Evaluating the Educational Impact of a Tutoring Hypermedia for Children

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Several hypermedia environments have been developed in the last few years with the intention of promoting the acquisition of knowledge on a wide range of topics and developing problem-solving abilities. However, there are many different and sometimes conflicting claims about the capability of these environments to promote meaningful learning. We have developed a hypermedia learning environment with a tutorial component that exploits Artificial Intelligence techniques. This hypermedia, called *Logiocando*, targets a special category of users, namely children of the fourth level of primary school (9-10 years old), to teach them basic concepts of logic. Two empirical evaluations of the educational impact of *Logiocando* have been performed. Such experiments compared two teaching approaches: the computer-based one that relies on the hypermedia system, and the traditional one that relies on classroom instruction. The studies involved a total of 94 pupils from a primary school. Results showed that *Logiocando* can certainly be considered a valid support in the process of learning and deepening logic knowledge, provided that children are adequately motivated.

Over the past few years, much research has addressed the use of computers in education. The aim is to design and develop knowledge-based hypermedia learning environments either online (on the World Wide Web, [WWW or Web]) or offline (on CD-ROMs), which can really help students

to acquire meaningful knowledge on a given topic, as well as to develop problem-solving abilities.

Whether or not hypermedia learning environments actually promote learning is a question still debatable (Murphy & Davidson, 1991; Suni & Ross, 1997). Some studies have shown that hypermedia systems are not always efficient learning medium because the navigational freedom they offer is often overwhelming, while they tend to ignore individual characteristics of the students. Thus, it is argued that only users capable of planning their own learning paths can take full advantage of hypermedia environments. Indeed, forming systematic mental representation by finding which knowledge is useful to acquire, and in what order, surely requires considerable ability (Lanza, & Roselli, 1991; Nakabayashi et al., 1995). A partial solution to this problem is provided by methods of Artificial Intelligence. They allow an opportune integration of self-exploration with a more explicit control and guidance to lead the student in the process of knowledge acquisition. Several empirical studies have demonstrated the pedagogical value of intelligent hypermedia equipped with a tutor module (Schank, 1993; Schank, Korcuska, & Jona, 1995; Roselli, 1995).

This article reports on our experience with the design and evaluation of a hypermedia with a tutoring component to teach basic *logic* concepts to children. This hypermedia is called *Logiocando*, a name obtained by merging two Italian words (Logica Giocando), whose meaning is *Playing with Logic*. Because of the special category of users, namely pupils of the fourth level of primary school (aged 9-10 years), design and development of *Logiocando* have been carried out following a strict user-centred methodology, to build a system that satisfies usability objectives specific for that category of users (Nielsen, 1993; ISO, 1998). To help the authors create an effective educational software to be integrated into the school curriculum, *Logiocando* has been designed in collaboration with teachers and evaluated with pupils of a primary school (Costabile, De Angeli, & Roselli, 2001; Roselli, La Via, Loverro, & De Candia, 2000).

Any educational instrument to be used by children must be properly evaluated (Buckleitner, 1999). Indeed, choosing the best books, toys, or software is an essential task for anyone who works with children. With the growing use of computers both at home and in classroom, the selection of software for children takes on more and more importance. However, despite the need for software review information, the number of evaluation studies is still low. A significant contribution of this article comes from the evaluation of *Logiocando*, performed in order to measure the pedagogical efficiency of the hypermedia in comparison with traditional classroom instruction.

More in detail, the article has the following organization. The following section presents related work with the objective of properly situating the research and highlighting its motivation. *Logiocando* is described in the next section, also emphasizing the user-centred approach exploited in its design and development. Then, the authors report on the experiments carried out for evaluating the pedagogical efficiency of *Logiocando*. Finally, the last section provides conclusions and suggestions for further works.

RELATED WORK

The problem of computer-assisted teaching is very significant and has attracted wide interest from the community of both educators and computer scientists. As was mentioned in the introduction, the question whether or not hypermedia environments enrich student learning is still debatable. Actually, there are conflicting claims about learning by means of such environments (Becker, & Dwyer, 1994; Benyon, Stone, & Woodroffe, 1997; Oliver, & Herrington, 1995; Thuring, Manneman, & Haake, 1995). Bagui (1998) referred to several studies showing that computer-based hypermedia can help people learn more information and learn it more quickly than classroom instruction. The author stated, "multimedia allows interactivity with the computer, multimedia is flexible, multimedia has a rich content, multimedia has motivational effects, and multimedia allows better structured instruction." These claims are supported assuming a parallelism between multimedia and the "natural" way people learn, as explained by the information processing theory.

