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Using New Technologies for Teaching and Learning Science

El uso de las nuevas tecnologías para la enseñanza y el aprendizaje de las ciencias

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Abstract

Given the irreversible presence of the new information and communication technologies (ICTs) in everyday life, particularly the Internet, it is necessary to clarify the different roles and uses they can have in education, and to review and assess the main trends in their scholastic application.

Recent educational research on the use of ICTs has developed a series of new concepts and new approaches that have caused a notable evolution of the field of teaching and learning. These approaches all have in common the fact that they belong to currents of socio-constructivist thought. The papers show that ICTs can implement pedagogical principles in which the student is the main actor in constructing his/her own knowledge, and s/he can learn better in the context of a concrete and meaningful, and at the same time, collective action.

Keywords: Teaching and learning of science, new technologies, collaborative learning.

Resumen

Ante la presencia irreversible de las nuevas tecnologías de información y comunicación (NTIC) en la vida cotidiana, particularmente Internet, es necesario clarificar los diferentes roles y usos que pueden tener en la educación, y revisar y evaluar las principales tendencias en su aplicación escolar.

La investigación educativa reciente sobre el uso de las NTIC ha desarrollado una serie de nuevos conceptos y nuevos enfoques que han hecho evolucionar notablemente el campo de la enseñanza y el aprendizaje. Todos estos enfoques tienen en común su pertenencia a corrientes de pensamiento socio-constructivistas. Estos trabajos muestran que las NTIC permiten poner en práctica principios pedagógicos en virtud de los cuales el estudiante es el principal actor en la construcción de sus conocimientos, y que puede aprender mejor en el marco de una acción concreta y significante y, al mismo tiempo, colectiva.

Palabras clave: Enseñanza y aprendizaje de las ciencias, nuevas tecnologías, aprendizaje colaborativo.

Application potential of ICTs for teaching and learning science

The integration of new information and communication technologies (ICTs) to support the teaching and learning of science seems to have a high development potential. One of the main benefits of using them points in the direction of achieving a way (perhaps the only one) to recapture the “real world” and reopen it to the student within the classroom, with ample opportunities for interaction and manipulation on his[1] part. This does not mean, as yesteryear’s empiricist might have assumed, that scientific knowledge will arise in the perceptual level when nature “comes in through the window of the classroom”; rather, it has to do with emulating scientific activity by taking advantage of the fact that the new technologies achieve executable representations that allow the student to modify conditions, control variables and to manipulate the phenomenon.

Those who advocate the integration of ICTs for learning science argue that these technologies, developed and used properly, have the ability to:

- Present the materials through multiple media and channels.
- Motivate students and engage them in meaningful learning activities.
- Provide graphical representations of abstract concepts and models.
- Improve critical thinking and other higher cognitive skills and processes.
- Enable the use of information acquired to solve problems and to explain the phenomena of the environment.
- Allow access to scientific research and contact with scientists and real databases.
- Offer teachers and students a platform through which to communicate with peers and colleagues from distant places, exchange work, develop research and function as if there were no geographical boundaries.

All school systems recognize the need to have laboratories available for the study of empirical or experimental science. However, very few schools have these; only some are always adequately equipped, and schools are not always willing to face the risks of using them. The technology permits, through videos, demonstrations and computer simulations, plus laboratory activities in a realistic manner, but without the risks and costs associated with laboratory experiments.

The simulations in science laboratories can use real data; the software known as datalogging allows the use of sensors and probes that are connected to the computer and the substance or phenomenon to be measured. Instead of manually feeding information into the computer, the sensor takes the measurement directly, thus reducing the margin of error, and reproducing a situation very close to the real experiment.

Computer simulation is particularly useful for learning science in the following situations:

- Experiments that are very risky, expensive or time-consuming.
- Sensitive experiments that require precision to enable the student to see patterns or trends.
- Experiments that require ideal conditions, the absence of friction or negligible resistance.
- Experiments in which ethical issues should be considered, such as experiments with live animals.

Simulations cannot substitute completely for the actual activities of experimentation, but they can help students to prepare laboratory experiments, in the same way that flight simulators prepare pilots before they fly real planes.

One of the greatest assets of the technologies used for science education lies in the fact that they act as catalysts for change. The technologies are an excellent way to challenge certain pedagogical practices that occur in the classroom. Used only as tools added to a traditional teaching practice, focusing on the transmission of knowledge, they give a very feeble showing of their potential. They may even exacerbate certain undesirable practices in the classroom, such as the excessive protagonism of the teacher. However, used with non-traditional pedagogical models, they can greatly increase the participation and interaction of students, achieving their integration and involvement in learning situations.

The computer today, with its multimedia features and the ability to connect to remote networks, rich in information of all kinds, is not just a mechanism for information management, it is above all a mechanism for communication and exchange. The enormous accessibility to diversified information favors the opening of disciplinary fields. ICT resources accent the need to establish links between educational disciplines, various studies, and extracurricular reality. However, in order for the information circulating on computers through networks, to be enriched and transformed into knowledge, must be accompanied by a change in the teacher's role: from being a provider of knowledge in the classroom, to being a mediator and facilitator of learning within an interdisciplinary context.

Many of the recent developments that integrate ICTs into teaching science are based on collaborative learning models, which make intensive use of the interactive and communicative potential of the new technologies, taking advantage, at the same time, of access to universal sources of information and scientific knowledge.

