The Limits and Possibilities of ICT in Education

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ABSTRACT:
I will begin this article by clarifying the concept of Educational Technology and its related terms. I will then go on to analyse the more conclusive results of research in this field in order to describe the projects in which I have been involved, where technology was used to produce innovation. This article does not mention any cognitive or educational "revolutionary experience", since this would surpass the limits of what technology is capable of accomplishing.

Part of the education of the new generations has to be conservative, i.e., the experience and knowledge constructed by earlier generations has to be passed down. Disciplinary knowledge is an exemplary condensation of human effort and talent. How can technology support the transmission and acquisition of such knowledge? Besides being capable of using technology, should the new generations not also have a rational and educated discourse on the subject? Is this not the role of the school also? These are some of the main issues I wish to address.

KEYWORDS:
Educational Technology, Information and Communication Technology, Teaching and Learning, Virtual Learning Environments

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INTRODUCTION

Human beings have a natural tendency to simplify the information they receive from the environment. They create categories and associations so as to memorise and understand what is going on around them. One of the most recurring associations in education is bringing teaching and learning together. This is only natural. Indeed, it is hoped by the teacher that what is taught is learned and in turn, the aim of the learner is to memorise and understand what is taught. Teaching and learning are two sides of the same coin, though they are not always in tune. There should be a relationship of sorts between what is taught and what is learned, however, as research has shown, it is not a simple one.

By the same token, the concept of technology has been associated with that of innovation and both with advances in the teaching and learning processes. It is thought that the introduction of new technological resources in the teaching process will produce positive results in learning. This stems from the belief that these new resources will change the way teachers have taught up to now and the way pupils have been learning. Furthermore, it is believed that new programmes, methods and curricula will guarantee better learning. Throughout the article we will see that such simple assertions are not always true.

DEFINITIONS

Let us begin with a conceptual clarification. What exactly are we talking about when we refer to Educational Technology (ET), Educational Technologies, Applied Educational Technologies, Information and Communication Technologies (ICT), New Information Technologies (NIT) or New Information and Communication Technologies (NICT), Computer Literacy and Technological Education?

The term *Educational Technology* already has a tradition in the Anglo-Saxon world. This field of education goes back to the 1940s and was developed by Skinner a decade later with programmed education (See Skinner, 1953, 1968). The term is not restricted to the technical resources used but covers all processes to do with the conception, development and evaluation of learning. Hence, the terms *Educational Technology* and *Instructional Technology* are used as synonyms for the "theory and practice of the planning, development, use, management and evaluation of learning processes and resources" (cit. Thompson; Simonson & Hargrave, 1996, p. 2), with a view to stabilising the terminology used in this field. This definition covers what is considered to be the field of Educational Technology, which includes three subfields, each of which has an impact on the student and his/her learning: 1) the functions of educational management, 2) the functions of educational development, and 3) learning resources. As we may see, the term Educational Technology is rooted in an Anglo-Saxon tradition which gives value to educa-

tion and is influenced by theory produced within the framework of learning psychology, namely by behavioural and cognitive theories as well as the more recent constructivist theories. The Theory of Systems and the Theory of Communication (see Thompson, Simonson & Hargrave, 1996) are also theoretical inspirations in the field of Educational Technology.

The term *Applied Educational Technologies* may be considered a synonym for *Educational Technologies* since it refers to all forms of technological applications to the processes involved in educational functioning, including the application of technology to financial and administrative management or to any other process including, of course, the educational process, itself.

For those who work in the field of Educational Technology not only the resources and technical progress are of interest, but also, and particularly, the processes which determine and improve learning. These may include specific types of technical resources such as, for example, the computer and the Internet. The use of the computer and the Internet for educational purposes may be considered a sub-field of Educational Technology.

The term *Information and Communication Technologies* (ICT) refers to the combination of computer technology and telecommunication technology, which is particularly strongly in the *World Wide Web* (WWW). When such technologies are used for educational purposes, namely to support and improve the learning of students and to develop learning environments, we may consider ICT a subfield of Educational Technology.

The terms *New Educational Technologies* (NTI) and *New Information and Communication Technologies* (NICT) seem, therefore, redundant as the reference to "New" brings nothing to the boundary and clarification of the field. Furthermore, what may be new today is no longer so tomorrow.