Aedo, Díaz, Fernández, Muñoz Martín, and Berlanga (2000) have a similar opinion. They claimed that the hypertext structure reflects a model of learning based on students' semantic memory model, and that the use of hypermedia provides interactive mechanisms allowing learners to manage, manipulate, and organise their lessons. These interactive activities encourage students to play an active role in the learning process, thus supporting the intentional construction of meaning at the basis of learning. Soo and Ngeow (1998) showed that multimedia computer-assisted instruction is significantly more effective than teacher-taught classes in increasing the English proficiency of students who averaged 21 years in age. Cybulsky and Linden (2000) showed that Multimedia Assisted Teaching Environment (MATE) is a valid complement to traditional teaching based on lectures, tutorials, and practical sessions. In Busby, Payne, Scamans, and Hibberd (2000), it was demonstrated that students were favourable to use a computer-based system

for learning expert practices of engineering. They preferred the computer system to books, because it was associated with something that was on their desks, immediately accessible, personal, and not rationed. Instead, they associated paper-based material with something that was remotely stored, not integrated, and shared, thus not readily accessible on demand.

Other authors are more sceptical about the use of hypermedia learning systems. For example, Hegarty, Quilici, Hari Narayanan, Holmquist and Moreno (1999) reported no differences in learning between a group of students who used a hypermedia manual instructing in mechanical systems and a control group, who used a traditional printed manual.

The introduction of Artificial Intelligence techniques help build more efficient hypermedia, since such techniques provide the learner with a control that is capable of guiding them through personalised learning paths (Schank, 1993; Schank, Korcuska, & Jona, 1995). The pedagogical value of this solution has been demonstrated elsewhere by one of the authors of this article (Roselli, 1995). Students, who used a hypermedia system embodying a rule-based tutorial component for learning logic programming, acquired more knowledge than a control group who used the same system without the tutorial component. In this case, as in the experiment reported in Soo and Ngeow (1998), the participants were university undergraduate students, that is, a special category of users because of their high motivation. On the contrary, *Logiocando* users are children of primary school. This opens a number of issues that require further investigation. Some of them have been addressed during the design and evaluation of *Logiocando*, as discussed in the sequel.

LOGIOCANDO

Logiocando is an educational software developed at the Department of Computer Science of the University of Bari. It has been implemented with the author system ToolBook Instructor and with the programming language Open Script. *Logiocando* exploits Artificial Intelligence techniques to guide children during the interaction. It is equipped with a tutor model, which directs navigation according to the information stored in a student model.

The idea of building *Logiocando* came from indications of primary school teachers who felt the need for a software product to support them teaching *logic,* a topic, which is often difficult to understand, but it is also very important as the basis for mathematics. The teachers have been actively involved in the design and evaluation of *Logiocando* providing suggestions and materials for the hypermedia, in accordance with the objectives of the primary school programs as stated by the Italian Education Council.

When designing software to be used by children, special attention must be devoted to usability. In particular, the system must be easy to learn and easy to work with, using a language that children find natural and suitable to them, but it should also be attractive and entertaining. In order to develop a system that conforms to these usability criteria, *Logiocando* was designed following a user-centred methodology whose basic principles are: (a) analyse users and tasks; (b) design and implement the system iteratively through prototypes of increasing complexity; and (c) evaluate design choices and prototypes with users (ISO, 1998; Costabile, 2001). In other words, the first steps of the user-centred approach requires understanding reality: who will use the system, where, how, and to do what. The system is then realised iterating a design-implementation-evaluation cycle. In this way, it is possible to avoid serious mistakes and to save re-implementation time, since the design is informed by empirical knowledge of user behaviour, needs, and expectations.

In accordance with this methodology, a lot of effort has been devoted to collecting user information by interviewing teachers and observing children at school. Furthermore, the teachers have been actively involved in the creation of *Logiocando*. According to a participatory design approach (Dix, Finlay, Abowd, & Beale, 1998), they provided definitions, hints on the presentation of the theoretical concepts, and examples of exercises. They also helped in revising the system throughout the design cycle.

