Computer-based communication in the classroom

Rosa Maria Bottino
Consiglio Nazionale delle Ricerche, Istituto per la Matematica Applicata, Via de Marini 6 16149 Genova, Italy. bottino@ima.ge.cnr.it

Keywords: communication, collaborative learning, problem solving, multi-environment systems, context of use

Abstract: This paper is based on a study aimed at investigating the potential of collaborative learning in mathematics problem solving using computer-supported learning environments that incorporate communication opportunities. The specific context in which the study was undertaken involved the use of the multi-environment system ARI-LAB, which was implemented to develop problem solving abilities in primary school students. On the basis of the results obtained from long-term experimentation with this system, some research problems are discussed with the purpose of investigating factors which influenced the nature and type of student interaction. The final aims are to support the design of effective computer-based instructional materials that incorporate communication opportunities and in particular to stress the importance of establishing a well-designed context of use for the technology.

1. INTRODUCTION

In the 1970s, educational computing research began exploring ways to support educational instruction. This culminated in the 1980s in sophisticated (but still basically drill-and-practice) integrated learning systems, which, in general, had a limited impact on school practice. In response, research over the past decade has begun to show the practicability and efficacy of alternative approaches whose presuppositions lie in the pedagogic theories that have steadily been gaining credence (such as constructivism and situated learning). The aim has been to build learner-centred systems where learning in a particular field is based on active exploration and personal construction rather than on a transmissive model. From the point of view of Human Computer Interaction, the reference

The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: 10.1007/978-0-387-35499-6_29

D. M. Watson et al. (eds.), *Communications and Networking in Education*

metaphor is that of the workspace. Modern graphical user interfaces and interaction opportunities have developed from this paradigm.

Current research in new environments, new competencies and collaborative and co-operative learning have led to the belief that the workspace concept, as an interaction metaphor, cannot adequately take account of the opportunities that information and communication technology is rapidly making available, and so it needs to be coupled with a new interaction model: the communication space. This new way of looking at human-computer interaction on the one hand, and educational computing on the other, is reflected in the dialogue between different conceptual models and research agendas. We make reference to Vygotsky's socio-cultural theory, Leont'ev's activity theory and the model of human activity developed by Cole and Engeström (Bakardjieva 1998).

The strong interaction between different points of view, theoretical perspectives and new communication possibilities offered by technological advancements is opening up new scenarios, and educationalist face the need not only to understand the technical and management problems related to the use of this technology but also to consider how these new possibilities influence or change the nature of the underlying pedagogy and its relation to theory and practice.

Too many projects seem to focus on the technical innovations and opportunities offered by communication and networking rather than on their role or use (Watson et al. 1998). In order to deal with this last perspective, at least three classes of problems need to be tackled in an integrated manner.

a) The design of potentially rich open-learning environments: How can communication opportunities be integrated? How can an environment that supports communication influence the processes involved in the acquisition of given knowledge? What is the relationship between communication opportunities and the whole learning environment?
b) The role of the context of use: How can effective communication be promoted? What factors influence the nature and type of student interaction? What are the students' needs in this area? How can a balance be reached in communication between users engaged in a partnership? How can cross fertilisation among them be promoted?
c) Analysis of the communication activity: How can we analyse the communication activity? What forms of learner interaction resulted from systems that explicitly integrate communication opportunities? How does the learners' dialogue and communication patterns support the learning activity?

On the basis of a specific example, I analyse some aspects related to these areas. The aim is to contribute to the outlining of a methodological approach that may be adopted to tackle the problems described.

2. INTEGRATING COMMUNICATION OPPORTUNITIES

This paper reports a research project that aims to integrate the use of ICT into mathematics teaching at compulsory school level (students aged 6-14 years). The research concerns the development comprehensive testing of a computer system, called ARI-LAB (Bottino and Chiappini 1995), which is designed to assist students in arithmetic problem-solving. ARI-LAB is an open-learning system comprising a structured and connected set of environments combining hypermedia and network communication technologies. Its main environments are: a *microworld environment,* a *solution environment*, a *communication environment* and a *database environment*. The *microworld environment* features several microworlds with dynamic and graphic representation. These include: 'coins', 'abacus', 'calendar', 'simplified spreadsheet', 'histogram', 'quotition division', 'partition division' and 'art bits'. To make an example, in the 'coins' microworld it is possible to generate coins (in Italian lire), move them on the screen, withdraw coins, change coins and replace them with other coins of the same value, etc. When the user interacts with a microworld and obtains a visual representation (e.g. a set of coins grouped in a given manner) that fits her/his goal, s/he can copy it into the solution environment. In the *solution environment* the student chooses an arithmetic problem from a set prepared by the teacher, and builds up a solution by using verbal language and graphic representations obtained through interaction with the microworlds. In the *communication environment*, the student can share messages and solutions with other students, while in the *database environment* the student can look up problems previously solved and stored, either by the teacher, by her/himself, or by another student.