As the reader may have already noticed, I prefer to use the term "Educational Technology" to define a theoretical research field with which I am familiar. However, I do not consider the terms "Educational Technologies" or "Information and Communication Technologies" to be unsuitable, as long as they are used in the above-mentioned sense.

The term *Computer Literacy* may be defined as "a set of competences, knowledge and attitudes in relation to computers which enable one to use computer technology confidently in daily life" (McInnerney, McInnerney & Marsh; Soloway, Turk & Wilay, cited by Tsai & Tsai, 2003, p. 48). This definition covers three areas which require clarification: the first, knowledge and competences with regard to computer technology; secondly, positive attitudes towards technology and finally, having the confidence to use computers comfortably, without anxiety. Therefore, the aim of computer literacy should be to support teachers and students in their initial acquisition or to improve their competences and knowledge in this area, to develop positive attitudes towards the computer and the Internet and to reduce anxiety towards its use and understanding. It should also support students, particularly those in secondary education, to critically analyse the evolution of technology and its fields of application.

Here, however, we are already entering *Technological Education,* another area. This is a far broader concept than the previous one, since it implies "knowing how to use" technology as well as analysing its evolution and impact on society. It also assumes the development of a rational discourse on technology. As Postman says (2002), "Technological education is not a technical subject, it is a branch of humanities" (p. 218). Education is only truly technological when students are taught the historical background of the different technologies (illuminated manuscripts, alphabet, typography… computers and the Internet) and their creators, their economic, social and psychological effects and even how they have reconstructed the world and continue to do so. It is also necessary to show how technology "creates new worlds, both good and bad" (Postman, 2002, p. 219). Furthermore, students should be taught to read and interpret and know how to differentiate the information that is transmitted to us by various symbols. For example, how do images differ from words, a painting from a photograph, spoken from written discourse?

Going back to the concept of technological literacy, first of all, some issues need to be addressed: a) What knowledge and competences should the students acquire in school, from pre-school up to the end of secondary education? b) How should the learning of this knowledge be organised and sequenced by developing a spiral curriculum? c)

Should such knowledge and competences be integrated in the curricula of the already existing subjects, should autonomous subjects be created (especially from the 2nd cycle of basic education onwards) or should both these strategies be used simultaneously?

There are no hard and fast answers to these questions. I believe that the best strategy is to supply the schools with some level of technology (namely computers with access to the Internet) and to use it in other subjects as well as the specific ones, such as ICT in Levels 9 and 10, an option brought in by the Ministry of Education.

TECHNOLOGY AND THE TEACHING AND LEARNING PROCESSES

In this part of the article, I would like to briefly describe some of the more innovative experiences with computer technology for developing learning environments. However, first of all, I would like to mention the more conclusive research results and characteristics in the field of educational technology and discuss what characteristics are considered to be representative of effective learning nowadays.

Research Results

Research has shown that the strategy of adding technology to the already existing activities in school and in the classroom, without changing habitual teaching practices, does not produce good results in student learning (See De Corte, 1993; Jonassen, 1996; Thompson, Simonson & Hargrave, 1996, among others). Nevertheless, this has been one of the most widely used strategies. There are a number of understandable reasons for this, but two of them are particularly important.

The first is due to the fact that the vast majority of teachers are not proficient users of technology, especially computer technology. A number of studies have shown that most teachers consider the two main obstacles to using technology in pedagogical practices to be a lack of resources and training (See. Paiva, 2002; Pelgrum, 2001; Silva, 2003; among others).

The second reason is based on how the innovative integration of technologies demands great reflection and the alteration of teaching conceptions and practices, something most teachers are reluctant to take onboard. Changing these aspects is not easy at all since it depends largely on effort, persistence and dedication.

The problem is that some teachers have a romantic conception of the processes that determine learning and knowledge construction and, concomitantly, the use of technology in teaching and learning. They think that equipping classrooms with computers and the Internet is sufficient for students to learn and for practices to change. We know very well that this is not the case.

