ICT and science education: promises and usages. Introduction

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Introduction

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“While many researchers and experts underline the potentially major role of ICT in education primarily as learning support but more specifically in the instrumentation of practical work (computer-aided measure and experimentation) and in the simulation of phenomena, the curricular uses are still rare apart from those in technical and professional courses. The gap between promises and curricular usages is not proper to sciences and techniques but specifically questions these fields in which research and professional practices massively use IT resources.

As the technologies available change quickly and the training practices integrating them are unstable, new potentialities appear especially with the technologies of virtual reality or augmented reality and mobile devices such as cell phones and tablets with access to the Internet.

New work practices – whether they are on an individual or collaborative basis – emerge. In particular, while entirely or mainly distance learning and training courses are not common in compulsory education, hybrid forms combining presence and distance courses through ICT-based individual or collective activities emerge (distance practicals, debates via forums, activities based on information search, coteaching, etc.).

While teachers have always been leading the development and adaptation of educational resources for pupils, these were mainly individual resources with rather local exchanges between teachers. More collective forms of design and exchange of educational resources and more largely of educational practices are currently developed as part of associations of teacher collectives.”

The paragraphs above refer to the beginning of the call for contributions for the topical part of this issue of the journal RDST initially entitled “Networking, design and use of digital resources for the teaching of sciences and techniques”. This call mentioned that the issue was intended to deliver review papers and disseminate new research towards:

– On the one hand assess the uses of ICT and computing in science and technical education and in training: what developments, what lessons can be drawn from the experiments made and what are the prospects?
– On the other hand, focus on more recent uses around individual or collective distance courses whether they are with pupils or teachers or uses of recent technologies
Quite few contributions were sent (seven draft articles) and the fields we wanted to cover are still little documented, thus confirming the fact that while many ICT-related experiments are conducted, studies of the teaching-learning processes (or didactical works) remain rare, at least in the French-language world. This special issue contains only three contributions. Margaret Cox provides a detailed panorama of the past forty years of research, and presents trends, dilemmas and implications for the future. Harinosy Ratompomala and his coauthors analyse how the future physics teachers from several académies (regional education authorities in France) are and feel prepared to use ICT in their teaching on the one hand and how some practicing teachers have become users of ICT and what they do with them on the other hand. Finally, Jean-François Rhodes provides a detailed account of an experiment consisting in a field trip in the forest with an online geolocation tool.

While the current issue of RDST provides information on the matter of computer technologies in science and technical education, it is far from offering a comprehensive panorama. In this short introduction, we will first try to discuss the reasons why there are quite few ICT-related didactical works. Then we’ll give an overview of ongoing research, detail the content of the three papers of this special issue and eventually see what the prospects are for didactics.

**An evolving provision compatible with constructivist pedagogical approaches**

Let us mention briefly that the technological provision is rich. As part of constructivist and social constructivist traditions, a number of pedagogical applications of ICT provide pupils with material and symbolic tools to work with concepts and processes in a discovery, exploration, experimentation and problem-solving perspective. Therefore, such applications could contribute to science and technology education according to contemporary didactical perspectives. There are four main application categories (Bruillard, 1997; Depover, Karsenti & Komis, 2007):

- Those that enable learners to present the knowledge they developed (electronic portfolio, blogs, etc.), to represent their developing knowledge (conceptual maps or other written or graphic expression systems) or organise and present new knowledge (web page design, etc.).

- Those that provide learners access to environments based on scientific or social models they must appropriate by using exploration or discovery processes: simulation, virtual reality and serious games environments.

- Those that provide pedagogical guidance and support in which learners create models and develop scientific knowledge based on observations and experimentations. These environments are related to micro worlds and modelling.

- Those that rest on the use of technical interfaces enabling learners to manipulate objects and make experimentations based on real life situations, most often outside the classroom and with mobile devices. These are pedagogical robotics environments or almost real computer-assisted experimentation laboratories allowing learners to develop knowledge in the manner of a scientist.

This is obviously a very attractive provision. The question it raises is that of the effective
uses of these technologies in class or out of it for educational purposes as well as the research conducted to develop, understand or account for them.

**What research to conduct in didactics and technologies in education or for education?**

First, it should be underlined that the relation between didactics and the uses of technologies in education and training cannot be taken for granted. ICT often appear of secondary importance. It may be assumed that these technologies are considered part of the “field” in the didactical sense of the term, one component of the engineering procedure implemented and, in this sense, they should not be paid particular attention. A focus on knowledge and the idea that instruments are not part of it might also prevail. As a result, ICT-related didactical research will focus either on innovation without the distance necessary for research, or on syntheses for training purposes. While instruments are considered of secondary importance in “conceptual” works, major field surveys are not conducted either.

The situation across the Atlantic is different as regards the relation to instruments, the launch of large-scale surveys and maybe also in a shared belief in the capacity of technologies to contribute to educational innovation. That has made the technologies used in class somewhat visible.