This potential for use, however, requires a thorough review of theoretical and empirical frameworks that support it. In what follows, we will try to give an overview of the prevailing trends in research and educational development, and we will present a case study.

Theoretical Trends

Recent educational research on the use of ICTs shows a series of new concepts and new approaches that have caused considerable evolution in the field of science teaching and learning. Let us point out, for example, the approaches of situated cognition, collaborative learning, mediated cognition, technologically-enriched environments, learning communities, distributed cognition, etc. All these approaches have in common the fact that they belong to the socio-constructivist thought increasingly present in research papers on the applications of technology in education. In particular, these works show that ICTs can implement pedagogical principles which assume that the student is the main actor in the construction of her own knowledge, based on situations (designed and developed by the teacher) to help her learn better in the framework of a concrete and meaningful action which is at the same time, collective.

As a synthesis of current trends in research on the use of technology in education, there arises the perspective of CSCL (Computer- Supported Collaborative Learning), in which the theoretical currents of collaborative learning and the learning environment converge, together with the methodological approach of micro-analysis of interactions.

Throughout history, our conceptions of human cognition and learning have been related with and configured by the development of technology (see, for example, Burke and Ornstein, 2001, and Donald, 1993). This parallel between our psychological understanding and the technology becomes evident in the field of computer-assisted collaborative learning, where technology converges with psychology, pedagogy, philosophy and science. The technology favors the collective work, modifying attitudes, skills, concepts and cognitive processes.

It is difficult to say when CSCL emerged as an independent field of study. In 1996, Koschmann (1996) introduced the CSCL perspective as an emerging paradigm for studying education in technologically rich environments. The first CSCL symposium was held in 1991, and the first international congress was held in 1995 in

Bloomington, Indiana. Partly, the inspiration for CSCL emerged from research in Computer-Supported Cooperative Work (CSCW). This investigation brought into relief some features relative to the collaborative nature of the work when it was done using software like Groupware (Galegher, Kraut and Egido 1990; Greenberg 1991).

The CSCL perspective is interested primarily in determining: 1) how assisted collaborative-learning technologies can enhance peer interaction and teamwork, and 2) how collaboration, as well as technology, facilitates the sharing and distribution of knowledge, as well as the development of abilities and skills among community members.

Concepts and theories underlying CSCL research.

In everyday language, the term collaboration refers to any activity that two or more individuals perform together. In academic areas, however, collaboration is defined in a more precise manner. In scientific work, what the different definitions have in common is that they emphasize the idea of co-responsibility in the construction of knowledge and the commitment shared by the participants. In this sense, collaboration can be considered as a special form of interaction. Roschelle and Teasley (1995), for example, stress the role of shared understanding, and say that collaboration is "a coordinated and synchronized activity, resulting from a sustained attempt to construct and maintain a shared concept of a problem" (p. 70). Crook (1994) holds that there is a line of development which goes from children´s intersubjectivity and symbolic play, to sophisticated reciprocal comprehension and shared knowledge. In children’s symbolic play, the material world has a crucial role in coordinating the play activities and in creating a shared frame of reference for collaboration.

Many theories and approaches on collaboration minimize the effect and the possibilities of the material environment for facilitatingf mutual understanding and reaching shared goals. However, the manipulation of material objects offers referential anchors useful for mutual monitoring and understanding. Computers, especially, may offer a wide repertory of referential anchors and shared points of relation. According to Crook (1998), there are three features of interaction that are central to a productive collaboration: trust among the participants, availability of external resources (like computers), and stories of joint activity previous to the interaction.

Engeström (1992, cited in Lipponen, 2000) proposed the existence of three levels in the development of interaction: coordination, cooperation and reflective communication. At the level of coordination, each actor focuses on and carries out her own actions, according to a predetermined script. In cooperative interactions, Engeström says, the actors share the problem, trying to find mutually-acceptable ways to conceptualize it. This level meets the definition given above for collaborative by Roschelle and Teasley (1995) (although Engeström uses the concept of cooperation). The third form of interaction produced by the author is that of reflective communication, in which the actors focus on a reconceptualization of their own systems of interaction in relation to their objects of shared activity: both the objects and the scripts are reconceptualized. Only through this expansive cycle is the system of interaction transformed, and there are created new objects for collaborative activity. The advantage of this model is that it attempts to explain how to create new forms of collaborative activities; according to Engeström, these three phases are the natural cycle of a genuine learning activity.

Collaboration can be defined as a process of participation in knowledge communities. As Brufee points out (1993, p. 3), collaboration is “a process of enculturation that helps students to become members of knowledge communities whose common property is different from the common property of the knowledge communities to which they belonged before”. Scardamalia and Bereiter (1994) speak of the building or constructing of knowledge (knowledge-constructing communities). The constructing of knowledge is a special form of collaborative activity aimed at developing conceptual devices and advancing the collective understanding. In a learning community, as proposed by Brown and Campione (1994), the center of activity is participation in the collaborative process of sharing and distributing skills, “learning and teaching depend on creating, sustaining and expanding a community of research practice “(p.10). In communities of practice, learning is constructed when meaningful activities are shared (Lave and Wenger, 1991). The sense that emerges from knowledge is a social construction in action, shared in the same place of experience. The members of a community depend on each other in a decisive way: none of them is isolated, no one knows everything; collaborative learning is not only desirable, but is necessary for survival. The idea that collaboration is a basic form of human activity, essential for cultural development, has been highlighted repeatedly by many authors throughout the history of psychology (Bruner, 1996, Mead, 1934; Tomasello, 1999, Vygotsky, 1962; Wundt, 1921).