Early prototypes of *Logiocando*, starting with paper prototypes, have been evaluated by using several methods, primarily experts inspections, observation of users working with prototypes, and contextual interviews (Nielsen, 1993; Dix et al., 1998; Nielsen, & Mack, 1994). Evaluations involving teachers and children proved to be extremely useful to select the language, icons, and presentation layout of the hypermedia. Once *Logiocando* was completed, the experimental evaluations described in this paper were carried out, with the objective of assessing its educational impact (Costabile et al., 2001; Roselli & La Via, 2001). An overview of the educational content and of the architecture of *Logiocando* is provided in the rest of this section.

Overview of *Logiocando*

Logiocando aims to help pupils to master logic. It covers basic topics, such as set definition; union, intersection, and complement operations; classification of objects according to two or more attributes; representation through Venn, Carroll, and tree diagrams. The system is organised in four units: *Sets, Set Operations, Logic Operators, and Diagrams*. Each unit focuses

on a specific concept in accordance with its title and is divided in three sections: Explanations, Logic Games, and Tests.

The Explanations section illustrates a set of concepts related to the topic of the unit using text, images, and/or sounds. An example is provided for each concept. It can be visited by clicking on the specific hot-word, namely the word "esempio" (example in English), as illustrated in Figure 1 that presents the concept of Set Intersection in Unit 2, or *Set Operation*.
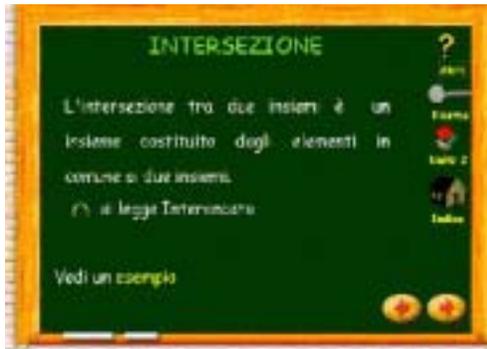

Figure 1. A page of the Explanations section in Unit 2

Pupils navigate in the Explanations section going forward and/or backward through the opposite arrows. Other buttons are available. The button "Aiuto" is the Help facility. The button "Ricerca" gives users the possibility of searching the meaning of a word. The button "Unità 2" allows users to reach the general index of the unit they are navigating in (Unit 2 in the case of Figure 1). Finally, the button "Indice" goes to the index of that section.

The Logic Games section (Figure 2) includes a set of exercises of increasing complexity related to the concepts illustrated in the Explanations section of the unit. In the example in Figure 2, the pupil has to select the right sentence explaining the situation illustrated in the picture among three sentences. Pupils have the possibility of verifying their score by selecting the button "Punteggio." They can also see the correct answer by clicking the button "Soluzione." If the pupils do not understand the exercise, they can reach the page of the Explanations section of the specific unit by clicking on the button "Esempio." This allows them to revise the concept necessary for performing the exercise.
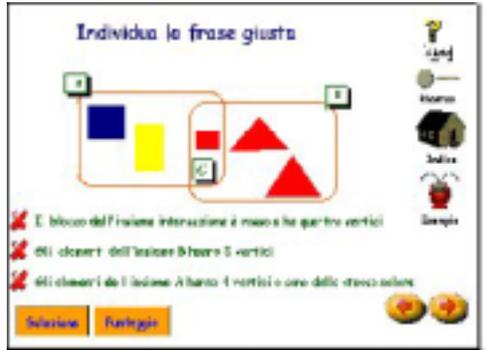
Figure 2. Example of an exercise in a Logic Games section

The Tests section (Figure 3) allows users to assess their knowledge. It includes 10 questions of various types. At the end of this section, the sum of the score of each question is computed and a judgement about the knowledge level of the user is reported.

Figure 3. Example of a question in a Tests section

Sections Logic Games and Tests were designed by considering the taxonomies of the educational objectives defined in Bloom, Engelhart, Furst, Hill, & Krathwolh (1986), while the number of games and questions were established by applying the formula reported in Priore (1995).

Architecture of *Logiocando*

The main concern of educational software is to support learning. To this aim, it should include explanation and exercise modules, but it should especially test the skills acquired by pupils during their interactions with the system. It is also desirable that the system manages and stores pupils' results, and possibly guides them in their learning path.

