Societal Challenges and New Technologies:
Education in a Changing World

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ABSTRACT

Education is facing challenges and issues that arise both on the changing needs of modern society and on difficulties to which it has always been difficult to offer effective solutions. This paper, considering this general context, briefly introduces the research field of Educational Technology and identifies and discusses two main lines of evolution that have characterized this sector from its beginning. Then, some perspectives that depict the current situation are proposed. The aim is to sketch a framework to support the understanding of the variety of approaches and research questions assumed by research studies in the field of educational technology.

KEYWORDS

Computational Thinking, Educational Technology, Learning Environment, Perspectives, Technology Enhanced Learning

INTRODUCTION

Today's society is crosscut by dynamics that determine the need for new models for development and that configure knowledge as an increasingly strategic resource for economic and social progress and the quality of life. It is therefore necessary to rethink the processes of learning and teaching at all levels and in all fields. Education systems, in particular, have to face challenges and problems that arise both from the changing needs of today's society and from the shortcomings and needs for which it has always been difficult to offer effective solutions.

The learning model on which they are based, linked to the accumulation of content and skills, has traditionally been pursued through methods and approaches that are now insufficient. Consequently, there is a growing need to give all students methods, tools and skills that will enable them to deal effectively with an increasingly complex and accelerated society where technology, globalisation of relations, scientific development, the growing flows of migration, changes in family structures and social behaviour, to mention only some of the main factors, pose new challenges and needs (Collins and Halverson, 2010).

Thus on the one hand, there is the need to meet the new educational needs by developing the capacities to tackle a profoundly changed situation, on the other, there is also the need to overcome difficulties which, although traditionally found in our educational systems, like, for example, science education (Rocard et al., 2007), need to be addressed with new tools and strategies (OECD, 2008). Consider, for example, the significant problems showed by students around 15 years of age in key areas such as mathematics, science and language literacy in many countries, as revealed by the results of international studies such as, for example, OCSE PISA - Programme for International Student Assessment.

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Placed in this structured and complex panorama is the research field of Educational Technology that aims to study and analyse the role that new technologies have in innovation of the processes of teaching and learning. The focus, however, is on education and not on technology. Indeed, pedagogical innovation and technological innovation must proceed in a non-separate way, or rather, they must co-evolve: on the one hand, indeed, there is little educational value in making new tools available if you do not transform educational strategies, activities and, in the final analysis, the overall environment in which learners and teachers move. On the other, pedagogical innovation should be based on an analysis of the potential offered by new technologies and how these change substantially, directly or indirectly, the very form and content of learning and teaching activities.

In the following, the research field of Educational Technology is briefly introduced making specific reference to the European context. Subsequently, two main trends that have characterized the sector from its beginning are identified and discussed according to their main lines of evolution in time. Then, some perspectives that can be useful to characterize the current situation are proposed. The aim is to sketch a framework to support the understanding of the variety of approaches and research questions assumed by research studies in the field of educational technology. Specific reference is made to school education and, in particular to compulsory school (age 6 - 16), while other application sectors of educational technology research studies, such as university education or vocational training are not addressed.

EDUCATIONAL TECHNOLOGY AS A RESEARCH SECTOR

Educational Technology, in the European arena often referred to as “Technology Enhanced Learning (TEL)”, is a non-traditional and relatively new research field that was born in the past century around the mid-sixties. Even if it was at times regarded as belonging either to pedagogy, information and communication technologies (ICT), cognitive science, or to the specific disciplinary fields where new technology is applied, it has progressively established itself at the international level as an autonomous interdisciplinary research sector with its own journals, conferences, proper funding programmes, university and research centres. For example, in Italy, the National Research Council (CNR) was a pioneer in this field with the establishment, in 1974, of the Institute for Educational Technology (ITD), the only public scientific institution devoted entirely to this sector.