Roschelle (1994) proposes the concept of collaborative technologies, defined with reference to an expected goal: the construction of common ways of seeing, acting and knowing. The author holds that technology can be a means for society to resolve its uncertainties and construct common practices. Thus, collaborative technology is a tool that enables individuals to commit themselves mutually in the active production of a shared knowledge. With this, Roschelle is located in the context of situated learning, which implies the need to take into account the social interaction and practical activity that constitute the act of learning (Brown, JS, Collins and Duguid, 1989).

In regard to the theories of collaboration, the two main perspectives from which to explain the mechanisms of learning in a CSCL scenario refer, respectively, to the thinking of Piaget and Vygotsky. The first mechanism considered to promote learning in the context of CSCL is the sociocognitive, of Piagetian origin. Children at different levels of cognitive development or with the same level of cognitive development but different perspectives, can commit themselves in a social interaction that leads to cognitive conflict. This “shock of our thought on coming into contact with others" (Piaget, 1928, p. 204) can create a state of imbalance among the participants, which results in the construction of new conceptual structures and a new understanding. According to this view, the new knowledge is not so much a product of construction in common, or of shared understanding, but is rather the understanding that occurs in individual minds. This new understanding can then return to the level of social interaction and collaborative activities. Another interpretation of Piaget's theory emphasizes more the idea of the construction of shared knowledge and mutual understanding. According to this interpretation, the shared construction of knowledge takes place through the increasing ability of the individual to consider the perspectives of others. This ability evolves through the five stages of development that go from the egocentric and undifferentiated social perspective to a deep sociosymbolic perspective in adolescence (Selman, 1980).

The second mechanism known to promote learning in the context of social interaction is formulated based on the ideas of Vygotsky. There are two basic interpretations of Vygotsky's thought. The first and most traditional is that because of the commitment to collaborative activities, individuals can produce something they could not produce before the collaboration. The individual gains in knowledge and develops new competencies as a result of the internalization that occurs in a context of collaborative learning. In other words, collaboration serves as a facilitator of individual cognitive development.

The other interpretation of Vygotsky's ideas emphasizes the role of mutual commitment and the shared construction of knowledge. According to this view, learning is more a matter of participation in a social process of knowledge construction than an individual effort. Knowledge emerges through a network of interactions, and is distributed and mediated among those who interact (humans and tools) (Cole and Wertsch, 1996).

From the socioconstructivist perspective, learning is centered in the student, who learns when she finds herself in technologically-enriched learning environments that allow her to construct an understanding of the world based on the objects she manipulates and on which she reflects. The relationships required to construct this understanding are sources of knowledge, to the extent that they give meaning to these objects and to the world around them. Additionally, this sense is anchored in a given culture. As Bruner (1996) affirms, even if the meaning is in the mind of those who conceive it, its origin and meaning are in the culture in which it was created. For Bruner, the construction of reality (attributed to the world) is the product of the meaning, which takes its form from the traditions, tools and ways of thinking within the culture. Education consists in helping children and young people to acquire their own tools to give meaning and to construct reality, in such a way that then can adapt themselves better to the world and participate in its transformation. This activity, according to Bruner (1996), the existence of a sub-community in interaction, is formed by the students and the teacher, and at least one substitute agent such as the book, television, film or computer. The idea allows one to assume that if it is true that the student herself constructs her knowledge, and that this is an individual activity, then cultural knowledge is defined and constructed in a cultural development that is involved in the community.

Methodological settings

The background of the paradigms of educational technology refers mainly to experimental research designs; however, the CSCL perspective leans mainly towards a variety of methods that have emerged in the fields of anthropology, communication sciences, linguistics research, etc. Typical methods for CSCL analysis are ethnographic methods and discourse analysis with descriptive data, observational and not experimental, emphasizing the ecological validity of research. In contrast to its predecessors which studied human cognition with experimental laboratory designs, CSCL research is conducted in "real-world contexts", such as schools.

What should researchers consider in the context of CSCL? Some researchers propose that there should be studied very specific interactions which highlight the mutual commitment and trust among participants. Dillenbourg (1999) suggests that rather than talking about the effects of collaborative learning in general, we should discuss it more specifically—that we should speak about the effects of particular categories of interactions. There should be analyzed a posteriori what interactions actually occurred during the collaboration (pp. 16-17); for example, study the way ideas are improved and refined throughout the interaction, without putting too much attention on isolated individual statements. In other words, one should approach more carefully at the micro level of collaborative interactions.

However, if one studies only the interactions that reflect the commitment between two or three participants, it is not clear what the relevance of CSCL is in schools, or in general, in the workplace. The dilemma is this: if collaboration is understood as "a coordinated, synchronized activity, which is the result of a continued attempt to construct and maintain a shared conception of a problem" (Roschelle and Teasley, 1995, p. 70), it refers to a form of interaction that can be, strictly speaking, maintained only among a small group of people, and perhaps only in face-to-face situations. An approach to close collaboration only in terms of this type of meetings between small groups seems, however, a very limited approach to CSCL, since CSCL talks about collaboration and learning communities in different contexts and in relation to network environments of learning. As noted earlier, collaboration can also be regarded as a process of participation in the practices of a community.