As I have already mentioned, the most conclusive research results based on the monitoring of the large scale introduction of computer technology in education (especially since the 80s) show that simply adding these resources to the activities that already exist in schools does not produce visible positive results in student learning, in classroom dynamics or in teacher dedication (De Corte, 1993; Jonassen, 1996; among others). Some authors, such as Clark (1994), believe that Educational Media alone will never influence student performance. Positive effects only emerge when the teachers believe and adopt a "wholehearted" approach to the learning and mastering of this area and when they draw up challenging and creative activities which make the fullest use of the possibilities provided by technology. For this to be accomplished, teachers need to present technology to students a) as a new formalism for processing and representing information; b) as a means to support students in their construction of significant knowledge; c) in order to develop projects, by creatively integrating (and not adding) new technologies in the curriculum.

Let us briefly analyse each one of these aspects.

Considering that teachers should use *computer tools as new formalisms* in order to process and represent information first implies understanding that written language, the decimal system and basic arithmetic operations, the logic of classes and relations (classification systems), graphs… are Conventional Information Representation and Processing Systems, in which all communication power and knowledge processing is contained (Mendelsohn, 1999). In this literate and post industrialised world of ours, they should be learned and dominated with

a certain amount of skill by the end of the 1st Cycle, when the children are aged between 9 and 10 years, and this learning process should continue until they are fully mastered by them. What is interesting is that the learning of these systems radically changes the way children perceive the world and themselves (mainly in terms of self-awareness), in other words, they interfere with the natural course of development (Luria, 1990; Vygotsky, 1991, 1994) by broadening it (Bruner, 1998, 1999). Cognitive development follows a pattern that is characterised precisely by the progressive mastery of spatial representations (forms and transformations), symbolic representations (where language and the written word are influential) the processing of relations (creating category systems, classes and their relations) and the processing of dimensions (number, arithmetic and later algebra). There seems to be harmony between the development of superior psychological functions (Vygotsky, 1994) and conventional information processing and representation systems.

What happens is that these computer systems, seen as new formalisms for processing and representing information, which are strongly anchored to conventional systems, will change how children are accustomed to learning and also broaden their cognitive development. The following are examples: text processors have changed the way children write; not only do they need to learn the conventions and procedures of writing on paper, but also the procedures and functions of a text editor. The same may be said of the design programmes, graphs and data bases. They alter the way of creating design, graphs and classifying things since they are based on formalisms which are not the same as traditional ones. They demand new ways of learning and increase the former ones. In most schools teachers believe this type of learning may be acquired through analogical transference, without the need for a more structured and formal type of learning, which has led to some disappointment.

However, if the teacher masters these new tools, he/she will be in a position to offer support to students to explore the potentiality of these new information processing and representation systems. Writing may be expressed in a far more flexible way when a text processor is used. Constructing and transforming graphs can be a very rewarding activity, not to mention the construction of data bases on every subject imaginable.

Changes in ways of learning and cognitively organising information will not be visible immediately, since all mental change processes are slow and can last generations. However, the learning of certain symbolic systems and their formalisms interferes with, or rather, leaves its "marks" on mental and even brain organisation according to Vygotsky (1991, 1994) and Luria (1990) and has an impact on what is being brought to light by research in the field of neurosciences (See Squire & Kandel, 1999).

With these new information and communication processing and representation systems, teachers may develop *activities to encourage the acquisition of significant disciplinary knowledge.* This can only occur if learning is viewed as a (re)constructive, cumulative, self-regulated, intentional, contextualised and collaborative process.

Learning is a re(constructive) process, which means that students construct new knowledge on the basis of already acquired structures and representations on the phenomena being studied and may be cognitively and emotionally involved in the processing of new information. Effective learning should demand effort and keep the pupils motivated to accomplish tasks. This must be achieved with an optimum level of uncertainty (Bruner, 1999) and within the zone of proximal development (Vygotsky, 1991), in other words, it should not prevent the crisis of thinking (Van Hiele, 1986). Teachers should take care not to impose their structure and thinking style on the students but instead, create situations, problems, exercises and projects that will lead the pupils to higher levels of knowledge.

Cumulative learning implies that new knowledge is acquired on the basis of previously accomplished learning (Gagné, 1975). All subjects demand this previous knowledge. However, there are some which are more cumulative than others, such as mathematics and also physics, to a certain extent. Here, the main problem seems to stem from the difficulty in altering conceptions already developed by the pupils to explain different phenomena, before initiating their scientific study. These spontaneous concepts often contradict those accepted by the scientific community and, more often than not, hinder rather than facilitate further learning (See Gardner, 1993; Pina, 2005).

