The evolution of ICT-based learning environments: which perspectives for the school of the future?

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Abstract

This paper briefly outlines the evolution of ICT-based learning environments discussing some of the main aspects that have characterised such evolution (e.g. technological evolution, changed cognitive and pedagogical frameworks, changed role assigned to ICT-based systems in education). The objective is to point out how the implementation of innovative learning environments based on advanced technology, is the result of the strict interrelation between educational and cognitive theories, technological opportunities, and teaching and learning needs. In this paper some indications for current and future evolution are evidenced. Reference is made to an ICT-based multi-environment system that supports teaching and learning activities in the domain of arithmetic problem solving at compulsory school level.

Introduction

In recent years there has been strong pressure (both from outside and inside schools) to make use of information and communication technologies (ICT) in classroom teaching, in terms of both content and methods.

In the course of time (though with differing approaches, methods and instruments) the drive towards “computer innovation” has substantially had the following objectives: i) to develop new capabilities in the students, permitting their integration in a society that has been drastically modified by information technologies; ii) to use computer-linked methods, contents and tools for transforming and improving teaching and learning processes in the framework of traditional curricula.

The first objective brought with it the need to introduce some new competencies and skills in secondary school curricula, while the second one is related more to analysing how the use of ICT in classroom activities can produce significant changes both in the nature of the knowledge imparted and in the nature of the processes involved in acquiring it. This paper is related to this second objective.

Notwithstanding the good results produced in a number of experimental settings and the considerable budget invested by many European Governments for equipping schools with hardware and software tools it can be said that computer use has had a limited impact on schooling throughout the world (see, for example, Pelgrum, 1996; Prometeus, 2001; Venezky & Davis, 2002). One of the main reasons for this is that technology has often been introduced as an addition on to an existing, unchanged...
classroom setting. Nowadays it appears fundamental to adopt a more integrated vision where ICT are considered together with the educational strategies, contents and activities the students engage in. Technology design and use should be progressively considered in relation to the whole teaching and learning activity and not merely to the development of specific abilities and/or the accomplishment of particular tasks. An understanding of the conditions under which the educational use of ICT tools might be meaningful in the school context and of the ways in which their use may help to bring about changes in the overall approach to education must be developed.

In this paper the evolution of ICT based learning systems is briefly analysed trying to determine the main elements characterizing it, that is, mainly, technological evolution, changed cognitive and pedagogical frameworks, and changed role assigned to ICT-based systems in education.

This analysis develops from a paper (Bottino, 2001) where some learning metaphors have been outlined and put into relation with different types of educational software. The present paper develops from that initial idea and tries to sketch a possible direction for future evolution. Examples taken from author’s experience in the design and experimental evaluation of an educational multi-environment system are integrated to support the ideas outlined.

The focus is on schooling that is discussing elements that characterise the design of ICT-based learning tools that can be utilized in schools (primary and secondary school).

The aim is to give some indications for identifying current perspectives and future trends in the design and use of advanced ICT-based learning systems.

**Visions of learning and relationships with ICT design and use**

Research on ICT-based learning and instruction has undergone a deep transformation in the course of time, due in part to the parallel evolution of pedagogical and cognitive science theories. A set of ideas and principles has been produced which have substantially changed orientations, at least at the research level, regarding the design and use of educational software.

In the following I briefly consider some of the main orientations that it is possible to single out in the design and use of ICT-based educational tools. Necessarily my discussion is neither detailed nor complete and tends to simplify orientations and models in order to highlight their main aspects.
Three models can be singled out as a starting point for eliciting ideas about crucial issues in ICT based learning systems:

a) The transmission model
b) The learner centred model
c) The participative model

In sketching such models main aspects considered are the following: educational theories used (implicitly or explicitly) as reference framework, main characteristics of ICT-based systems from the point of view of their use in classroom activities, the ways in which users are expected to interact with them, and the relationships supported.

a) The transmission model

The first ways in which the computer had been used for educational purposes were influenced by behaviourism that considered learning as an induction of a required behaviour according with the well-known model “stimulus-answer”. The reference (implicit or explicit) to this model is most evident in the design of drill and practice programs that are mainly aimed to exercise the student in the development of specific, often quite limited, competencies and abilities (Reigeluth, 1987). These programs, in the course of time, have undergone evolutions from a computer science point of view: from the first systems with rigid interfaces where all the possible answers were pre-programmed, to systems where the use of Artificial Intelligence techniques and methods allowed personalization of the interface, the type of proposed exercises and the feedback obtained. Drill and practice systems, even now, represent the more relevant part of the educational computer-based systems available on the market. They usually employ some form of questioning strategy and often use some gaming techniques for encouraging participation and motivation. They include only minimal content instruction and are usually used to test the acquisition of a given ability or to provide additional exercises to students who show problems or delay in the acquisition of some of the skills foreseen by the curriculum. Ordinarily these programs are not used during normal classroom time but for individual training or remedial activity during “ad hoc” hours or at home.