When should we, then, speak of and discuss collaboration at the collective level (macro)? One way might be to see the communities as networks of interaction, and the interactions as "strong" and "weak" links among participants. Strong links are established between those community members who meet frequently (see Granovetter, 1973). We assume that strong bonds and intensive interaction among community members produce intense and productive collaborations. As Wellman *et al*. (2000) pointed out, we could talk about social networks assisted by computers.

To date, there is no consensus on the unit of analysis for CSCL studies; it may be individuals, pairs, groups, communities, collectively-produced knowledge objects or conceptual artifact. All these units of analysis have been individually used to study the CSCL label, the unit of analysis depends on the theoretical framework and the definition of 'collaboration' used.

It is risky to compare the empirical studies conducted under the label CSCL, because they differ from each other in significant respects. First, there is no agreement on whether the effects *of* or effects *with* CSCL should be studied. In 1991, Salomon, Perkins and Globerson (1991) made educators aware that there were two ways of thinking about learning and technology. You can see the effects of technology, i.e. what the subject has learned and can transfer to another position working with the computer. On the other hand, the effects can be studied with the technology: what one can achieve in synergy with a computer. In the same sense, one can speak of the effects of CSCL, that is, as a result of interacting with others and with computers; people individually acquire new skills and gain knowledge that can transfer to new situations. Or, one can speak of effects with CSCL, referring to the processes that people and computers achieve in synergy.

Second, there is variation in research procedures; in the length of studies; in the number of students that participate; in the age of the students; and in whether the students work individually, in pairs or in small groups. Insofar that in analyzing the scenarios of CSCL learning, researchers have used different learning tasks and have studied how specific concepts are learned, or how conceptual changes are achieved (Roschelle, 1992). Sociocognitive effects of CSCL have been analyzed, (Järvelä, Hakkarainen, Lehtinen and Lipponen, 2000), as have complex reasoning and levels of argumentation (Hoadley and Linn, 2000); there have been explored the learning of science and the processes of inquiry (Edelson, Gordin and Pea, 1999; Lipponen and Hakkarainen, 1997), and the collaborative construction of knowledge (Lipponen, 2000; Scardamalia, Bereiter and Lamon, 1994). Cognitive and metacognitive understanding have been studied (Brown, A. L., Ellery and Campione, 1998), as well as motivational aspects in CSCL (Hakkarainen, Lipponen, Järvelä and Niemivirta, 1999). Lately, emphasis has been placed on themes of participation (Guzdial and Turns, 2000; Lipponen, Rahikainen, Lallimo and Hsakkarainen, 2001).

Third, what makes the comparison between the different studies even more difficult is that there is a great variety both in the technologies used, and in the purposes and how a particular application is used. Does it favor the collaboration of the students around a computer (for example with simulation programs)? Or is it favored by environments of learning and technology networks used to structure or mediate collaboration? (Dillenbourg, Eurelings and Hakkarainen, 2001; Hall, Miyake and Enyedy, 1997; Hoadley, 1999).

The sometimes disproportional enthusiasm for technology has made researchers consider the potential of technology and collaboration as empirical evidence of the real benefits of CSCL. Certainly some small-scale intensive studies have been successful in promoting quality learning assisted by computer networks (Scardamalia, Bereiter and Lamon, 1994). But on a larger scale, there is no solid evidence that collaboration through networks lead to exceptional learning results. Stahl (1999) has even suggested that CSCL environments are mainly used for personal exchanges and to send superficial information, and not for collaborative knowledge construction. In addition, we may ask ourselves whether some of these results achieved in CSCL studies would have been achieved without the support of computer networks.

Among other drawbacks in the field of CSCL investigation is the small amount of research that has been done on how students participate in mediated collaborative networks, what are the different patterns of participation, and how these are related with other aspects of CSCL, such as the quality of students' discourse (Lipponen, Rahikainen, Lallimo and Hakkarainen, 2001). Because of the ambiguity (or wealth, if you will) of empirical studies in CSCL research, it is still difficult to integrate the studies and the findings, and to come to sound conclusions about any particular approach, or whether any instructional method or application would give better results than others. It is not known, either, what circumstances would allow a set of results to be extended to other contexts. Despite these drawbacks, CSCL research is so far promising.

The TACTICS project

The TACTICS project (Collaborative Learning Techniques with Information and Communication Technology Science / *Techniques d'Apprentissage avec Collaboratif des Technologies de l'Information et des Communications en Sciences*) is a joint project between the Centre for Research and Advanced Studies (CINVESTAV) of Mexico and the University of Montreal, whose theoretical and methodological perspectives fall within the mainstream of CSCL educational research. That is, it is a research project in collaborative learning in which information and communication technologies play a central role.

The community of practice, comprised of teachers, researchers and graduate students, creates the design from a socioconstructivist perspective of ICT pedagogical integration modules, seeking collective construction—within learning communities of students and high-school teachers—of knowledge about a general theme in a context of the integration of curricular disciplines (physics, chemistry, biology, mathematics, social sciences, Spanish, foreign languages). Each module of activities is limited in time, space and extension, and regroups the activities of a subtheme of the general theme, to be performed by students during a period of four to six weeks.