Research works, among which those funded by the National Science Foundation in the USA, first gave an impetus to ICT innovation in the classroom. For example, the CoVis project (Learning Through Collaborative Visualisation) led by Gomez, Fishman and Pea (1992) and their colleagues was conducted in school rather than in academic laboratories. They sought to innovate by engaging pupils in inquiry approaches in science through videoconferencing and a notebook written by several pupils. Blumenfeld et al. (2000) conducted a large-scale research innovation in the schools of Detroit where pupils were completing scientific projects based on carefully selected authentic questions (driving questions). The WILD¹ (Wireless Internet Learning Devices) project led by Roschelle and Pea (2002) was focused on the geo spatial affordances of these tools. They showed the basics of what augmented physical spaces towards collaborative learning could look like. Among major initiatives, the WISE (Web-based Inquiry Science Environment) project launched by Linn in Berkeley and also financially supported by the National Science Foundation has provided a platform since 1997 (see Slotta, 2010) for a history and an analysis of this project.

In Quebec, Barma, Power and Daniel (2010) made experimentations on augmented reality thanks to mobile technologies. In addition, the recent book directed by Riopel, Potvin and Vásquez Abad (2009) emphasised research experiments carried out by members of the mobile laboratory for the study of learning routes in science (LabMECAS) and MATI Montreal. This book, like other books (Aubé, David & de La Chevrotière, 2004); Bracewell et al., 2007; Turcotte, 2012) is the sign of both collective efforts for the study of technology use in science education research and of a dynamic research trend in Quebec.

More generally, the works in Canada around Knowledge Building/Knowledge Forum (Scardamalia & Bereiter, 2006, 2010) show the interplay between theory, pedagogy, technology and the learning community (Slotta, 2010; Zhang et al, 2011; Van Aalst &

¹ [http://wise.berkeley.edu/webapp/index.html].
There are quite similar programmes in Europe and several research projects funded by the European Commission have been conducted since the 2000s. They mainly contributed to the development of pilot environments and to the establishment of academic networks gathering specialists in science didactics and educational psychologists on one side and computer scientists focusing on IT environments for human learning on the other side). Among these projects, let us mention ModellingSpace, Comode, Co-Lab and SimQuest.

The ModellingSpace project, which was based on a series of pedagogical and epistemological principles, aimed to enable learners to develop and use qualitative, semi-qualitative and quantitative models in a context of distance collaborative learning (Dimitracopoulou & Komis, 2005). Classroom experimentation of the environment by researchers showed interesting findings (Ergazaki, Komis & Zogza, 2005; Komis, Ergazaki & Zozga, 2007) but the ensuing Comode project designed to introduce Modelling Space and its didactical approach in European schools did not have the same success. However, the promising findings do not seem to influence the daily practice in science classrooms.

In a word, ICT for education are becoming popular in classrooms and the subject of research but the contribution of research to classroom practice is challenged. One prior question is raised: what do we know of the advent of ICT in education?

**Historical elements: a succession of phases**

There is often a lack of historical background to understand the place taken by IT in education. Daniel Beaufils (2006) developed a twenty-year, computer-based review as a laboratory tool in physics. Margaret Cox provides a panorama of almost 50 years of development and use of ICT in scientific education. Her research team has recently participated in the development of the award-winning HapTEL (haptics in technology-enhanced learning) for the training of dentists².

According to Margaret Cox, it is necessary to consider a triple focus to understand this history: technological developments, educational (national) initiatives and the applications to teaching and learning. There was a shift from teaching software on specific subjects (corresponding to what is called computer-assisted instruction) to simulation and modelling and then to mobile learning, online lessons, the development of digital tools or knowledge by users, and to social networks. While technologies have changed, so have their social uses and aims as well as educational methods.

Margaret Cox distinguishes five types of application:
- tutors, mere practice software, exercise devices to more complex forms;
- simulations for the exploration of data games;
- modelling, programming software to build environments;
- computer-assisted experimentation to monitor experiments, collect, process, visualise data derived from experiments;
- integrated and connected technologies.

According to Cox, teachers over the past few years have limited their uses to focus simply on commercial software like spreadsheets and data bases. She raises the question of the impact of ICT on knowledge, the fact that this knowledge is now hardly dissociable from

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these technologies that have changed the representations and actions over these representations. But there is a form of resistance of school basic modes of knowledge transmission or processes that demands to rethink training itself.

As we mentioned above, the promises of scientific publications do not materialise in tangible classroom uses or in the science laboratories of schools. On one side, the much-supervised conditions of scientific research are not easily reproducible in everyday school reality (lack of “ecological viability”). On the other side, many observers underline a lack of pedagogical training among teachers, which makes the adoption of technological and pedagogical innovations more difficult. While the IT environments dedicated to scientific education can provide a cognitive framework favourable to learning and the active construction of knowledge, the actualization of their cognitive potential depends on the personal investment and commitment of learners on the one hand and on the didactic strategies adopted by teachers on the other hand. In these technology-mediated relations between teachers, pupils and knowledge, there might be a partial explanation for the lack of ICT integration in schools. Anyhow, the key role played by teachers is once again emphasised, which brings the question of their professional development all the more acute.