Self-regulated learning means that the teachers should support students in their development of learning strategies, so as to acquire study and intellectual work habits as well as patterns for correcting their own work, with a view to acquiring progressive independence from the teacher (See Brown, 1987; Collins & Brown, 1988).

Learning for specific purposes implies that knowledge, on the part of students, of the purposes or requirements to be met in each learning situation, facilitates the process of knowledge construction since it guides him/her towards an intention or objective (See Bruner, 1999). Furthermore, it has the advantage of motivating students to achieve the established aims, thus, guaranteeing greater ability to overcome the obstacles found in any learning process (See Gagné, 1984; Lemos, 2005).

Nowadays, it is generally thought that effective learning should also be contextualised and collaborative. While the afore-mentioned characteristics leave me with no doubts, these two have not yet been proven by the research results. Nevertheless, they are important learning characteristics, especially in terms of environments that can be modelled with recourse to computers and the Internet.

Contextualised learning means that its meaning comes from the context in which it took place. The contexts themselves facilitate or hinder the application of knowledge. People learn not only that which is directly taught to them, but they also develop participation patterns in practising communities by progressively adapting to the discourse, knowledge and know-how of each community, its resources and even identities (See Greeno, 1998; Lave, 1997; Lave & Wenger, 1995; among others). So, the creation of practising and learning communities is facilitated today by the Internet.

To say that *learning is collaborative* means that it occurs in contexts in which social practices imply collaboration among students and, likewise, between students and adults. In principle, the latter become tutors who progressively mould specific knowledge and attitudes. In these situations, learning is viewed primarily as a social interaction process which should be encouraged by teachers. For example, the development of cognitive structures, especially formal thinking, depends largely on cognitive decentration, i.e., being able to cooperate with others, in other words, accomplish tasks together by listening to arguments and counter arguing (Perret-Clermont & Schubauer-Leoni, 1989; Piaget, 1971). The Internet can facilitate such collaborative learning if the teacher creates projects where students (and other adults) may carry out activities, resolve problems in cooperation and participate in common tasks. However, not all learning is achieved collaboratively and not all students are comfortable or learn in this kind of environment (See Hopper, 2003). Around 20% of university students prefer to work and learn alone (McClanaghan, 2000, cited by Hopper, 2003).

As we may see, it is not enough to introduce computers and the Internet in schools to obtain positive results in student learning. It is also necessary to reflect on what makes it effective and to change the organisation of the spaces and curricula activities so that these new tools may support the acquisition of significant disciplinary knowledge. For instance, the use of technology in the educational practices of teachers may contribute towards greater technological literacy for students and teachers, generate motivation, create relationship networks, etc. These are all extremely important aspects for the integration, and not the addition, of technology to curricular activities.

Experiments

The following four experiments highlight what I have just mentioned. Due to the word limit imposed upon this article, I will briefly describe only one of them. Further information may be found in the works listed in the bibliography.

One of these experiments was developed within the context of research leading to a PhD and is called *Concepção de um ambiente de aprendizagem Logo em meio escolar: efeitos na cognição e nos conhecimentos geométricos de crianças de 9-10 anos* [Conception of a learning environment within a school framework: effects on the cognition and geometric knowledge of 9 to 10 year old children] (Miranda, 1998).

Two were carried out by students taking a Master's degree in Education Sciences, the specialisation area in Educational Technology. One is entitled *Comunidade Virtual de Aprendizagem de Matemática: uma experiência com alunos do 10º ano de escolaridade* [Virtual Maths Community: experiment with Level 10 pupils (Inácio, 2006*)* and the other is called

Integrar a teoria e a prática através de um fórum de discussão: um estudo de investigação-acção aplicado à enfermagem da criança e do adolescente [Integrating theory and practice through a discussion forum: a research-action study applied to the nursing of the child and adolescent] (Paixão, 2006).

The last experiment was developed in the context of preparing a degree monograph and is called *Projecto Prom@tic* (Rolo, 2001). An article was published describing this experiment (Miranda & Rolo, 2002) and is available online at: http://www.leeds.ac.uk/educol/documents/00002194.htm.