An important role for the consolidation of the TEL research area in Europe has had the funding by the European Commission of networks of research organizations in this field. The first initiative, PROMETEUS “Promoting Multimedia access to Education and Training in European Society” dated back to 1999 and was then followed by the two Networks of Excellence: KALEIDOSCOPE “Shaping the scientific evolution of technology enhanced learning” (VI FP, 2003-2007) having a pedagogy and research oriented perspective and PROLEARN (Professional Learning) having a more computing technology perspective (VI FP 2003-2007). The Network of Excellence STELLAR “Sustaining Technology Enhanced Learning Large-scale multidisciplinary Research” (VI, 2009-2013) moved beyond the earlier networks by setting a new and more critical foresight agenda for technology enhanced learning. Other networks were dedicated to specific field of interest within the general TEL context. For example, GALA “Games and Learning Alliance” (VII FP 2010-2014) was dedicated to games based learning and serious games while ETNA “European Thematic Network on Assistive Information and Communication Technologies” (EC – CIP, 2011-2013) had a specific focus on e-inclusion. The Framework Programmes (FP) are the European Commission’s main way of funding collaborative research and development across different countries. CIP is European Commission Competitiveness and Innovation Framework Programme.

These initiatives encouraged cooperation and integration among the main players in the sector and helped make its importance grow by spreading awareness of the need for educational innovation. In a public consultation launched by the European Commission (2009), for example, technology enhanced learning was listed as one of the research priorities in the field of Information and Communication Technology (ICT).

The objective of research in educational technology is to study the role that ICT has in the processes of learning and teaching, considered not only at the institutional level (school and university) or vocational training but also in a broader perspective that includes everything throughout a person's life, as highlighted in the Digital Agenda for Europe, one of the seven "pillars" of the Europe 2020 strategy (European Commission, 2010).

Research in educational technology has an interdisciplinary nature as it autonomously develops and elaborates contributions and models drawn from different disciplines: information science, pedagogy, cognitive science and the teaching of the various curricular disciplines. The subject of investigation is aimed at educational sectors and domains of practical knowledge that contribute, on the one hand, to the design of a suitable approach to the practical problems that are to be dealt with and, on the other hand, to the definition of new research themes that, often, do not find adequate interpretation in the theoretical models used and, therefore, contribute to highlighting new needs even on the level of theoretical elaboration and basic research. Indeed, an understanding of learning processes is the basis of the design of valuable digital tools which, in turn, create new environments for learning and, therefore, allow one to investigate new basic issues. The aspects of conceptual elaboration, accordingly, are often intertwined with the development of prototypes (interactive environments, mobile or tangible devices, etc.) and with their trials in the field. These trials, having educational processes as subject, can have a prolonged extension over time, requiring models to process data and results and usually have a transfer component. The results are on different levels: theoretical analysis and definition of methods and models; development of innovative systems; experimental analysis and development of methodologies for the transfer of results.

Due to this diversified panorama, educational technology research studies are characterized by approaches, models and methodologies that derive from different research traditions, disciplines and perspectives. Thus, in the following some trends that can be useful to characterize the past are identified and some overarching perspectives are outlined to support orientation in the current situation.

MAIN LINES OF EVOLUTION IN EDUCATIONAL TECHNOLOGY RESEARCH

Although educational technology as a field of research has developed since the sixties of the last century, it was in the late '70s, with the advent of the first personal computers, that ICT entered schools.

Over time, even though with different approaches, methods and tools, the use of technology in school has had two main objectives:

I. The development of new skills and abilities to prepare students to face a society dramatically changed by technological evolution.
II. The use of computer-linked methods and tools to improve teaching and learning of curricular subjects.

The first objective brought to introduce new competencies and skills in secondary school curricula, while the second one is related more on analysing how the use of ICT can produce significant changes in the environment in which learning takes place.

The first objective has resulted in studies that have focused on the new technical and conceptual skills required by the knowledge society, the second to consider how the use of ICT could change the learning environment and the way in which curricular subjects are taught. In the following the evolution of research in educational technology is briefly outlined considering these two orientations.