When designing ARI-LAB we drew on various theoretical approaches. These include the socio-cultural approach to thinking and learning and, in particular, Vygotsky's notion of cognitive tools, i.e. objects provided by the learning environment that allow students to incorporate new auxiliary methods or symbols into their problem solving activity. Moreover we considered the model of human activity that Engeström has built on Leont'ev's 'activity theory'. This interprets human learning as a systemic formation, taking into account its tool-mediated, object-oriented nature and its grounding in community practice. From the point of view of mathematics education research, we have taken into account research on applied problem solving, on situated learning, on the role of visual representation and on interactive learning. We start from the pedagogic consideration that primary school students, and often secondary school students, usually have serious difficulty tackling arithmetic problem solving and that teachers have trouble assisting them adequately. In the school tradition, symbols are used as mediating tool even in the very first approach to problem solving. Basically, traditional teaching relies on the early introduction of arithmetic symbols and written computation algorithms as the only way to describe the solution process and to obtain the result.

This approach seldom works well, as is witnessed by the fact that too many students, when solving a problem, try to guess what operation is necessary: they are not able to give meaning to the arithmetical signs in relation with the situation described in the problem. The introduction of arithmetical symbols and written computation, can be introduced fruitfully when children have already experienced the potentialities of a numbering system, and are able to enact informal strategies within concrete problem situations. It has been shown (Lesh 1981) that symbols which are not completely arbitrary but present some analogical connections with the reference objects can assume a very important role in the learning process. Representation systems such as coins, calendars and histograms can act as mediators between the situation described in the problem and the mathematical ideas, relations and processes involved in the solution. A number of such representation systems have been implemented in ARI-LAB's microworld environment, exploiting the graphical and interaction possibilities of the computer. In this way the mathematical ideas involved in problems of additive and multiplicative structure are made more accessible to students, by means of perceptive-type control, grounded in the children's extra-school experience.

In designing ARI-LAB, an alternative architecture to the one usual present in traditional education systems (student-computer) has been adopted. At least three agents have been brought into the learning process (student-computer-collaborative partner). For this reason, we have integrated into ARI-LAB a communication environment that has been designed so that users can engage in problem-solving within a social interaction process. This can change students' attitudes towards the problem, their assumptions on how to solve it and the validation context in which the resolution process is set. In the following chapters we will analyse how this has been made possible. ARI-LAB offers the user various communication opportunities: distance communication through a network or via a modem connection, or communication with the teacher or with classmates through a local network. There is also a variety of interaction modes. The user can choose the partner to communicate with at a given time, exchanging written messages and problem solutions. Moreover, the user can decide whether or not to read a message or solution as soon as it is received, store a received solution in the database, display the entire dialogue held with a partner. From the interface viewpoint, the microworld, solution and communication environments are presented simultaneously in the same display frame so that the user can easily switch from one to the other at any time. The reason for this is that communication must be an integral part of the problem solving activity and students must develop a synergy between communication and the other activities performed (building a representation, explanation of a solution).

If all the opportunities foreseen in the design of the system are to be effectively exploited the system must be used within suitable contexts of use that are planned and implemented within the overall education strategy. In the following, I briefly discuss an example to show ways in which ARI-LAB has contributed the restructuring of teaching and learning activity in the classroom. These examples are taken from the experimentation performed with the system over the past few years.

The experimentations had been performed in various school situations with children, some of whom were deaf. With one class, in particular, experimentation was carried out through almost the whole cycle of primary school, from the second to fifth grades; in this case the system was integrated into most of the mathematics syllabus. The teachers of the classes involved were present throughout all the experimentation and participated actively in following the students' work on the computer.