The first computer-assisted instruction systems were not able to satisfy all these requirements because they lacked a methodology for a diagnostic evaluation that permitted personalising learning. The introduction of Artificial Intelligence techniques, in such areas as knowledge representation and learning, provided a solution for organizing, retrieving, and presenting information in a wide variety of formats (Schank, 1993; Jonassen, Wilson, Wang, & Grabinger, 1993). Intelligent Tutoring Systems (ITSs) integrate learning systems with Artificial Intelligence techniques and hypermedia to offer better support to students. They usually combine an attractive multimedia interface with capabilities to adapt to individual student needs.

Logiocando follows the general architecture of ITSs, which consists of four main modules: (a) *interface module, (b) tutor module, (c) student module,* and (d) *domain representation module,* as illustrated in Figure 4.
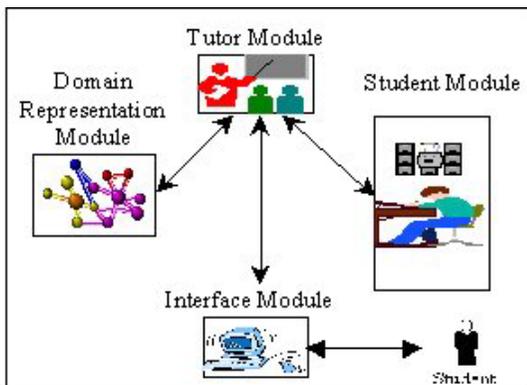

Figure 4. *Logiocando* architecture

In the design of *Logiocando*, particular attention has been devoted to the user interface, which is simple and pleasant to use, with a few, essential widgets. Images and objects used in *Logiocando* are familiar to the pupils. In fact, the interface is based on the "*school metaphor*" reproducing images

like blackboard, chalk, and so forth. The *interface module* allows learners to navigate the content, choosing their own paths with the aid of menu and other widgets active on each page. A different presentation style characterises each unit and section, to make them immediately recognisable, thus decreasing the risk of getting lost in the learning environment.

The *tutor module* is intended to emulate the teacher. It should facilitate the learning process by providing suggestions on how and what to study. This module is realised by means of several sets of IF-THEN rules, organised as diagnostic rules, exercise rules, presentation rules, remedial rules, and others. It is activated when the pupils decide to make use of it, by choosing the guided path. In this case, *Logiocando* didactic units become propaedeutic and the pupils can navigate a specific unit only when they have achieved a preset score in the preceding one. If the pupils choose the free path option, the tutor module is not active and pupils can freely visit any unit they wish to. This free path option has been provided to permit the study of single units.

The *domain representation module* organises the hypermedia content. Such content is structured according to the results of a study conducted by Paolucci (1995) to compare three different schemas for structuring knowledge domain, namely (a) conventional, (b) hierarchical, and (c) branching schema. The author has demonstrated that the conventional schema, in which nodes and links are relatively unstructured and learners can freely access any node, provides greater degree of freedom in self-exploration but tends to generate significant disorientation. The hierarchical schema, in which nodes and links are tightly structured, allows learners to visit the nodes with almost no disorientation, but results in a boring navigation. The branching schema, which is a compromise between the previous two, appeared to be the best solution; hence, it was implemented in *Logiocando.* This schema provides choice points or nodes at which different responses will result in different alternative paths the learner is suggested to follow. In some cases, access to lower level nodes might be blocked until all nodes at higher levels are viewed. This organization permits a medium degree of self-direction, but it limits the risk of disorientation. Thus, *Logiocando* provides a balanced approach between guided instruction and opportunities for active self-directed exploration.

The *student module* contains and manages data identifying the individual registered during a work sessions. It keeps track of the learning history during the interaction, including explored units, exercises performed, and performance achieved. Student models are exploited by the tutor module to suggest personalised learning path.

THE EMPIRICAL EVALUATIONS OF *LOGIOCANDO*

According to Buckleitner (1999), the evaluation of software for children should address the following questions: (a) What is the intended purpose of the software and where is the software intended to be used? (b) What is the developmental level of the intended audience? (c) How does the software under evaluation compare with competitive products?

Regarding question (a), *Logiocando* was designed to be used, in class or at home, as a complement to and not as a substitute for the human teacher. From a pedagogical perspective, it is intended as an instrument to facilitate constructive learning through creative problem solving experience. The basic philosophy behind the system is to give pupils the possibility of revising concepts already introduced by the teacher at increasingly deeper level of understanding. Therefore, *Logiocando* emphasises the integrative processing of learning or the formation of multiple links between new knowledge and concepts of existing prior knowledge. In this view, a major role is played by the tutor module, which should ensure that pupils acquire accurate and systematic knowledge.