Tutorial systems, in contrast with drill and practice systems, include content instruction in a given topic. In their design, importance is ascribed to factors such as reinforcing memorization, presenting objectives, specifying prerequisites, eliciting and assessing performance. Presented questions require application of the concepts or rules covered...
in the instructional sequences. Feedback is often diagnostic by identifying processing errors and prompting remediation or recasting of the instruction (Case and Bereiter, 1984). Their use in classroom practice is limited since they often are perceived more as substitutes for teachers than as tools to help them in their work. It can be observed that this kind of approach to the use of computers in education is also the basis of some distance learning courses on the web that are becoming progressively widespread.

The educational advantages of both drill and practice and tutorials programs are quite limited. Their utility has been underlined in specific cases such as, for example, the performance of remedial activities (i.e. the handling of written calculations algorithms in arithmetic, or, in the domain of language, the development of spelling and grammar abilities) or the instruction on specific topics (i.e. initial training in the use of a software product).

The prevailing metaphor is that of the system as an environment where knowledge is transmitted in order to be acquired by the user.

The transmission metaphor is at the basis also of the development of many educational hypermedia systems. The main difference is that, in interacting with them, the user begins to assume an active role since s/he has the possibility to explore the presented contents following her/his needs and preferences according to personal paths (Tomek et al., 1991).

b) The learner centred model

An increasing interest in constructivist theories has changed the reference paradigm within which the computer is considered for learning aims. The attention has been progressively focussed on the internal aspects of students, on their attitudes and behaviours and on the cognitive processes that are involved in learning interactions with the computer (Brown et al, 1989).

One of the major forces which has driven change has been the assumption that meanings are lost if learning is simply seen as the transmission of information. Learning is progressively considered as being based on an active exploration and personal construction, rather than on a transmissive model.

Microworlds are an example of systems that are designed according with this general framework. The notion of microworld has undertaken a deep evolution since when, for the first time, this term had been used by Minsky and Papert in an MIT report. As the
matter of fact, the notion of microworld changed - from a notion useful to instruct the computer to automatically solve problems in circumscribed and constrained contexts - to a notion useful to design environments suited for learning within a given knowledge domain (Papert, 1980). Even if there is no standard definition of the term ‘microworld’, there is agreement among researchers on a number of characteristics, which are usually considered necessary for qualifying a system as a microworld (see, for example, Laborde and Strasser, 1990). For example, microworlds should provide the user with a number of primitives (objects and functions) that can be combined in order to produce a desired effect (computational, graphical, etc.). They should embody an abstract domain described in a model, and offer a variety of ways to achieve a goal. Moreover they should allow the direct manipulation of objects. A microworld is built up around a given knowledge domain which has to be explored interacting with the program. Hence, in the design of microworlds for educational aims, a crucial role is assumed by the objects that are made available to the user through the interface of the microworld. Papert defined them as transitional computational objects, that is, objects which are in between the concrete and directly manipulable and the symbolic and the abstract. Consequently, an increasing importance is ascribed to the epistemology at the basis of a microworld as a key factor to distinguish between potentially powerful environments and environments less appropriate for exploration. The exploration is necessarily constrained but in a way suited to favour learning. In the mathematical field, a well-known example of this type of computer-based system is Cabri Geometre, which has been designed to develop capacities in the formulation of conjectures and proofs in Euclidean geometry (Laborde, 1993).

Even if the above described orientations have brought the development of a number of projects that have produced significant results at the research level, it is nevertheless true that the high expectations regarding ICT-based tools potential to drive change and innovation in school remain largely unfulfilled. One of the main reasons for this (disregarding factors related to hardware availability and management, and to the traditional resistance of both the school system and teachers themselves to change) is that technology has often been introduced as an addition on to an existing, unchanged classroom setting (De Corte, 1996).

e) The participative model
Many research studies reveal that it is pointless from a pedagogical point of view to make computers available at school if the educational strategies and activities the students engage in are not suitably revised.