The modules are designed to facilitate the meaningful integration of school subjects and at the same time, a knowledge of other cultures, realities and ways of life, through the effective exchange of information and affective communication.

Based on the idea that students should make a presentation or a particular product that will be recognized (Savoie and Hughes, 1994) proposes as a goal the construction of a web site on the topic assigned. On this site appear the knowledge constructed and represented by the learning communities of different geographical locations.

To secure the remote operation of these learning communities, corresponding teams are defined. These are related in a sort of electronic dialogue. This dialogue seeks the development—by students and with the help of their teachers—in a series of questions about the subject matter mutually exchanged by e-mail. Each team, upon receiving the question from its corresponding team, must find the answers and exchange them so as to promote a collective and collaborative construction on the theme. To facilitate the joint construction of responses, various collaborative tools such as electronic discussion lists or software collaborative networking are used. Students use word and image processors, and web page editors. The knowledge produced and represented in text, images and sounds, before it is published on the web page, must be validated by the learning communities, to verify the pertinence and the level of cultural attachment. The site works as the poster sessions of research congresses: it is a place where learning communities publish their work products, and around which they can gather other interested people (students from other groups and schools, science teachers, etc.) who raise questions and exchange information to enrich the topics discussed. The site has, for these purposes, an electronic mailbox with the addresses of the different participating learning communities, and a discussion list that allows visitors to express their opinions and comments. All operations are automatically recorded in a database to make them available to other visitors. Productions on the site are made in three languages—Spanish, English and French— to promote the use of a second or third language.

Because of the cross-cultural and international nature of the project, questions are raised that, although they are part of the curriculum in both countries, are not approached at a precise time on the school calendar. Another important characteristic of the contents is that they present an intrinsic interest so that points of interest for both societies can be shared. The work of the students should aid the learning of the content itself; however, it is essential to seek a special contributions in other cognitive areas and in attitude toward learning, such as transversal cognitive skills (including problem-solving, research, structuring and communication of information); toward group work (including planning, organization, distribution and control tasks as well as conflict resolution), and toward motivation and attitude toward science.

The project was carried out in six schools at the high school level (with students from 15 to18 years of age), four of them Mexican and the other two Canadian. In its pilot stage, 81 Mexican students and 21 Canadian students participated. Currently (school year 2001-2002), 175 Mexican students and 109 Canadians are involved.

The Mexican schools are located in four different places: Mexico City. Jojutla and Cuernavaca in the state of Morelos, and Pachuca, Hidalgo. One is a private school, two belong to the state university system, and the fourth is a technical high school in the federal system.

As for Canadian schools, one is a bilingual public school (English-French) and the other is a French private school, both located in the city of Montreal.

The distance between the schools justifies the use of the Internet as a means of communication among the students. A service of the free public server Yahoo, Inc. (www.yahoo.com), call e-groups is used. This site lets you view messages sent to the whole team, individual messages, links with reference sites, databases and documents, and shared documents and a photo album. Also available is a chat module for synchronous communication in which all team members can participate. Occasionally, students have held videoconferences via Netmeeting.

Each team has its own e-group, and each participant has access to his e-group through a personal identification (Yahoo ID) and password.

As a CSCL project, the axes articulated are, on the one hand, collaborative work; and on the other hand, the technologies of information and communication. However, the project becomes complex when considering the communication between different cultures and languages, with inherent differences in ways of approaching it. For Mexican students, the use of computers in public schools as a learning tool, is relatively recent. Additionally, because of in the working conditions in schools, it is uncommon for collaborative methods to be incorporated in regular teaching practices, so that the complete project has been received in the Mexican schools as an innovational project both technological and pedagogical.

By contrast, in Canada, since most families have access to a computer at home, it is assimilated in students' daily lives. Therefore, there can be seen a greater interest in collaborative work sustained and supervised by the teacher.

The project was carried out within the framework of a science course. Students at one school were organized into sub-teams (called specialists) who, in turn, were part of a collaborative team, which consisted of three sub-teams from three different schools. Each team was assigned a topic which brought about a convergence of various aspects of the regular subjects of the school curriculum. The topic was divided into subtopics, which were assigned to each of the three sub-teams to be studied in depth (with the idea that each sub-team would become "specialists" in the subtopic allocated).

For the 2001-2002 school year, teams were organized as shown in Table 1 (the first two first letters of the group key indicate whether it is in Canada school [Ca] or Mexico [Mx]; the following numbers identify, respectively, the school [1-6] and the team within the school [1-10]).

Table I. Composition of the groups and allocation of items
for the 2001-2002 school year

Topics	**Subtopics**	**Group 1**	**Group 2**	**Group 3**
Pollution	Air	Ca2-5	Ca1-2	Mx4-4
	Soil	Mx2-1	Ca2-6	Mx1-2
	Water	Mx1-1	Mx3-3	Ca2-1
Waste treatment	Domestic	Ca2-3	Mx3-5	Mx1-4
	Hospital	Mx4-1	Ca2-7	Ca1-4
	Industrial	Mx1-3	Mx2-4	Ca2-2
Production of medicines	Traditional	Ca1-5	Mx3-2	Mx1-6
	Alopathic	Mx1-5	Ca1-6	Mx4-2
	Homeopathic	Mx3-1	Mx2-5	Ca1-3
Alternative energy	Biomass	Ca1-7	Ca2-9	Mx1-8
	Solar	Ca2-8	Mx2-3	Mx4-3
	Wind	Mx1-7	Ca1-8	Ca2-4
Reproduction	Prenatal diagnosis	Ca1-9	Mx2-2	Mx1-10
	Assisted reproduction	Ca2-10	Ca1-10	Mx4-5
	Cloning	Mx1-9	Mx3-4	Ca1-1

The students' work was done in two stages. In the first stage, they had to conduct a study within their sub-team; that is, with people from the same school (from 2 to 5 students per sub-team). During this time, communication with the team (which included the three schools) was carried out as voluntary messages—using e-groups—and with an obligatory work diary in which research activities were reported every two weeks.