Virtual Maths Community

This experiment was developed in the academic year 2004/2005, with a Level 10 class by Ricardo Inácio, a student of the Master's degree in Educational Technology at the time. This experiment has since been continued.

The main aim was to create, develop and evaluate a virtual maths environment (VLE). It also set out to study the factors that have positive and negative impacts on the development of a virtual learning community (VLC) in a school environment, functioning as a compliment and not a substitution for contact hours in the classroom. It was also the aim to analyse the effects of this environment on school results and student approaches to learning.

The Virtual Learning Environment (VLE) was based on the WWW and acted as a support resource to student learning for the three areas that integrate the Maths program: Plane and Spatial Geometry I, Functions I and Statistics. The construction of this virtual environment, as the author states, "has been characterised as a slow, evolutionary phased process" (Inácio, 2006, p. 99). The creation and construction of the page took nine months and underwent a number of stages. I will only refer to the most important ones: (a) creation of storyboards, which consisted of drawings and tables with reference to colours, sources, texts, navigation bars, content layout and communication tools; (b) development of the page, conciliating a variety of programming languages; (c) validation of the VLE, by specialists, both from a technical perspective and in terms of maths content; (d) presentation of the VLE to the students, explaining how it functioned and what the aims were.

There is a great variety of content in this VLE but, as far as I am concerned, the most interesting is the combination of the different types of content with the maths activities, the synchronic and asynchronous communication activities and also the social activities. The tools that were available were used by the students, some more than others, as is common in all environments, be they presential or virtual. The teacher had an important role in stimulating this environment, not only in terms of the teaching and learning process, but even in the construction of a real virtual Maths community. Transforming an environment into a virtual community is not an easy task since there has to be a group of people who share knowledge, interests, and aims in a specific field and where friendships may be made through cyberspace (See Inácio, 2006). The varying durability of Virtual Learning Communities also depends on a number of factors. However, the role of the motivator is crucial so that the "life span" of a VLC may be longer. The one we are describing lasted an academic year even though the teacher is extending the experiment to another Level 10 class.

The most remarkable results of this study are: (1) understanding that it is possible to create, develop and use virtual learning communities in secondary education to the service of the pupils and the innovation of teaching methods, especially in a subject that is generally considered to be difficult and in which there is a high failure rate; (2) analysis of the factors that facilitate and hinder the construction of a VLC, thus, contributing to the understanding of these communities; (3) greater interest in this subject on the part of most pupils, despite the fact that those who used and benefited most from this environment were the pupils who were initially prepared to study and give more importance to academic commitment; (4) the existence of a positive and significant correlation between VLC Frequency and Pupil Classifications (r=0,715; p<.05); (5) pupils with a profound approach to learning before the experiment (pre-test) went on to use typical strategies of this approach with more frequency. The difference between the pre and post-test was significant (p<.5); however, those pupils with a superficial approach did not significantly alter their learning strategies from the pre to the post-test (p>.05).

Although the VLE has contributed to getting most students interested in mathematics, these briefly described results seem to indicate that as is the case in other fields, in this field those who benefit most of all from the resources made available to them are the more motivated and committed students who give greater value to learning and academic success. Those who have more difficulties are the less motivated students who give little value to academic performance and hardly use the resources made available to them. This tendency was referred to by Resnick and Collins (1996) as the *"rich get richer" problem*. More structured environments aimed at helping these students overcome their difficulties need to be created for them. This, however, was not the aim of the described experiment. As I have already mentioned, I do not believe that the introduction and use of information and communication technology in education should only be evaluated in terms of its effects on learning and pupils' academic results. This is merely one of many variables which need to be considered, although I personally view it as the most important one. Other relevant variables are: the contribution to greater technological literacy on the part of teachers and students; greater interest on the part of students in subjects that rely on technological resources in an innovative and creative way; a change of teaching methods and strategies on the part of teachers to acquire confidence for having mastered the technologies that are considered important in a particular society, subsequently leading to a greater sense of belonging to that same society.