With reference to question (b), *Logiocando* targets pupils of the fourth level of primary school. Software for children needs to be carefully designed by individuals who have a good understanding of the way children think. Graphics, style of music, and choice of characters influence children reaction to a software product (Buckleitner, 1999). For this reason, *Logiocando* design has been supported by both teachers and children.

Finally, as regards the comparative evaluation required by question (c), *Logiocando* has been evaluated in an ecological context of use. To assess its pedagogical efficiency, the system has been compared with the work performed by a teacher in a traditional classroom setting. The experimental studies reported in this section aimed at answering the following questions:

1. Can children actually improve their knowledge of logic using *Logiocando*?
2. Can *Logiocando* be as effective as a teacher's lesson for revising logic concepts?

As a basic experimental hypothesis, the authors predicted that *Logiocando* had pedagogical potentialities that could equal those of a human teacher. They believed that *Logiocando* had peculiar advantages over traditional classroom instruction that could compensate for the intrinsic benefits of skilled face-to-face teaching. *Logiocando*'s strengths mainly rely on its interactivity and flexibility that allows pupils to organise their own learning paths in a nonlinear, yet controlled way (Bagui, 1998). Moreover, as every

computer-based learning tool, *Logiocando* relies on a one-to-one relation-ship which in traditional classroom is only seldom possible. Hence, pupils may take advantage of *Logiocando* to accommodate their personal require-ments. To test this hypothesis, two controlled user evaluations were run. They apply the same experimental paradigm but present a fundamental moti-vational difference in the way the system was introduced to children.

Experiment One

Method and results of the first controlled user evaluation of *Logiocando* are described. The discussion will provide the rationale behind the second experiment.

Participants

Participants were selected and recruited from pupils attending the fourth class at the primary school E. De Amicis of Bari. Initially, 80 children were administered a pretest to evaluate their knowledge of logic. The test was de-signed by the teachers of the school according to the pedagogical require-ments of the Italian Education Council. It consisted of a number of open questions and a set of exercises referring to standard concepts of logic taught during the previous four months. Children had to solve the problems individually in one hour as part of their class work. Then, the teachers evalu-ated each test individually. Final scores ranged from 0 to 10. According to the pretest results, 54 children were selected for participating in the study. They scored below seven in the pretest assessment. Hence, they all qualified as students who might benefit from revising and doing further exercises. All pupils were familiar with the use of PCs, primarily for playing games and for browsing the Internet, but nobody had previous experiences with learn-ing hypermedia.

Design

The experiment is based on a pretest/posttest control group design. Af-ter recruitment, participants were assigned to one of two groups, balancing gender and pretest scores. Each group was then randomly assigned to a dif-ferent teaching method. The control group, Teacher Assisted (TA), revised concepts of logic in class attending two lessons given by the teacher. Pupils

assigned to the experimental group, Computer Assisted (CA), revised the same concepts individually using *Logiocando*. Learning was evaluated comparing pretest with posttest grades.

Procedure

The evaluation was carried out in March 2000. It consisted of two sessions, theory revision and practice. Each session lasted an hour, with a two-day interval in between. During the theory revision session, children assigned to the CA condition were required to revise individually two units of the hypermedia, namely *Set Operations* and *Diagrams.* These two units have been chosen since they illustrate concepts that were more problematic for the pupils, as indicated by the pretest results. Interacting with *Logiocando*, pupils revised the basic operations and the graphical representations of sets. The TA condition was introduced to the same didactic material as the CA condition during one hour lesson taught by the teacher in class. During the practice session, pupils were required to do a set of exercises on the concepts previously revised. Again, the CA group used *Logiocando*, while the TA group did the same exercises in class with pen and paper.

One week after the experiment, all the pupils were given a posttest as part of their class work. They had to answer a set of questions designed by the teachers to match the pretest ones. However, to avoid carry-over effects, the wording of the posttest was slightly different. Furthermore, in the attempt of controlling confounding variables related to the participants' history, no other logic lessons were taught during the period of the experiment nor were pupils given any relevant homework.