Collaborative work in this part, among the sub-team members, while desirable, was not monitored systematically. Students were free to proceed as they deemed most effective. Formally, they were advised to report their problems, observations and findings to the whole team, so as to receive, in turn, feedback from their peers.

When they had competed their research on the subtopic, students had to share the information they had gathered to make a synthesis of the three subtopics. This part was done collaboratively in accordance with the following procedure, so as to ensure the sharing of knowledge between the three basic sub-teams.

1. A synthesis (approximately one page) of the subtopic investigated was made; this was to the rest of the team.
2. Five questions about the group's own work were drawn up, contemplating what, according to the sub-team of experts, was the most relevant information. These questions were sent to the team (this was done so that the sub-team of experts could verify that their synthesis contained the most import information on the topic, and that is was understandable for their teammates.
3. The other syntheses were read, and the 10 questions posed by the other two sub-teams were answered.
4. The 10 answers (to the five questions posed) received from the other two sub-teams were reviewed, and corrections were sent if necessary.
5. The synthesis was reworked, based on the questions and the commentaries received from the other two sub-teams.

6. Of the three sub-teams, one chosen by lot analyzed the three syntheses to identify the factors and features common to the three subtopics. Another sub-team worked with the different features, and the third produced a first draft that summarized the three subtopics, based on the analysis performed by the other two sub-teams.
7. The first draft of the synthesis of the three subtopics was reviewed and discussed until a consensus was reached.
8. The synthesis was published on the website (www.tactics.cinvestav.mx).

Some results of the pilot study

The pilot phase of the TACTICS project began in February of 2001. After a period of socialization, in which the three sub-teams contacted each other informally and exchanged photographs and personal information, the project followed the programmed stages (information search, collaborative exchange, and completion and publication of the synthesis).

The teachers informed their students that they could use e-mail, chat and even some type of collaborative software (such as Netmeeting) to make their exchanges. Students wrote in their native language, and could make use of translators to read the messages from their counterparts. To keep track of these exchanges, we requested that all be made through e-groups. Information search was not restricted to just one type of media, and in fact, most teachers encouraged their students to use both electronic sources and conventional sources. In some schools, teachers promoted public presentations in science fairs or similar events.

The body of observational data for this pilot phase includes records of interchange (between students, and between teachers and students), informal interviews and questionnaires. Although there have not yet been analyzed, it is possible to outline some areas of risk and potential gains for the project.

The first results of the pilot study show that technical problems, no matter how small, constitute the greatest obstacle to the realization of such projects. It became clear that schools need, in addition to the appropriate electronic equipment, technical support that can anticipate and address the difficulties that continually arise in the level of technological infrastructure.

There must also be a careful selection of the software so as to have programs compatible with the equipment available in schools (in our case, for example, it was not possible to get the free Netmeeting software installed and running on all the computers of the network).

One of the main problems in communication between the students was the difference in network speeds: while schools in Montreal have high-speed cable connection, Mexican schools are usually connected through 56k modems. This made voice and video communication virtually impossible, and was one of the greatest sources of frustration among students.

Many previous studies have limited communication between participants in e-mail and chat, but in a multilingual setting, with students who are not proficient in writing in a foreign language, it seems of crucial importance to find a solution to the problem of synchronous communication.

Another likely source of problems is related to synchronization of the calendars of the collaborative work. Although school cultures seemed appropriate for this type of projects (similar curriculums, content and flexible pedagogical practices), some factors, such as different vacation and examination periods, made the establishment of a minimum synchronized common working time difficult, and gave excessive rigidity to the timetable, leaving little room for possible adjustments.

During the pilot phase, the weight of the technological component easily surpassed that of the pedagogical and scientific components. Given the initial conditions of the students in Mexican schools (only the private school had the necessary computer equipment, one school had just one laptop for all its students, and the other two schools frequently had to use Internet cafes because their computer laboratories were not available; 37% of the students had no regular access to a computer, and 55% had no regular access to the Internet; 20% had never used e-mail, and 14% had never used the Internet), the gain in technology management was more important for them than for their Canadian companions, whose conditions of technological infrastructure, but at school and at home, were optimal from the beginning of the project.

Initially, only 39% of the Mexican students considered themselves to have good computer skills. At the end of the project, 59% considered that their use of the word processor was “very good” or “excellent”, 66% believed that their use of the e-mail was “very good” to “excellent”, and 90% believed that their ability to find information on the Internet was “good”, “very good” or “excellent.” After the project, 76% of the Mexican students said they used the computer more than three times a week. Of the students, 58% consider that their major gain in the project was learning to use the technology, and only 31% think they learned to do scientific research.