In recent years an interest on the whole teaching and learning situation has increasingly emerged. This means that progressive consideration is given to the needs of the teachers who will be using the technology, the ways in which it will be used, the curriculum objectives, the social context and the way in which teaching and learning activities are organised. Moreover important consideration is given to the definition of meaningful practices through which technology can be used effectively (Bottino & Cox, 2002).

In recent years, these issues have represented a major topic for discussion in the debate that researchers have been conducting in the domain of educational computing. At theoretical level, we have assisted a progressive move from cognitive theories that emphasize individual thinkers and their isolated minds to theories that emphasize the social nature of cognition and meaning (Resnick, 1987). An increasing importance is ascribed to theories that highlight the importance of studying the relations among individuals, mediating tools, and the social group (reference can be made to theories such as Activity theory, Situated Action Models, Distributed Cognition). Increasingly, technology is being studied in relation with long-term teaching and learning processes of the kind needed for the development of complex articulated knowledge (e.g., arithmetic problem solving, Newtonian principles in Physics, comprehension and communication in language, etc.). For the development of such abilities, the student-software unit of analysis is not sufficing as it is necessary to consider the whole set of interactions established in a class over the course of time.

As the matter of fact the mediation offered by a given software to cognition, is not sufficient to explain the learning aspects related with motivation, with goals formation and with the attribution of a meaning to the whole activity which goes beyond the meaning of the single actions involved in the performance of a task. The analysis of these aspects requires looking at learning not only as an individual construction developed during the interaction with the computer but also as a social construction developed within the whole learning environment.

This shifted paradigm has two different implications for the implementation of effective ICT-mediated learning environments. On one hand, technological tools influence and transform the activities performed with their mediation, but, on the other
hand, practice can deeply influence the technology used. This is particularly true now, when technological progress is constantly opening up new opportunities (for elaboration, representation, communication, etc.) whose potential for educational purposes has yet to be fully exploited. In other words, according with this approach, the way in which technology can be used in social practice can prefigure new functions to be included in the technology. These new functions and opportunities can change the models of practice, which have inspired the construction of the technology itself.

It can be noted that the development of new models of practice can prefigure new ways of using existing ICT-based tools that can change the role that such systems has previously had and, consequently, the mediation that they can offer to teaching and learning processes. For example, in appropriately designed didactic situations, a hypermedia system can be used to introduce students to activities of meta-cognition, such as a reflection on their ways of organizing knowledge in a given field, instead of as a tool to deliver information on a given topic field (see, for example, the experience reported in Bottino et al, 1998).

An aspect of particular relevance, which is often overlooked, is that of assessment methods. Even in contexts that represent significant, and contextually much richer, departures from the traditional approaches to learning, assessment methods often appear determined by the old mechanistic paradigms. This suggests that a strong need exists for exploring other much more contextual forms of assessment, such as those afforded by the use of portfolios, problem based assignments, peer refereeing and evaluation, and other emerging ways of looking at the challenges of assessment.

**Situated multi-environment learning systems**

We can observe that, in general, school curricula subsume different types of teaching and learning methods, and so no single method or type of tool used can be the choice for all occasions. Moreover, within any learning domain, students’ and teachers’ needs evolve over the activities in which they are involved and tools have to support this evolution.

Situated multi-environment learning systems can be considered as a new generation of open-learning systems which are more suited to mediate the new ways of looking at teaching and learning processes that are now progressively affirming themselves. These systems makes available tools able to support not only the relationship of the
student with the knowledge to be learnt (learning object) but also all the relationships that are established between participants during a teaching and learning activity. These systems are typically designed with the classroom in mind. Rather than constrain the learning experience to be narrowly individualistic, this next-generation technology supports socially situated interaction and investigation.

It is possible to delineate some general indications for the design and analysis of such systems. Of course, these indications are to be detailed and specified according to the characteristics of the specific field of application and educational context considered. In particular, in the design of situated multi-environments learning systems, the following issues assumes a crucial importance:

- The computational objects and interactivity that a system makes available to the user and their relationship with the cognitive processes involved in the acquisition of the knowledge for the learning of which the system has been realized.
- The tools offered to validate student’s actions and the support they offer to the evolution of student’s knowledge.
- The tools offered to support the re-elaboration of personal experience and its sharing within the class.
- The tools offered to support the setting up of a social context able to assist students’ performance and the evolution of competencies and knowledge.

