug-ins can be adapted for the European context where there is a wide fragmentation of languages. Initial piloting was carried out in Italy, Greece and Hungary, and therefore not just with three different languages, but also with two types of alphabets;
- they operate with non-proprietary environments, but ones that are widespread in schools and universities and are therefore already familiar to teachers and tutors. It is not surprising that the prepared plug-ins operate in Moodle (although in future they may be prepared so that they can dialogue with different LMSs).

Clearly, the flexibility of the system, which is not limited either by the domain nor by the type of students, makes the response supplied more “generic” and it is precisely for this reason that its use is envisaged as a support and not as a replacement for the tutor. In the end it is the teacher/tutor or the student who decides how to use the suggestions and the displays that come from the intelligent system.

**Conclusion**

Research in the sector straddling Education and AI over recent decades has supplied some interesting input for research in the two sectors. Equally, EDM has contributed not only with operational tools, but by operationalizing the various processes, it has allowed theoretical aspects to be studied in more depth and opened up new work and research prospects (Romero and Ventura, 2010). The point of view which researchers in the United States and Canada have started from has always been slightly different from the European standpoint where less homogeneity in curricula, greater linguistic fragmentation and greater attention to pedagogical-teaching aspects have created smaller spaces for developing ITSs linked to specific domains.
Over the past few years the greater integration of AI sector research with educational aims, as J. Underwood and R. Luckin (2011) remind us, is favouring new directions and new approaches in constructing intelligent supports for education. If, at first, research was aimed at constructing artifacts dedicated to specific disciplinary domains and at supporting students in solving well-defined problems, since 2000 research projects have shifted their interest onto emotional and motivational aspects and onto self-regulated learning, on the one hand, and onto ill-defined domains and problems, on the other. A further step is to understand whether the intelligent applications for education can also take into account in-itinere regulation and teaching sustainability. Constructing applications that require very little initial work for the teacher, that supply the elements for in-itinere regulation, that operate with widespread environments and can be used in different domains, is a further prospect for research in the sector.

Clearly, the role of the artifact is changing, as are the teaching interaction characteristics that are created in its use. If a classic ITS replaced the teacher and the interaction was student-machine, the intelligent plug-ins that supply modellings of the path and of class and student behaviours, described in the contribution, are mediators between teacher and student; they promote a reification of the interaction itself, with the representations displayed, and they support, and do not replace, tutor and teacher in the teaching activity.

References