As for the problems in the implementation of the project, 44% of students, both Mexican and Canadian, believed that the greatest obstacle was in communication, while 40% felt that it was the lack of time (participation in the project was voluntary and extracurricular).

Of the students, 93% are convinced that technology can help them learn.

The research projects

Taking advantage of the global montage of the TACTICS project, the researchers and graduate students involved in it have defined a number of individual studies to explain diverse educational phenomena that occurred with TACTICS, and the modifications, conceptual and practical, produced in students and teachers as a result of having participated in the project. These studies are:

1. Transformation of teachers' beliefs and practices
2. Evaluation of interfaces and tools for use on the Internet
3. Representations of science in students' discursive production
4. Quality of interactions between students
5. Preconceptions and conceptual change
6. Motivation toward science.
7. Written communication between speakers of different languages
8. Ways of dealing with information obtained via the Internet

The general methodology of the study falls within the paradigm of qualitative research. We based our work on the interactive model of Miles and Huberman (1994): collection of data with triangulation, condensation of data, codification and categorization, production and verification of conclusions. We used various observation and data-collection techniques, and various analysis tools, according to the needs and types of questions. There were, for example, data-collection instruments such as interviews, videotaped observations, file cards, tests, questionnaires, observation diaries, etc; as well as methods of analysis and the analysis of the processes of conceptual changes (Winer and Vazquez-Abad, 1997), principally in the study of the process of knowledge construction and mechanisms of knowledge validation (arbitration, negotiation, consensus, etc.) We also developed original analysis tools for the study of the function of technology as a collaborative tool and for the study of students' mediated transactions (spokespersons, communications media, purposes, characteristics, collaborations, etc.) Structural analysis and content analysis were used for the in-depth study of the products produced and published, emerging from the knowledge constructed by the students. These methods also serve to analyze the ways of representing this knowledge and the mediated transactions of the students (content, objects, vocabulary used, level of language and discourse, etc.)

References

Brown, A. L. & Campione, J. C. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 229–270). Cambridge, MA: MIT Press.

Brown, A. L., Ellery, S., & Campione, J. C. (1998). Creating zones of proximal development electronically. In J. G. Greeno & S. V. Goldman (Eds.), *Thinking practices in mathematics and science learning* (pp. 341–367). Mahwah, NJ: Lawrence Erlbaum Associates.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of knowledge. *Educational Researcher*, *18*, (1) 32-42.

Brufee, K. (1993). *Collaborative learning*. Baltimore: Johns Hopkins University Press.

Bruner, J. S. (1996). *Culture of education*. Cambridge, MA: Harvard University Press.

Burke, J. & Ornstein, R. (2001). *Del hacha al chip. Cómo las tecnologías cambian nuestras mentes*. Barcelona: Planeta.

Cole, M. & Wertsch, J. V. (1996). Beyond the individual-social antinomy in discussions of Piaget and Vygotsky. *Human Development*, *39* (5), 250–256.

Crook, C. (1994). *Computers and the collaborative experience of learning*. London: Routledge.

Dillenbourg, P. (1999). Introduction: What do you mean by "collaborative learning"? In P. Dillenbourg (Ed.), *Collaborative learning: Cognitive and computational approaches* (pp. 1–19). Amsterdam: Pergamon, Elsevier Science.

Dillenbourg, P., Eurelings, A., & Hakkarainen, K. (Eds.). (2001). *European perspectives on computer-supported collaborative learning. The proceedings of the First European Conference on Computer-Supported Collaborative Learning*. Maastricht: University of Maastricht.

Donald, M. (1993). *Origins of the modern mind. Three stages in the evolution of culture and cognition.* Cambridge, MA: Harvard University Press.

Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *The Journal of the Learning Sciences, 8* (3-4), 391–450.

Engeström, Y. (1992). *Interactive expertise: studies in distributed working intelligence*. (Boletín de investigación No. 83). Helsinki: University of Helsinki, Department of Education.

Galegher, J. R., Kraut, E., & Egido, C. (Eds.). (1990). *Intellectual teamwork: Social and technological foundations of cooperative work*. Hilsdale, NJ: Lawrence Erlbaum Associates.

Granovetter, M. (1973). The strength of weak ties. *American Journal of Sociology*, *78* (6), 1360–1380.

Greenberg, S. (Ed.). (1991). *Computer-supported cooperative work and groupware*. New York: Academic Press.

Guzdial, M. & Turns, J. (2000). Effective discussion through a computer-mediated anchored forum. *Journal of the Learning Sciences*, *9*, 437–469.

Hakkarainen, K., Lipponen, L., Järvelä, S., & Niemivirta, M. (1999). The interaction of motivational orientation and knowledge-seeking inquiry in computer-supported collaborative learning. *Journal of Educational Computing Research*, *3*, 261–279.

Hall, R., Miyake, N., & Enyedy, N. (Eds.). (1997). *Proceedings of CSCL '97: The Second International Conference on Computer Support for Collaborative Learning*. Mahwah, NJ: Lawrence Erlbaum Associates.

Hoadley, C. (Ed.). (1999). *Proceedings of CSCL '99: The Third International Conference on Computer Support for Collaborative Learning*. Mahwah, NJ: Erlbaum.

Hoadley, C. & Linn, M. (2000). Teaching science through online, peer discussions: Speak easy in the knowledge integration environment. *Journal of Science Teaching, 22* (8), 839–857.