In general, situated multi-environment systems are characterised by a strict integration of tools for supporting visualisation, re-elaboration of knowledge, and communication. The aim is to offer tools for problem exploration, for representing solution strategies and processes and for communicating such processes as well as tools to support learning evaluation. Of course tools and features cannot by themselves guarantee learning. They have to be used in order to support the construction of activities in which learning could be the result of a social construction of meaning and of its justification. It can be noted also that situated multi-environment systems can integrate environments of different kinds, such as microworlds, specific drill and practice systems, communication environments, simulation systems, etc.

Below I briefly present an example of an ICT-based system designed according with some of the indications outlined.
The aim of such description is to show how technology can be designed to support an activities rich educational environment and not to illustrate in details the specific system to which I refer.

An example of educational technology supporting mathematics learning

The work I am referring to here concerns the realisation and evaluation of an open multi-environments system that supports teaching and learning activities in the domain of arithmetic at primary and lower secondary school level. This is a long-term project that has undertaken major transformations from the initial prototype (Bottino et Al., 1994), to the first commercially available version (ARI-LAB, 1999), to the new versions (ARI-LAB-2 and ARI@ITALES), which have been completely re-designed and currently under implementation.

ARI-LAB-2 is the stand-alone version of the system that runs on CD. It has been developed to support the teacher in designing arithmetic problem solving activities with his/her class, and the students in the solution of arithmetic problems.

ARI@ITALES has been accomplished to offer the teacher tools to build web-based learning activities in the arithmetic domain to be inserted in an on-line course, and to offer the student interactive and visual tools to develop such activities on the web. ARI-LAB-2 and ARI@ITALES are designed and implemented within the research project ITALES (IST-2000-26356) partially funded by the European Commission within the 5th Framework Program.

The examples that I illustrate in the following refer mainly to ARI-LAB-2.

Even if it is not possible to give account here of the evolutive character of the work, it is worth noting that an iterative approach to design has been used. That is, the design of technology has been informed by the study of the integration of initial prototypes in real class situations (Bottino & Al., 1994), (Bottino & Chiappini, 2002). As the matter of fact, the process of design used was one in which the whole educational environment was designed and tested. The technology was just one component.

Background

Difficulties in math learning are frequently reported as well as the low results that students often obtain in this field (see, for example, the Third International Mathematics and Science Study, IEA: http://timss.bc.edu/). For teachers too mathematics is traditionally a sector where they experiment major problems in finding
appropriate pedagogical approaches suited to overcome the difficulties encountered by a considerable part of students. Often the ability of understanding or not understanding math is a key factor in school success.

Already at compulsory school level “doing math” is frequently perceived by students as an execution of repetitive exercises according with formal rules whose meaning they often do not understand or master only at the syntactic level.

These considerations put in evidence the importance of research efforts as well as experimental evaluations in this area. The objectives of our work within the ARI-LAB project are to study and test new approaches to maths concepts and new methodologies for maths teaching and learning mediated by ICT environments and tools.

Based on the theories of mediation and their basis in social interaction derived from Vygotsky work and Activity Theory key ideas (see Bottino & Chiappini, 2002), the principles which have inspired the design of such tools are the following:

**Maths rich activities**: children should have access to, and be involved in, maths rich activities to which they can attribute a concrete meaning and should be using age-appropriate tools and representations based on computational artefacts that they can refer to their own experience thus contributing to make concrete abstract concepts.

**Construction**: children should be allowed to construct, manipulate, and validate artefacts and to share them with their community.

**Collaboration**: educational environments should involve collaboration between teachers and students and between individual learner and fellow learners. They should make available tools for developing pedagogical activities based on the comparison and the negotiation of the mathematical meanings involved.

**Context**: an educational technology tool or environment should be designed to support all the activities that are developed through its mediation in the context of use. For example, a technology must be designed to support not only students’ learning activities but also teachers’ activities, because it is only by understanding and designing for the whole educational situation that effective and valuable changes can be brought about in the classroom.

In the following I examine how the previously outlined principles have inspired and informed the design of the ARI-LAB-2 system.
Supporting knowledge representation, and validation

Representation systems play a central role in mathematical education as a way to ease the access to such an abstract domain of knowledge. The symbolic re-constructive approach to mathematics concepts, which is fundamental for expert mathematicians, often constitutes a serious obstacle for students. Researches in cognitive science and in maths education have shown the importance of making reference to students’ experience in their every-day world. ICT can play a crucial role in approaching a mathematical domain of knowledge, which is abstract and formal, through the exploration and the manipulation of concrete representations that help them to deal with such knowledge from a visual and motor perceptive perspective. Besides, the availability of concrete representations lends naturally itself to a social process of knowledge construction based on negotiation of meaning.