Digital Competencies (I)

In the late 70's – beginning of 80's of the last century, when computers began to enter in schools, application programs for personal computers were almost non-existent but they had included a programming language (often Basic or Pascal). Initially, therefore, an important area of research in educational technology was linked to the teaching of elements of computing not only for professional courses but also for the basic compulsory school. The stated aim was to introduce topics such as basic elements of programming languages, modelling of situations, problem solving, algorithm development, the passage from natural to artificial language, etc. (Cornu and Ralston, 1992). These topics were considered important both as an introduction to computer science and for the correlations that could be made with the teaching of other disciplines, most notably mathematics. So much so that in some countries, like Italy, the introduction of basic elements of informatics at secondary school level was considered by focusing on the similarities (and differences) of these two disciplines (Italian National Plan for Informatics, launched in 1985). In general, numerous initiatives were developed in schools for introducing programming and information technology promoted by teachers, several national governments and also by international institutions (see, for example, "UNESCO/IFIP Curriculum – Information and Communication Technology in Secondary Education" delivered in 1994: http://wwwedu.ge.ch/cptic/prospective/projets/unesco/en/welcome.html). There was much debate on the educational value of computer science and on the choice of programming languages appropriate for schools (think, for example, of the discussion on declarative and procedural languages).

The evolution of hardware and software, which made interaction with the computer more and more direct, and the parallel evolution of pedagogical and cognitive frameworks of reference, led to a change in the way of conceiving and using digital technology for educational purposes in schools. Gradually one passed from interest centred on the integration of computing elements and methods to an approach aimed at the use of technology to improve and innovate the processes of teaching and learning in the various disciplines. Even in this changed context, however, interest in the introduction to computational thinking continued to play a significant role and research studies and in-field experiments, often with a constructivist orientation, were conducted at all school levels. Starting from the research of Papert (1980) the idea was established that programming could be a useful tool to learn how to think if it was taught to create situations in which to explore "powerful" ideas (such as, for example, differential geometry with the turtle microworld or feedback with Lego robots). Computational thinking provides an approach to reasoning about problems that draws on concepts fundamental to computing (Wing, 2006). Mainly, abstraction, algorithmic thinking, evaluation, decomposition, generalization (Curzon, Dorling, Ng, Selby and Woollard, 2014).

Currently, computational thinking and coding are again in the pipeline of school education in many countries. In Europe, for example, the UK Royal Society (2012) published the report "Shut down or restart? The way forward for computing in the UK". The French Académie des Sciences intervened on this subject with the report (2013) "L'enseignement de l'informatique en France. Il est urgent de ne plus attendre". Moreover, Informatics Europe and the ACM Europe Working Group on Informatics Education (2013) urged Europe "not to miss the boat" on this subject. All reports call for a change in the curriculum to make room for informatics. This process has already begun, as computational thinking and informatics concepts are beginning to appear in policy documents on school curricula: in the USA they are included the National Research Council (2012) framework for K-12 science education; in the UK national curriculum, informatics will replace digital competencies (UK Government, 2013) in the 2014-2015 school year, in Italy the National Plan for Digital Schools (Ministero dell'Istruzione, dell'Università e della Ricerca, 2015) includes the development of computational thinking competencies as one of the targets of compulsory school education.

Learning Environment Integrating Technology (II)

Technological progress and the evolution of pedagogical theories have progressively led to the evolution of the concept of a learning environment based on information and communication technologies (Bottino, Artigue and Noss, 2009). We have moved from substantial identification of a learning environment with the computational system itself, to a broader conception which not only considers the relationship of the student with the technological tool but also the overall characteristics of the learning activities that are realised by integrating the technology.