3. DESIGNING A CONTEXT OF USE

A number of possible strategies may be used for promoting and supporting collaborative learning activities based on computer-mediated communication (Slavin 1996). These strategies have a strong influence on learner behaviour and subsequent learning outcomes. In experimentation with ARI-LAB, an itinerary of classroom activity was planned to serve as a catalyst for collaborative learning. Tasks were included for which communication and co-operation among users might be meaningful for the specific object of the activity, namely a learning objective. The objective in this case was the development of abilities in the use of the decimal positional system and in solving additive and multiplicative problems. In my experience, at least with young students, the best tasks appear to be those which provide a method and allow a context for collaboration to be built. These tasks must scaffold the activity, that is, provide assistance at critical times offering methods and links to previous knowledge and experiences that the students themselves are unable to apply.

In the research with ARI-LAB, three strategies have been investigated in particular that have shown strong potential. These are pairing students with symmetrical roles and tasks; giving responsibility and control to them; developing investigative and open-ended tasks without single answers. Due to space limitations, I cannot discuss and exemplify all three strategies, so I chose to briefly analyse one example involving the first two.

During experimentation with ARI-LAB second-year primary school students were set the following task, to be performed communicating in pairs:

> *The teacher chooses a given amount of money and tells the whole class. Each student generates coins to make up the given amount and then, by means of the communication environment, has to send his/her classmate a message indicating the amount obtained and the coins used to make it up (e.g. one 1000 lire note; three 100 lire coins, etc.). The interlocutor has to check if the solution received is correct and then make up the same amount in another way. Then s/he in turn sends her/his solution to the other student as in the previous manner, and so on until one of the two students makes an error or is unable to find a new combination of coins. The rule is that it is not possible to propose previously used representations. If one of the students' representations is wrong (with respect to the amount given) and the interlocutor identifies the error, the latter wins the game.*

This game was proposed to students who had already developed experience in counting and in using the 'coins' microworld of ARI-LAB to make up given amounts. It was proposed at a stage which is critical for the development of the number concept, i.e. when students must progress from a view of the number as the result of a counting process to a view of the number in its relationships with the other numbers, relationships which can be functional to the solution of a problem or of a class of problems. The game pursues this objective inside the framework of monetary equivalence, which is meaningful for students since it allows them to draw on their extra-school experience. Playing the game, the students explore different ways in which an amount can be formed and are required to co-ordinate representation by means of coins on the one hand, and the representation in written language necessary for communicating with the partner on the other. The game develops through the written dialogue between the two interlocutors.

The game structure calls on the students to plan representation strategies that are increasingly articulated and complex. In doing so, the student can rely on the assistance given by the 'coin' microworld. The game structure fosters the need for the students to evaluate their own personal strategy as well as that of their interlocutors. Moreover, it promotes the co-ordination between the representation of the given amount by means of coins (in the microworld), its verbal representation together with coin representation (in the solution environment), and the indication in verbal form of the structural components of the number (in the communication environment).

The communication context of the game motivates and assists co-ordination of this activity in both the production and strategy evaluation phases.

4. ANALYSIS OF THE COMMUNICATION ACTIVITY

The system automatically stores dialogues between students and these can be later analysed together with the work that each student performs in the system's other environments, which is also recorded. For example, let us consider an excerpt (translated in English) of a real-time dialogue mediated by the computer between two children tackling the task described in the previous example (the amount to achieve is 2350 lire).

ANNA-M:	2 one-thousand lire banknotes, 3 one-hundred lire coins, a fifty lire coin
MARIO-R:	that's correct
MARIO-R:	2 one-thousand lire banknotes, a two-hundred lire coin, a one-hundred lire coin, a fifty lire coin
ANNA-M:	you did it correctly
MARIO-R:	2 one-thousand lire banknotes, seven fifty-lire coins
MARIO-R:	four five-hundred lire coins, a two-hundred lire coin, a one-hundred lire coin, a fifty lire coin
ANNA-M:	10 one-hundred lire coins, 5 two-hundred lire coins, 3 one-hundred lire coins, a fifty lire coin
MARIO-R:	you got it exactly right. Well done
ANNA-M:	you got it right too

The communication exposes the students to different ways of forming the given amount. When a student receives a solution from their interlocutor, in order to check it, they can reconstruct it in the coin microworld. In this way the student can acquire the partner's strategy and elaborate it in order to obtain a new solution. As the example shows, Mario, starts from the solution sent by Anna and applies single-step changes in order to produce alternative solutions. In this case also the structure of the dialogue (decomposition of the amount into its components in written language) contribute to support this activity.