ARI-LAB-2 supports students in the solution of arithmetic problems by making them available a set of microworlds where they can visually represent and manipulate problem situations in a variety of concrete contexts, which are meaningful also from the mathematics point of view. The microworlds currently available are: “Euro”, “Calendar”, “Abacus”, “Number Building”, “Number Line”, “Graphs”, “Spreadsheet”, “Arithmetic Operations”, “Fractions”, and “Arithmetic Manipulator”. Microworlds make available both tools for actions in relation to the problem at hand (e.g. to visually represent the problem situation, to perform a solution step, etc.) and tools for the validation of the solution strategy performed. Some microworlds (such as Euro or Calendar) have been designed to model common situations in every-day life such as “purchase and sales” or “time measure” problems. Others have been designed to model different arithmetic fields and tools for solving problems (graphs, spreadsheets, etc.).

Let us examine an example. To solve a problem involving a money transaction the student can enter the “Euro” microworld where s/he can generate Euros, move them on the screen to represent a given amount, change them with other Euro coins or banknotes of an equivalent value, etc. Figure 1 shows the interface of the Euro microworld.
Figure 1: Interface of the Euro microworld. In this microworld the user can drag coins in the working space (in the left bottom section), move and group them in different fashion, change selected coins with other coins of the same value (moving coins to be changed in the right bottom section). In the specific case shown in the figure, the student had initially represented a 10 Euro banknote, then he changed this banknote with 10 Euro coins and subsequently he changed two one Euro coins with two 50 cents coins and ten 10 cents coins. Then the student grouped two 60 cents coins (in order to represent the money for the 2kg of bread), and 1 Euro and 20 cents coins for represent the money for the ham, and so on.

Since ARI-LAB-2 offers the possibility to access a number of different microworlds while solving a problem, it is possible to obtain different representations (in different microworlds) of the same mathematics concept or entity. For example, an amount represented with Euro coins can also be represented interacting with the abacus and with the Number Line microworlds. Thus different representations of the same value can be obtained and put into relation. The comparison and conversion into different registers of representation is a crucial cognitive activity to give meaning to mathematical concepts (see, for example, Duval, 1993).

Differently than in other approaches, validating a solution strategy in a microworld does not mean to receive a correct or wrong feedback from the system, but to receive a specific feedback only for some crucial actions that the student can control at a
perceptive level. Feedback is done in such a way to give students, if necessary, hints for correcting his/her actions.

For example, in the Euro microworld it is possible to select a (previously generated) coin or group of coins and to hear its amount pronounced orally by means of a voice synthesizer incorporated in the system (clicking on the “speaker” button). This validation tool is of crucial importance to acquire experience with the rules of the Euro currency system. The same function is available also in other microworlds, such as, for example, the Abacus microworld. Moreover, in each microworld, some actions performed by the user are controlled by a set of rules integrated in the system that prevents her/him from taking specific incorrect steps. For example, if a student tries to perform an incorrect change of coins, or of balls in the Abacus, the system prevents her/him to continue and addresses a specific error message and in some cases also an animation of the correct procedure.

However the overall control of the solution strategy performed is not done directly by the system but left to the user and to the interaction with the class and with the teacher.

**Supporting the elaboration of personal experience and its sharing**

ARI-LAB-2 makes available a specific environment, the Solution Sheet, where it is possible to elaborate the solution process enacted within the microworlds, transforming it into a product to reflect on and to share with others (teacher, other students, etc). The underlined metaphor is that of the math workbook where usually a student does her/his exercises and builds solutions to problems.

In the solution sheet the user builds up a solution to the problem at hand by copying into this space the graphic representations produced in the microworlds that s/he considered meaningful for working towards the solution. The student can employ verbal language and arithmetic symbolism to comment on the graphical representations copied and thus to explain the solution performed. The underlined metaphor is that of the “post-it” that is a short note or comment that it is possible to add, remove, correct, move about, etc.

In the solution sheet the student can copy representations obtained in different microworlds thus better supporting their comparison and the passage from one representation register to another. From the solution sheet it is possible to access directly microworlds and the other environments of ARI-LAB-2.
Figure 2 shows the interface of the solution sheet environment with an example of a problem solution.