The first educational software substantially made reference (implicit or explicit) to a transmissive metaphor: material is taught systematically and additively and the user is trained to develop a specific skill or set of skills. The "drill and practice" programs and tutorial systems (Reigeluth, 1987), among the first to be implemented for educational purposes, are examples of these kind of systems. In the first case one is dealing with programs aimed mainly at exercising the student in the development of specific skills and abilities. They use some kind of interrogation strategy and often use some gaming techniques to encourage participation and motivation. Tutorial systems, unlike the "drill and practice" systems, involve the display of content on a given topic. In their design importance is ascribed to factors such as clarification of the objectives and prerequisites, the strengthening of memorisation and performance evaluation. The questions asked require the application of learned content, concepts or rules. Feedback is often diagnostic through the identification of errors and request for correction or reformulation of the response given.

The transmissive metaphor does not belong only to the early stages of research into educational technology but has influenced, albeit with different means and characteristics, the development of applications until the present day. Consider, for example, the so-called hypermedia systems, certain types of e-learning courses (up to MOOC) or some serious games. These programs have evolved in terms of functionalities and user interaction: the first systems with rigid interfaces have given way to more flexible systems where the use of different techniques and methods, even based on artificial intelligence techniques, have enabled, for instance, the customisation of the interface, the personalization of exercises proposed and the feedback received. The user has progressively taken a more active role in the interaction, having, for example, the possibility of exploring the contents exposed following her/his own needs or of configuring a system in a customised way, adapting it to her/his preferences and skills.

The growing interest raised by constructivist theories has progressively led to seeing learning as an active process based on exploration and personal construction, rather than on the transmission of knowledge, focusing attention on the student's cognitive processes and attitudes. Microworlds were a type of system designed referring to this set up. These computational environments exemplify an abstract environment described in a model, providing the user with a series of primitives (objects and functions) that can be combined in order to obtain a desired effect (computational, graphic, etc.). A microworld is built around a framework of knowledge that should be explored by the student interacting directly with the system. In the design of microworlds for educational purposes, an essential role is played by the objects that are available to the user through the interface of the microworld. Papert (1990) defined them as "transitional computational objects", that is, objects that are halfway between what is concrete and directly manipulable and the symbolic and abstract. The exploration of a microworld (Hoyles,1993), though necessarily restricted, must be such as to promote learning. So, increasing importance has been attributed to the epistemology behind a microworld as a key factor to distinguish potentially effective environments from environments less appropriate for exploration (Balacheff and Sutherland, 1994). In mathematics, a well-known example of this type of system, besides the aforementioned turtle microworld, is Cabri Géomètre (Laborde and Strasser, 1990), which was designed to develop skills in the formulation of conjectures and proof in Euclidean geometry and which now includes features for non-Euclidean geometry. In the area of arithmetic, the ARI-LAB (Bottino, Chiappini and Ferrari, 1994) system can be cited. It is based on the integration of different microworlds to solve additive and multiplicative problems. ARI-LAB microworlds have been designed to model common situations in everyday life such as "purchase and sales" or "time measure" problems. For 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, and so on.

These systems influenced the subsequent development of dynamic and interactive educational software for mathematics learning (like, Geogebra (http://geogebra.en.softonic.com), Cindarella (http://www.cinderella.de/tiki-index.php), Alnuset http://www.alnuset.com/en). In some cases, these systems have been used widely in secondary school classrooms to develop learning activities in geometry, algebra and calculus, even if they do not change substantially the way in which mathematics is thought and learned.

As the matter of fact, although the orientations described above have led to the development of a variety of projects that have achieved significant results in terms of research, it is still true that the great hopes pinned on the potential of ICT tools to kick-start change and innovation in schools have been substantially disapponting (see, for example, Luckin, 2012). One of the main reasons (apart from factors associated with the management and the availability of the hardware and the traditional resistance to change in schools) is that technology has often been introduced as an addition to the existing school context, which remained unchanged. Indeed, numerous studies have shown that from a pedagogical point of view there is no advantage in introducing computers in schools if the instructional strategies, activities and, overall, the school system does not evolve at the same time.