Results

The average value of the pretest and posttest scores in the two experimental groups are illustrated in Figure 5. To assess eventual differences in learning, these scores were entered as repeated measures in a mixed design analysis of variance, with Learning as the within-subjects factor and Teaching Method as the between-subjects one. The effect of learning is evident ($F_{(1,52)} = 207.428$, $p < .001$). All participants improved their knowledge of logic, obtaining better grades on the posttest than on the pretest assessment. However, learning is not homogeneously distributed across the two groups, as demonstrated by the two way interaction, Learning * Teaching Method

$(F_{(1,52)} = 9.26, p < .01)$, and by the main effect of Teaching Method $(F_{(1,52)} = 13.18, p < .01)$. Pupils attending the classroom lesson learned more than those who used *Logiocando*. In particular, pupils taught by the teacher had an average improvement of 30% on the 10 point scoring scale, while those who used *Logiocando* had an improvement equal to 19%.
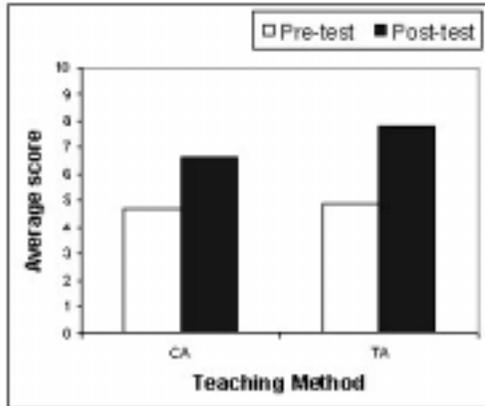

Figure 5. Average pretest and posttest scores as a function of Teaching Method in experiment one

Table 1 further illustrates these results by reporting basic descriptive statistics related to the learning gain. This variable was computed for each participant subtracting the pretest score from the posttest score. The first row reports the arithmetic average of the learning gain, the second one its standard error.

Table 1
Average Learning Gain and Standard Error as a Function of Teaching
Method in Experiment One

	CA	TA
Mean	1.93	3.0
Standard Error	0.22	0.26

Discussion

The experiment demonstrated that *Logiocando* has the potential for facilitating learning in a sample of 9-10 year old children. However, contrary to expectations, the hypermedia was not found to be as effective as the human teacher was. Despite this disappointing result, the study turned out to be very useful since it gave the authors the opportunity to observe the behaviour of children in the two learning settings. This provided a few insights into the reasons of *Logiocando*'s pedagogical deficiency.

The fundamental difference between the two learning settings appeared to be the pupils' motivation. To both experimenters and teachers it appeared that the children did not take seriously enough the work with *Logiocando,* which was considered as a game to play with rather than as a learning instrument. During both the revision and the practice sessions, pupils browsed the system ignoring the tutor module recommendations and concentrating mainly on the Logic Games and on the Tests sessions rather than on the Explanations one. This behaviour can explain the unsatisfactory results of the experiment. The learning gain was mainly due to incidental learning through experience rather than to the active construction of meaning.

To conclude, the authors hypothesized that *Logiocando* failed to provide the complex and varied role expected by a teacher of primary school. Because of the experimental procedure adopted, *Logiocando* was not situated in a meaningful context. Hence, it did not foster individual responsibility but was rather seen as a recreational instrument far away from the disciplined activity performed in class under the supervision of the teacher. Therefore, we decided to run another experiment in which we carefully controlled children's attitudes, making them responsible as much as possible of the work they had to perform.

Experiment Two

The study was performed in February 2001 and followed the same procedure as experiment one. The only difference was that this time great care was devoted to motivate the pupils to get the best out of their interactive experience with *Logiocando*. The system was presented formally, as a very important pedagogical tool for the class activity. Moreover, it was clearly explained to children that their performance would be carefully evaluated by the teachers as part of their class work. Finally, in contrast with experiment one, the teachers monitored the children's activity throughout the experiment, without interfering with it.

Initially, 71 pupils of the primary school E. De Amicis were administered the same pretest used in experiment one to evaluate their knowledge on logic. Forty children were then selected for participating in the study. They all scored below seven in the pretest assessment. Twenty pupils were assigned to the TA condition and 20 to the CA condition.