Figure 2: Interface of the solution sheet. In this environment the user can paste visual representations obtained in the microworlds (in this specific example in the Euro and Abacus microworlds). He can also add “post-its” to comment on the representations obtained. The user can as well add pages to the solution sheet, print the solution performed, cancel the work done (using the buttons on the bottom of the interface). The user can also access the other environments of ARI-LA-2 by clicking on the buttons on the top left of the interface.

The availability of the solution sheet supports the teacher in the planning of the pedagogical activity. For example, the teacher can initially ask students to solve an arithmetic problem working in microworlds, then s/he can ask them to convert the solution produced into written verbal language, and, subsequently, to convert it into formal arithmetical relations explaining the meaning of such relations. Moreover, the teacher can build examples of problems solutions that can be sent to students for reference. As the matter of fact, as it is explained in the next section, the solutions produced by a student in the Solution Sheet can be exchanged with other students and with the teacher.
Supporting communication, comparison, and collaboration

The learning activity in ARI-LAB-2 is inserted in a social dimension where communication and collaboration activities among students and teacher assumes a crucial importance. While solving a problem with ARI-LAB-2, an environment, the Communication Environment, can be accessed. In such environment it is possible, at any time, to establish a connection with other users and share messages with them. A local network is foreseen at this regard. The communication environment allows not only to exchange messages but also solutions among students and with the teacher. A variety of interaction modes are supported. The user can choose the partner/s to communicate with at a given time, decide whether or not to read a message or a solution when received, look at them later, display the entire dialogue held with partners. The opportunities given by the communication environment allow to insert the problem solving activity in a social interaction practice which can change students' attitude towards the problem, the validation context in which the resolution process is set, and the way in which assistance can be given to students. For example, a student can confront his/her solution to a given problem with those of his/her classmates and discuss with them the evidenced differences. The teacher can send to each student one or more correct solutions for the problem at hand to allow him/her to compare them with his/her own thus favouring the enactment of learning by analogy strategies.

A number of possible pedagogical strategies may be used for promoting and supporting collaborative learning activities based on computer-mediated communication (Slavin, 1996). In my experience, at least with young students, the best tasks appear to be those which provide a method and allow a context for collaboration to be built. Three strategies have been investigated in particular that have shown strong potential in this respect and which can also contribute to change the form and status of arithmetic problems. These are: pairing students with symmetrical roles and tasks; giving responsibility and control to them; developing investigative and open-ended tasks without single answers.

Supporting teacher’s planning and management of the learning activity

ARI-LAB-2 offers the teacher an environment, the Teacher’s Environment, where s/he can write texts of problems, prepare problem solutions, and manage the local network. A number of configurability and personalisation opportunities are offered. For example, the teacher can send, through the local network, texts of problem and
solutions to the students of her/his classes. It is possible to send them to all the students of a class or only to the ones chosen by the teacher in the class list. Moreover, the teacher can choose the microworlds to be made available for the resolution of a specific problem; he/she can also select the validation tools to be made available during the solution of a specific problem (e.g. the voice synthesizer). The teacher can as well impart different problems to different students, and send messages and solutions both to groups of students, to the whole class, or to each individual student. From the teacher environment, through the local network, the teacher can also control the work performed by a student by looking at the problems s/he has solved.

**Conclusions**

ICT tools can influence and transform learning by fundamentally changing the way in which a content can be taught and learnt. When considering the design and use of such environments we need to consider the whole learning situation, for example, not only the tool, but the teachers who will be using the software, the ways in which it will be used, the curriculum objectives, the social context and way in which learning is organised. This means that consideration needs to be given not only to the software design but also to the definition of possible ways it might be used effectively. Software tools should include ideas about good pedagogical practices where the increasing scope for collaboration and communication needs are also to be considered both for subject based and cross-curricular based teaching. From one hand, the didactical functions supported by an educational tool influence the way in which the teaching and learning activity can be carried out, but, on the other hand, these functions cannot be fully exploited if the whole learning environment is not considered.

The design of new tools should include, where appropriate, the use of pictures, figures, drawings, films and sound, and should also offer the learners the opportunity to interact with a variety of screen based objects to enable them to access knowledge from a different and more constructive perspective. ICT based tools should support students problem solving processes and provide them with the opportunity to carry out open-ended problems, that is problems which do not have a closed defined answer.

The discussion performed in this paper is grounded on the assumption that learning processes cannot be fully understood if only the individual learner is considered without taking into account the relationships that are established between the actors
involved (the student, the teacher, the other students) and the role played by mediating tools.

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Short Biographical notes

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