CONCLUSION

The effective use of technology in schools, namely in the classroom and in the development of virtual learning environments, is still a privilege for some teachers and pupils. The variables which seem to have greater influence on this process are multiple, even though the strong technical and pedagogical training of teachers, coupled with commitment on their part, seems to be a decisive factor. Technologies still need to be viewed not as "appendices" to the other curricular activities or as a prize to be won by well-behaved pupils or even as an unusual "tic" that some teachers may have acquired, but rather as a field which is as important as (or even more important than) others to be found in the school curriculum. Only then will it be possible to generalise the use of technology in education. From a pessimistic or somewhat realistic perspective, perhaps we will have to wait for this driving force to come from the generations born into the "information society". Indeed, according to Arendt (2005) novelty is and should be introduced by the new generations. Such is the natural and cultural trajectory of humankind.

Bibliographical references

Arendt, A. (2005 [1961]). *Entre o passado e o futuro*. Traduzido por J. M. Silva. Lisboa: Relógio d'Água Editores.

Brown, A. (1987). Metacognition, executive control, self-regulation and other more mysterious mechanisms. *In* F. E. Weinert & R. H. Kluwe (eds.), *Metacognition, motivation and understanding*. New Jersey: Erlbaum, pp. 65-116.

Bruner, J. (1998 [1960]). *O processo da educação*. Tradução de M. C. Romão. Lisboa: Edições 70.

Bruner, J. (1999 [1966]). *Para uma teoria da educação*. Tradução M. Vaz. Lisboa: Relógio d'Água Editores.

Clark, R. (1994). Media will never influence learning. *Educational Technology Research and Development*, 42, 2, pp. 21-29.

Collins, A. & Brown, J. (1988). The computer as a tool for learning through reflection. *In* H. Mandl & A. Lesgold (eds.), *Learning issues for intelligent tutoring systems*. New York: Springer-Verlag, pp. 1-18.

De Corte, E. (1993). Psychological Aspects of Changes in Learning Supported by Informatics. *In* D. C. Johnson & B. Samways (eds.), *Informatics and Changes in Learning* (IFIP - A34). North Holland: Elsevier Science Publishers B. V., pp. 37-47.

Gagné, R. M. (1975). *Essentials of learning for instruction*. New York: Holt, Rinehart & Winstons.

Gagné, R. M. (1984). Learning outcomes and their effects. Useful categories of human performance. *American Psychologist*, 39, 4, pp. 377-385.

Gardner, H. (1993). *La mente no escolarizada. Cómo piensan los niños y cómo deberían enseñar las escuelas*. Tradução de F. Meler-Ortí. Barcelona: Paidós.

Greeno, J. & MMAP Project Group (1998). The situativity of knowing, learning, and research. *American Psychologist*, 53, 1, pp. 5-26.

Hopper, K. B. (2003). In defense of the solitary learner: a response to collaborative, constructivist education. *Educational Technology*, March-April, pp. 24-29.

Inácio, R. J. P. (2006). *Comunidade virtual de aprendizagem de matemática: Uma experiência com alunos do 10º ano de escolaridade*. Dissertação de mestrado. Lisboa: Faculdade de Psicologia e de Ciências da Educação da Universidade de Lisboa.

Jonassen, D. (1996). *Computers in the classroom. Mindtools for critical thinking*. N. J.: Prentice Hall.

Lave, J. (1997). *Cognition in practice. Mind, mathematics, and culture in everyday life* (6th Ed.). Cambridge: Cambridge University Press.

Lave, J. & Wenger, E. (1995). *Situated learning. Legitimate peripheral participation* (4th Ed.). Cambridge: Cambridge University Press.

Lemos, M. S. (2005). Motivação e aprendizagem. *In* G. L. Miranda & S. Bahia (orgs.), *Psicologia da educação: Temas de desenvolvimento, aprendizagem e ensino*. Lisboa: Relógio d'Água Editores, pp. 193-231.

Luria, A. R. (1990). *Desenvolvimento cognitivo: Seus fundamentos culturais e sociais*. Tradução de L. M. Barreto, M. K. Oliveira, M. M. Andrade & R. H. Maciel. São Paulo: Ícone Editora Ltda.