Anna and Mario approach the goal at different levels. While Mario is able to re-elaborate Anna's solution, Anna, initially reasoned in terms of the coins she wanted to use, drawing on the support offered by the 'coin' microworld in order to obtain the required amount.

The following frames, (Figures 1-4) show how Anna interacted with this microworld to obtain the last amount she sent to Mario.

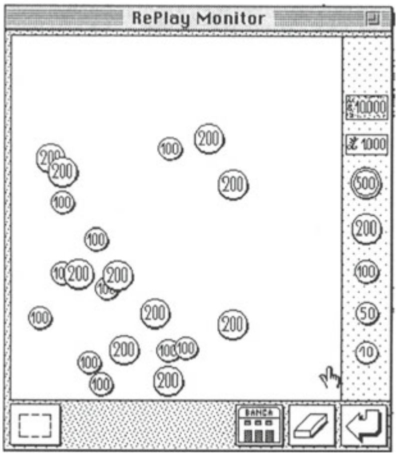

Figure 1. Frame 1

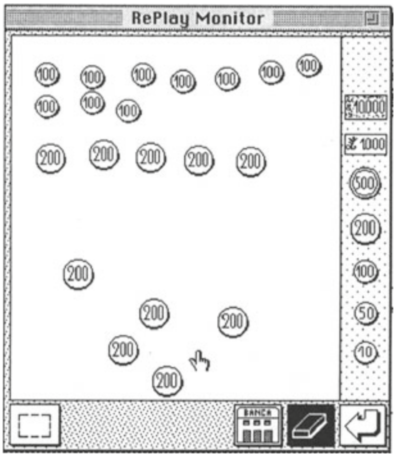

Figure 2. Frame 2

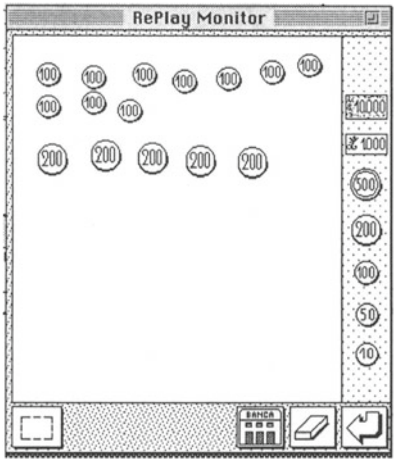

Figure 3. Frame 3

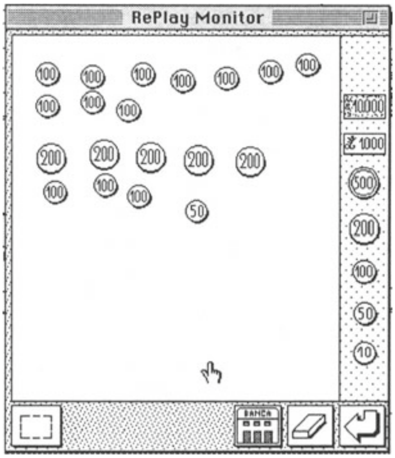

Figure 4. Frame 4

It is clear from Frame 1 that the student is unable to work out the problem in advance. Nevertheless, she begins to apply a strategy: she starts off using the 100 lire coins and applies knowledge about the equivalence of coins (10 hundred-lire coins make a thousand). She then moves on to 200 lire coins, but without taking account of the overall total (Frame 2). When she starts counting (Frame 2), she realises that she has too many 200 lire coins, so she cancels them (Frame 3) and adds the coins needed to make up the total (Frame 4).

It's worth noting that when interacting with the system (generating coins, grouping them in the workspace, and so on) the student is able to adjust her behaviour according to the goal to be reached, albeit in a step-by-step rather than comprehensive manner. At the same time she explores new representations (e.g. five 200-lire coins make one thousand) that can be used later on. Let's see how the communication unfolds:

MARIO-R:	ten two-hundred lire coins, three one-hundred lire coins, a fifty lire coin
ANNA-M:	Exactly right
ANNA-M:	a one-thousand lire banknote, 13 one-hundred lire coins, a fifty lire coin
MARIO-R:	Exactly right
MARIO-R:	11 two hundred lire coins, a one-hundred lire coin, a fifty lire coin
ANNA-M:	That's wrong
MARIO-R:	Why is it wrong?
ANNA-M:	because 11 two-hundred lira coins make two thousand lire, a one hundred lire coin makes two-thousand one-hundred, fifty lire coin makes two-thousand one-hundred and fifty
MARIO-R:	No!!! I tricked you with 11 two hundred lira coins, they make two hundred and fifty
MARIO-R:	I am wrong!! They make two thousand two-hundred.