Results

Observing the experiment, it was immediately clear that the motivational manipulation succeeded. The behaviour of the children who used *Logiocando* was completely different than the one observed during the first experiment. Pupils were disciplined and worked very seriously, precisely executing the tasks they were asked to. This behavioural difference led to different results (Figure 6) from the ones obtained in experiment one.
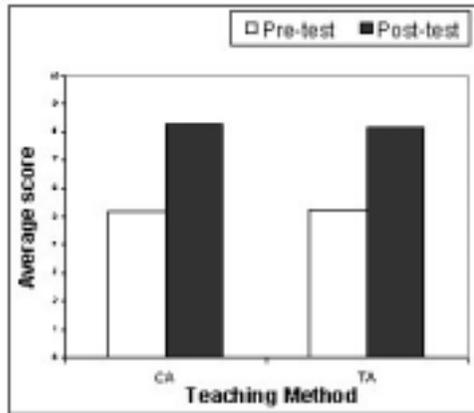

Figure 6. Average pretest and posttest scores as a function of Teaching Method in experiment two

Pretest and posttest scores were analysed by a two-way mixed design analysis of variance with Learning as the within-subject factors and Teaching Method as the between-subjects one. The learning improvement is once again evident: all the children increased their knowledge of logic, $F_{(1, 38)} =$ 100.7, $p < .001$. However, this time, the main effect of Teaching Method and the two-way interaction are absolutely negligible, in both cases $F_{(1, 38)} < 1$. This implies that all the children have learned during the experiment and

that this learning was almost identical in the two teaching groups. Average values and standard errors of the learning gain (difference between posttest and pretest scores) are reported in Table 2.

Table 2

Average Learning Gain and Standard Error as a Function of Teaching
Method in Experiment 2

	CA	TA
Mean	3.10	2.92
Standard Error	1.49	2.23

Discussion

Results of experiment two confirmed the main experimental hypothesis claiming that *Logiocando* could be a good substitute for the teacher as a revision tool. All the children significantly enhanced their knowledge during the experiment independently of the teaching method they were exposed to. It is worth noticing that this improvement is equivalent to the one achieved by pupils attending the teacher lesson in experiment one. Once the students are properly motivated, *Logiocando* can reach the same performance as a teacher, allowing children to improve their knowledge of logic.

CONCLUSION

The aim of the studies was to evaluate the educational impact of the intelligent tutoring hypermedia *Logiocando* and to understand the difference between computer-based learning and classroom instruction. The first evaluation was unsatisfactory and pupils who interacted with *Logiocando* performed significantly worst than those taught by the teacher. This was explained by claiming that experiment one failed to situate *Logiocando* in a meaningful and realistic learning context. Hence, *Logiocando* failed to provide the complex and varied role required to a teacher of primary school, ranging from supportive help to firm control. Because of this, *Logiocando* did not foster individual responsibility but rather was perceived as a game to play with.

By enhancing pupils' motivation, experiment two achieved different results. The group who used the hypermedia (CA group) had an excellent performance equalling that of the pupils who were taught by the teacher (TA group). The score of the posttest of the CA group improved an average of 30%, and the score of the posttest of the TA group also improved of 29%. Several factors can explain these results. Certainly, one is that interacting with an instructional hypermedia children can personalise their own learning path and follow their own learning rhythms. In this way, a child who needs a specific period of time for learning a concept can navigate in the hypermedia for the time he or she feels necessary. Considering the result of the experiment, we do not say that *Logiocando* can substitute the teacher, but it can certainly be considered a valid support in the process of revising and deepening knowledge on a topic.

Both experiments stressed the high acceptability of the *Logiocando* as a pedagogical tool in primary education. Pupils were very excited about the system. However, this excitement led to different results according to pupils' motivation and should be carefully controlled when designing systems for pupil instruction.

The process of learning is very complex due to the myriad of factors that interact with each other. Our experiments demonstrate that motivation affects learning through hypermedia. Intentional learning requires a motivated individual (Kintsch, Franzke, & Kintsch, 1996). Learning is not an isolated and individual activity but occurs in a social and cultural context. Technology is part of that environmental context. As previously mentioned, all pupils in the experiments had prior experience with computers but that experience mainly referred to video games, ludic instruments which are normally perceived very differently from the rigorous activity required by formal learning. More research is needed to learn how to embed this rigour in educational software without decreasing the software appeal. However, our experience certainly stresses the need for carefully controlling motivational factors in the evaluation of educational software, especially that designed for a children population. Furthermore, our findings may help account for the current lack of agreement on the pedagogical value of hypermedia learning environments (Murphy & Davidson, 1991; Suni & Ross, 1997; Lanza & Roselli, 1991; Nakabayashi et al., 1995).

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