Mendelsohn, P. (1999). *Technologies del'Information et de la Communication et construction du Savoir*. Retrieved May 2007 from http://tecfa.unige.ch/tecfa-people/mendelsohn.html

Miranda, G. (1998). *Concepção de um ambiente de aprendizagem Logo em meio escolar. Efeitos sobre a cognição e os conhecimentos geométricos de crianças de 9-10 anos* (Manuscrito não publicado). Lisboa: Faculdade de Psicologia e de Ciências da Educação da Universidade de Lisboa.

Miranda, G. & Rolo, A. (2002). The role of ICT in teacher education: The development of web pages by project method. *Education-line*. Retrieved May 2007 from http://www.leeds.ac.uk/educol/documents/00002194.htm

Paiva, J. (2002). *As tecnologias de informação e comunicação: utilização pelos professores*. Lisboa: ME/DAP.

Paixão, M. J. G. (2006). *Integrar a teoria e a prática através de um fórum de discussão: Um estudo de investigação-acção aplicado à enfermagem da criança e do adolescente* (Manuscrito não publicado) Lisboa: Faculdade de Psicologia e de Ciências da Educação da Universidade de Lisboa.

Pelgrum, W. (2001). Obstacles to the integration of ICT in education: results from a worldwide edu-

cational assessment. *Computers & Education*, 37, 2, pp. 163-178.

Perret-Clermont, A. N. & Schubauer-Leoni, M-L. (1989). Social factors in learning and teaching. *International Journal of Educational Research*, 13, pp. 573-684.

Piaget, J. (1971). A evolução intelectual entre a adolescência e a maturidade. Tradução de J. P. Ferreira da Silva. *Revista Portuguesa de Pedagogia*, V, 1, pp. 83-95.

Piaget, J. (1975*). L'équilibration des structures cognitives*. Paris: Puf.

Pina, J. A. M. (2005). *Um estudo exploratório sobre o papel das imagens nos manuais de ciências físico-químicas e na construção pelo alunos de modelos que explicam os fenómenos que representam* (Manuscrito não publicado). Lisboa: Faculdade de Psicologia e de Ciências da Educação da Universidade de Lisboa.

Postman, N. (2002). *O fim da educação. Redefinindo o valor da escola*. Tradução de C. Alcobia. Lisboa: Relógio d'Água Editores.

Resnick, L. B. & Collins, A. (1996). Cognition and learning. *In* E. De Corte & F. E. Weinert (eds.), *International encyclopedia of developmental and instructinal psychology*. U.K.: Pergamon Press, pp. 377-381.

Rolo, A. (2001). *Promatic* (Manuscrito não publicado). Lisboa: Instituto de Educação da Universidade Católica Portuguesa.

Silva, F. (2003). *Tecnologias e formação inicial de professores: um estudo de opiniões e práticas* (Manuscrito não publicado). Lisboa: Faculdade de Psicologia e de Ciências da Educação da Universidade de Lisboa.

Skinner, B. F. (1953). *Science and human behavior*. New York: Macmillan.

Skinner, B. F. (1968). *The technology of teaching*. New York: Appleton Century Crofts.

Squire, L. R. & Kandel, E. R. (1999). *Memory. From mind to molecules*. New York: Scientific American Library.

Thompson, A. D.; Simonson M. R. & Hargrave, C. P. (1996). *Educational Technology: A review of the research* (2nd ed.). Washington, D. C.: Association for Educational Communications and Technology (AECT).

Tsai, M. & Tsai, C. (2003). Students computer achievement, attitude, and anxiety: the role of learning strategies. *Journal of Educational Computing Research*, 28, 1, pp. 47-61.

Van Hiele, P. M. (1986). *Structure and insight. A theory of mathematics education.* London: Academic Press.

Vygotsky, L. S. (1991). Aprendizagem e desenvolvimento intelectual na idade escolar. *In* A. R. Luria; A. N. Leontiev & L. S. Vygotsky e outros, *Psicologia e pedagogia I: bases psicológicas da aprendizagem e do desenvolvimento* (2ª Ed.). Tradução de A. Rabaça. Lisboa: Editorial Estampa, pp. 31-50.

Vygotsky, L. S. (1994). *A formação social da mente. O desenvolvimento dos processos psicológicos superiores* (5ª Ed.). Tradução de J. C. Neto, L. S. Barreto e S. C. Afeche. São Paulo: Martins Fontes.

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