Over time then, a growing interest has been shown in approaches that consider the environment of teaching and learning as a whole. This means that gradually an increasing emphasis has been attributed to the needs of the teachers and students using the technology, the ways in which these are used, the curricular objectives, the social context, the roles played by the different actors involved and their needs, as well as to the definition of practices through which the technology can be used effectively.

At the theoretical level, there has been a shift from cognitive theories that put the individual in the foreground to theories that focus on the social nature of cognition and meaning highlighting the need to study the relationships between individuals, social groups and mediation tools (as, for example, Activity Theory). This paradigm shift has led to the development of environments characterised by close integration of tools to support visualisation, re-elaboration of knowledge and communication that can support not only the relationship of the student with the knowledge to be learned but also the relationships that are established between all the participants in the teaching activity (Bottino and Chiappini, 2008).

The concept of learning environment evolves in a broader sense (Johnson et al., 2014): it encompasses not only the tools used but also the organization of teaching and learning activities, their goals and content, the physical setting, the different roles, and so on. The network, also understood as the Internet, takes on a primary importance.

If you think about it, even the evolution of the web can be read in a way similar to that used to outline the evolution of research in learning environments integrating technology: from the web as a large container of information (web 1.0), to the web as a bidirectional and interactive place (web 2.0), up to the web 3.0 whose contours are not yet precisely defined because you can read it as many things in one: an aggregator of data, semantic or geospatial web, a web integrated with the potential of artificial intelligence, until the interpretation, of crucial importance for education, which sees the web as an environment of collective co-creation.

The two main orientations delineated above have allowed to draft the articulated and complex background in which research in educational technology has evolved. In order to outline a summary of the current situation, some perspectives will be considered in the following through which the various studies that characterise the sector can be framed. In fact, an analysis of the evolution of educational technology research shows that, although it is possible to highlight some general orientations (for example, the transition from a substantially transmissive paradigm to one more oriented to participation), the difference of viewpoints, encouraged by the inherently interdisciplinary nature of the sector, has led to a number of studies that have developed in a more or less independent way among various scientific communities and who have taken as reference a variety of theoretical constructs. For this it might be useful to consider some different perspectives through which one can read the research in educational technology since it is in the tension between different perspectives that innovative solutions to problems can be found.

PERSPECTIVES FRAMING CURRENT RESEARCH IN EDUCATIONAL TECHNOLOGY

As previously observed, when studies and projects in the field of educational technologies are designed different approaches can be followed (Balacheff, Ludvingsten, de Jong, Lazonder and Barnes 2009). It is therefore convenient to refer to some concepts, such as that of perspective (Bottino, 2012), to support orientation. The idea is not to provide an overall categorization of developments in educational technology, since this is a goal too broad and ambitious for the scope of this paper, but rather to propose some viewpoints that could be useful for the understanding the results obtained and to support their proper framing. The notion of perspective can be useful also to better connect the educational technology field with related areas and concepts.

In the following five different perspectives are outlined: pedagogical, computational, cognitive, social-cultural and epistemological.

When a pedagogical perspective is taken, the goal is often to start from the educational problems posed by concrete situations and contexts (for example, the difficulties that students have in solving arithmetic problems in primary school) to design situations mediated by technology that can respond to these problems, even following field-testing.

The computational perspective emphasizes the link between educational technology and computer science. The analysis focuses on what technology makes possible (platforms, simulations, microworlds, networks, mobile devices, tangibles, etc.) and considers how the features and characteristics of the various tools may change the way in which knowledge is accessed and even the very content of what is learned. In other words, we analyse how the relationship with knowledge changes, both from the point of view of the “what” (new topics that can be treated) and the “how” (for example, new ways of representing scientific concepts exploiting the possibilities of visualization and interaction offered by technology).