Järvelä, S., Hakkarainen, K., Lehtinen, E., & Lipponen, L. (2000). Creating computer-supported collaborative learning (CSCL) culture in finish schools: Research perspectives on sociocognitive effects. *International Journal of Continuing Engineering Education and Life-Long Learning*, *10* (2), 1–10.

Koschmann, T. (1996). Paradigm shifts and instructional technology: An introduction. In T. Koschmann (Ed.), CSCL: *Theory and practice of an emerging paradigm* (pp. 1–23). Mahwah, NJ: Lawrence Erlbaum Associates.

Lave, J. & Wenger, E. (1991). *Situated knowledge and legitimate peripherical participation*. Cambridge, UK: Cambridge University Press.

Lipponen, L. (2000). Towards knowledge constructing discourse: From facts to explanations in primary students' computer mediated discourse. *Learning Environments Research*, *3* (2), 179–199.

Lipponen, L. & Hakkarainen, K. (1997). Developing culture of inquiry in computer-supported collaborative learning. In R. Hall, N. Miyake, & N. Enyedy (Eds.), *Proceedings of CSCL '97: The Second International Conference on Computer Support for Collaborative Learning* (pp. 164–168). Mahwah, NJ: Lawrence Erlbaum Associates.

Lipponen, L., Rahikainen, M., Lallimo, J., & Hakkarainen, K. (2001). Analyzing patterns of participation and discourse in elementary students' online science discussion. In A. Dillenbourg, Eurelings, & K. Hakkarainen (Eds.), *European perspectives on computer-supported collaborative learning. The proceedings of the First European Conference on Computer-Supported Collaborative Learning* (pp. 421–428). Maastricht: University of Maastricht.

Mead, G. H. (1934). *Mind, self, and society*. Chicago: University Chicago Press.

Miles, M. B. & Huberman, M. (1994). *Qualitative data analysis: an expanded sourcebook* (2nd. ed.). Thousand Oaks, CA: Sage Publications.

Piaget, J. (1928). *The judgement and reasoning in children*. London: Routledge and Kegan.

Roschelle, J. (1992). Learning by collaborating: convergent conceptual change. *The Journal of the Learning Sciences*, *2* (3), 235–276.

Roschelle, J. (1994, mayo). Collaborative inquiry: Reflections on Dewey and learning technology. *The Computing Teacher*, *21* (8), 6-9.

Roschelle, J. & Teasley, S. D. (1995). Construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer-supported collaborative learning* (pp. 69-97). New York: Springer-Verlag.

Salomon, G., Perkins, D. y Globerson, T. (1991). Partners in cognition: Extending human intelligence with intelligent technologies. *Educational Researcher*, *20* (4), 9-20.

Savoie, J. M. & Hughes, A. S. (1994). Problem-based learning as classroom solution. *Educational Leadership*, *52* (3), 54–57.

Scardamalia, M. & Bereiter, C. (1994). Computer support for knowledge-constructing communities. *The Journal of the Learning Sciences*, *3* (3), 265–283.

Scardamalia, M., Bereiter, C., & Lamon, M. (1994). The CSILE project: Trying to bring the classroom into World 3. In K. McGilly (Ed.), *Classroom lessons; Integrating cognitive theory & classroom practice* (pp. 201–228). Cambridge, MA: MIT Press.

Selman, R. L. (1980). *The growth of interpersonal understanding*. New York: Academic Press.

Stahl, G. (1999). Reflections on WebGuide. Seven issues for the next generation of collaborative knowledge-constructing environments. In C. Hoadley (Ed.), *Proceedings of CSCL '99: The Third International Conference on Computer Support for Collaborative Learning* (pp. 600–610). Mahwah, NJ: Lawrence Erlbaum Associates.

Tomasello, M. (1999). The cultural origins of human cognition. Cambridge, MA: Harvard University Press.

Vygotsky, L. S. (1962). Thought and language. Cambridge, MA: MIT Press.

Wellman, B., Salaff, J., Dimitrova, D., Garton, L., Gulia, M., & Haythornthwaite, C. (2000). Computer networks as social networks: Collaborative work, telework, and virtual community. In E. L. Lesser, M. A. Fontaine, & J. A. Slusher (Eds.), Knowledge and Communities (pp. 179–207). Boston: Butterworth-Heinemann.

Winer, L. R. & Vázquez-Abad, J. (1997). The potential of Repertory Grid Technique in the assessment of conceptual change in Physics. *Journal of Constructivist Psychology*, *10* (4), 363–386.

Wundt, W. (1921). *Elements of folk psychology*. London: Allen and Unwin.

Links for topics related to the content of this article:

Collaborative Learning Bibliography: http://www.psu.edu/celt/clbib.html

Collaborative Learning Index: http://id.ucsb.edu/IC/Resources/Collab-L/CL_Index.html

IEEE Computer Society Learning Technology: http://lttf.ieee.org/

TechKnowLogia (Revista electrónica de tecnología y educación): http://www.techknowlogia.org/

Collaborating Reading Room: http://wellspring.isinj.com/collaborating.html

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[1] Translator's note: Before the feminist movement arose, in situations including both genders it was customary to use the masculine pronoun. Today, however, pronouns of both genders are used to avoid what is now seen as sexist language. To avoid the awkwardness of continually using "s/he", "his/her", we shall, in this paper, sometimes use the feminine pronoun, and sometimes the masculine.