Checking Mario's solutions was very important for Anna. It reinforced her counting abilities and, as the communication evolved, supported her use of previously seen strategies or facts (e.g. ten one-hundreds make a thousand, plus three one-hundreds – in total thirteen one-hundreds).

The communication context changed the students' attitude towards the problem: they moved from an application of rules which they consider were expected by the teacher to more personal motivations. For example, desire to win the game (as opposed to simply carrying out the teacher's instructions) induces Mario to produce increasingly difficult and tricky solutions that required a high level of mastery. This example offers some hints about the opportunities that close integration of communication and working environments may offer to problem solving activities.

Passing from the empirical materials collected during experimentation with ARI-LAB towards more general concepts, some observations can be made. Communication can be seen as a new mediational means that become a formative component of new systems of activity. These systems can induce and motivate more complex and articulated uses of knowledge that are supported by the close integration of communication with activities in other working environments. Conceptualising and modelling these activity systems as complex sets of learning objects and objectives, rules, roles and tools, rather a narrow focus on the technical aspects, is therefore the actual challenge facing the design and implementation of computer-based learning systems.

5. CONCLUSIONS

The purpose of this paper is threefold – to investigate some of the issues facing educational computing research as a result of the new opportunities made available by communication technology; to support the design of effective computer-based instructional materials; and especially to underline the importance of establishing well designed context of use of the technology (Oliver et al. 1998).

Outcomes from the ARI-LAB research project suggest a number of ways in which environments incorporating communication opportunities and related learning activities might be designed to enhance learning. Specially-designed tasks are needed for which communication and co-operation among users would be meaningful in relation to the learning objective of the activity. For example, in the reported experiment, the development of the number concept is supported by a communication task (a game), through which students can explore the different ways a given amount can be formed, and at the same time co-ordinate different representations for expressing it. These tasks must provide a method and allow the building of a context for collaboration. In the reported experiment, for example, the communication activity exposes the students to new methods of forming a given amount, supporting the use of previously seen strategies and changing their attitude towards the problem.

These goals can be achieved if attention is paid to strategies which have proved to have particular potential in this respect, such as pairing students with symmetrical roles and tasks, and giving them responsibility and control, as in the case reported. The possibility to implement these and other useful strategies requires that school pedagogy be attentive to the new opportunities offered by communication technology; for example, in the case discussed, the need to reshape the form and status of arithmetic problems has been stressed. Close integration of communication and activities performed in other working environments (e.g. microworlds and databases) can induce and motivate more complex and articulated uses of knowledge, contributing to the scaffolding of the activity by providing assistance at critical times and links to previous knowledge. This integration can be promoted also at the interface level, for example, by presenting within the same display frame the different workspaces made available by technology.

REFERENCES

Bakardjieva, M. (1998) Collaborative meaning-making in computer conferences: A socio-cultural perspective. In T. Ottmann and I. Tomek (eds.) *Proceedings of ED-Media and ED-Telecom 98*, Association for the Advancement of Computers in Education.

Bottino, R. M. and Chiappini, G. (1995) ARI-LAB: Models, issues and strategies in the design of a multiple-tools problem solving environment. *Instructional Science* Vol. 23(1-3) 7-23.

Lesh R. (1985) Conceptual analyses of mathematical ideas and problem solving processes. *Proceedings PME* 9(1) 73-96.

Oliver, R., Omari, A., and Herrington, J. (1998) Exploring interactions in collaborative world wide web computer-based learning environments. *Journal of Educational Multimedia and Hypermedia* 7(2/3) 263-287.

Slavin R. (1996) Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary Educational Psychology* 21(1) 43-69.

Watson, D., Blakeley, B., and Abbott, C. (1998) Researching the use of communication technologies in teacher education. *Computers and Education* 30(1/2) 15-21.

BIOGRAPHY

Rosa Maria Bottino is a Research Scientist. Her research interests are in the role of information and communication technologies for improving teaching and learning processes, mainly in the field of mathematics and computer science. She is the author of many scientific publications in both national and international journals, books and conference proceedings, and guest editor for journals, and conference proceedings. She has organised conferences and promoted projects both at national and international levels. She has been involved in the design and experimentation of educational software for primary and secondary school.