The cognitive perspective studies the relationship between cognitive processes and artefacts, not in themselves, but in relation to learning activities in various fields. According to this perspective, the analysis of learning environments that integrate technology looks firstly at what an individual can learn under certain conditions and the cognitive skills that the technologies require, promote or inhibit. For example, one analyses how the web changes the search for information and the evaluation of their reliability, or, one examines how digital games can be used to develop reasoning skills and strategic thinking.

The social-cultural perspective focuses on the social and cultural factors that influence learning. According to this perspective, technologies are analyzed from the point of view of the changes that they lead to the organization of educational contexts (the class, the school, the communities of practice, etc.). In this context, of specific interest are aspects such as accessibility, educational inclusion, issues related to the digital divide, etc.

Taking an epistemological perspective involves an analysis of how the characteristics of a particular domain of knowledge may influence the design and use of educational technologies. A significant example in this regard is that concerning the learning of mathematics. The main idea which characterized much research in this field was to design and use technology to facilitate access to mathematical concepts, traditionally perceived as abstract and formal, through the exploration and manipulation of concrete representations.

Obviously the distinction between the different perspectives is not rigid, and often there is a close correlation between them even in the same research project. Indeed, the development of new educational practices is frequently linked to the design of computational systems and their evaluation. This assessment requires the analysis of the cognitive aspects that emerged in the interactions that are established between the different actors of the learning situation and, often, specific social needs should be taken into account when the technology is integrated into real learning contexts. In addition, assumptions of epistemological, pedagogical and cognitive type underlie the design of educational software systems and this affects how these systems are perceived and used.

However, the perspectives described may be useful to clarify the different interpretations used in research in educational technology and allow a clearer definition of objectives and research questions and, therefore, to analyse the results obtained.

In Table 1, by way of example, the different perspectives are put into relation with some research questions that can be formulated following the briefly explained orientations.

CONCLUSION

Information and communication technologies are certainly important resources for education both in terms of improving processes of learning and teaching, and from the innovation of content, methodology and school organization. The integration of ICT in education, however, must be made in a critical way and bearing in mind the complexity of the underlying processes.

Being very extreme, one can identify opposing attitudes in the introduction of ICT in school education: on the one hand technology can become an end in itself, the very purpose of the teaching activity. Shaping the educational action based on what technology allows is likely to create unrealistic expectations, generating enthusiasm initially but then disaffection when the results are not up to such expectations. On the other hand, if technology is seen as a means to achieve specific educational objectives, one can remain tied to the situation and not consider all the variables that necessarily come into play if a real educational innovation is to be reached. There is, therefore, the need for a balanced and conscious approach. Without a perspective of innovation technology is not integrated into the education system but, without a prospect of actual improvement of the processes of learning and teaching, the use of technology does not last over time. Both careful analysis of the opportunities offered by technology and that of the educational needs that emerge from the context are therefore prerequisite to the integration of new technologies in schools and form the basis of the research activity in this area.

Table 1. Perspectives in educational technology and examples of possible research questions

	PERSPECTIVES				
	Computational	**Cognitive**	**Pedagogical**	**Socio-Cultural**	**Epistemological**
RESEARCH QUESTIONS questions	- What does technology make possible? - In which way can technology change the way we look at knowledge (“what” and “how”)? - How does technology change students’ relationship with knowledge and learning?	- Which competencies are necessary? - Which new skills does technology require, foster or hinder? - What can a student learn under specific conditions?	- How can ICT-based environments answer concrete educational problems? - How can ICT-based environments be organised to enhance learning? - How can technology change learning activities and interaction modalities?	- In which way can technology change information access and interaction at schools, in daily life, in informal learning settings? - How can different contexts change learning processes? - How do learning curricula, methods and organization change?	- How can a knowledge domain impact on the design and use of learning technologies? - How can the epistemological analysis of the difficulties encountered in a given domain be taken into account in the design of a learning environment able to support their overcoming?

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