**Insufficient institutional courses and selective self-study courses**

Do initial courses adequately prepare teachers to a professional use of ICT? Harinosy Ratompomalala and his colleagues conducted a survey in three teacher training colleges (IUFM) which showed that future teachers did not feel ready to use ICT with pupils and that the school system does not really promote this initiative. That’s why young teachers use them so little.

But this is a classical result in the end. Khaneboubi (2009) emphasises that there are two intertwined conditions behind the use of ICT in class: capacity for technical use of ICT and for classroom management. Bassy (2012) shows that what is ultimately at stake is not so much the technological tools as the development of new strategies to access knowledge and its development.

There are indeed teachers who use ICT but these are not beginning teachers. The second part of the contribution seeks to understand what these teachers do with ICT and how they were led to use them. It shows that practising teachers appropriated these technologies to cope with problems with their pupils.

The work performed by Harinosy Ratompomalada confirms the trends observed by Margaret Cox in current classroom uses. This is no longer specific but generic software that is used. As Cox wrote it in details, it is as if physics teachers were given an encyclopaedia instead of a specific physics textbook written by an expert in the field.

Successive works showed the difficulties faced by teachers in ICT use with and by pupils. As pointed by Vialle (2001), technology in computer-assisted experimentation can either turn into an “aid to manipulation” or an “obstacle to investigation”. This difficulty was confirmed by a study led by Hénocq (2009) into the uses of digital work environments in earth and life sciences. These environments are an additional resource between pupils and knowledge. While there is a wide range of innovative practices, their implementation requires different conditions that are not so easy to meet. The development of a computarised tool to follow the conceptions of pupils in mechanics (Coppens, 2007) must still understand the difficulties faced by teachers to adopt new technologies.
Stanislas Dorey (2012) pointed to saturation phenomena in her PhD dissertation: the software provision is large enough and its use can take only a minimal part of pupils’ work time. Developing truly constructive uses of some software requires a long enough learning time to have an adequate technical and conceptual command. But this command cannot be reached because of the current constraints of courses in secondary education.

Towards new field practices

But the development of critical approaches is not an obstacle to the creation of new educational situations that make the most of the opportunities offered by technology. Although Hénocq (2009) realised how little new technologies were used in official digital work environments, innovative teachers compensated a lack of equipment and suggested innovative situations. For example, as part of the Exacam project, Dargent, Dargent & Quirin (2007) generated images of an experiment shot by a camera of the school and posted on the Internet. Through this experiment in class and out of class, playing on the time factor, they led to another approach to experimental activities, leaving the laboratory behind.

New opportunities are offered, especially through geolocation (Sanchez, Genevois & Joliveau, 2011) but also through serious games (Sanchez, 2011), probably an avatar of the simulations to which specific scenarios are associated.

All these new practices are not always monitored by research but they are a sign of what might become school practice in the near future. Jean-François Rodes invites us to explore new practices. Evoking the didactical and scientific difficulties of the examination of an ecosystem during a field trip in the forest, he showed that various tools, especially those of geolocation, can help a female teacher orient students’ inquiry practices. Rodes particularly focused on how this teacher changed her activity thanks to Google Maps. In his conclusion, he confirmed the opportunity to continue the inquiry-oriented activities but it must be improved by more technical support than that initially provided by this teacher. How can a compromise be reached between technical and conceptual mastery of instruments and their use for pedagogical purposes? The question remains unanswered. While the trial approaches give promising results, the mid-term viability of the activities tested is far from being guaranteed.

Prospects

The call for contributions of the thematic part of this issue focused on the design and exchange practices of educational resources within associations or teacher collectives. This aspect was not covered by the proposals we received. While such practices are effective in other disciplines, they are hardly visible in experimental sciences. Raynal (2009) for example offered a free downloadable version of his own digital textbook for the teaching of life and earth sciences3 but this was only an individual initiative. Kalogiannakis (2004) conducted a research on the online communities of physics teachers but there has been no recent study on this issue.

Are there enough resources available? Are institutional resources, especially the Access4 site, sufficient? Is the development of additional resources a question of secondary

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importance? Despite the available resources, their use by teachers and pupils remains inadequate.

Similarly, all non-curricular learning – that outside national curricula – such as associations, museums, etc. was not addressed.

However, the contributions of this issue provide landmarks on the uses of new technologies in scientific and technical education. While the design research approaches are popular across the Atlantic and in Europe, they might soon develop in France. As Margaret Cox evoked the importance of national initiatives, the call for projects “innovative digital services for e-education”, which advocated the design of “demonstrators” and their dissemination to a larger scale after field tests, orients towards this type of approach.

While experimentation practices within classrooms dedicated to practicals will probably decrease in secondary education to the benefit of simulations or mere ICT-assisted visualisations, other extra-curricular exploration and experimentation practices making the most of mobile technologies could emerge. In this sense, this issue is a landmark. It raises a number of burning questions and throws light on recent phenomena of the joint development of technologies and teaching approaches to be carefully followed.

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