An Experimental Evaluation of *Logiocando*, an Intelligent Tutoring Hypermedia System

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**Abstract.** Several hypermedia learning environments have been developed in the last years, with the objective of helping students to acquire specific concepts in a given domain, as well as problem-solving abilities. However, there are still many different and sometimes conflicting claims about learning effectiveness using such environments. We present an empirical evaluation of a learning hypermedia with a tutorial component that exploits Artificial Intelligence techniques. This hypermedia, called *Logiocando*, has been designed for use by a special category of user, namely children of the fourth level of primary school (9-10 years old), to help them to learn basic concepts of logic. This category of user demands special attention to usability of the hypermedia. For this reason, design and development of the hypermedia have been carried out following a learner-centred methodology, in order to build a system that satisfies clear usability objectives. The aim of the study herein reported was to evaluate the learning effectiveness of *Logiocando* and to estimate the difference between two approaches: computer-based using a hypermedia system, and traditional, namely a typical lesson in the classroom. The results have shown that the hypermedia can be considered a valid support in the process of learning and deepening a topic.

**Keywords.** Intelligent tutoring hypermedia, usability, learner-centred design, learning effectiveness

**INTRODUCTION**

A large volume of research is currently addressing the use of computers in education. The aim is to design and develop knowledge-based hypermedia learning environments that can help students to acquire specific concepts in a given domain, as well as problem-solving abilities.

Whether multimedia/hypermedia learning environments actually enrich student learning is still debatable (Murphy & Davidson, 1991; Suni & Ross, 1997). Some studies have shown that hypermedia systems per se are not always efficient learning systems because the navigational freedom they offer is often overwhelming, while they tend to ignore individual characteristics. Only students capable of planning their own learning paths can take full advantage of this environment; indeed, building up knowledge by finding which information is useful to acquire, and in what order, surely requires considerable ability (Lanza & Roselli, 1991; Nakabayashi, Koike & Maruyama, 1995).

A partial solution to this problem is provided by methods and techniques of Artificial Intelligence (AI), since they are able to integrate the freedom of action of the learner with a more explicit control and guide, aiming to lead the learner toward valid personnel learning goals (Schank, 1993; Schank, Korcuska, & Jona, 1995; Roselli, 1995).

The first application of AI to education was Intelligent Tutoring System (ITS) that provides personalized advice to students based on the background and experience of individual students (Zhang, Cheung, & Hui, 2001). In other words, ITSs seek to reflect a method of teaching and learning
based one-to-one interaction between student and teacher. Intelligent tutoring systems are designed to provide individualised learning. They provide helpful guidance and make the teaching process more adaptable to the student by exploring and understanding the student’s special needs and interests, and by responding to these as a human teacher does (Siemer & Angelides, 1998). Research in education indicates that private tutoring has proven to be as much as four times as educationally effective as a normal classroom setting, and 98% of students perform better with private tutors (Bloom, 1984). Roselli (1995) conducted a study that demonstrated the superior performance of the group of participants that used a hypermedia system for learning logic programming embodying a rule-based tutorial component with respect to the control group which used the same system without the tutorial component.

This paper reports our experience with the design and the evaluation of a learning hypermedia with a tutorial component. The hypermedia we developed is called Logiocando (Playing with Logic). It has been designed for use by a special category of user, namely children aged 9-10 years attending the fourth level of primary school. The chosen hypermedia domain is logic, considered to be a topic difficult for children to understand, but it is also very important as the basis for teaching mathematics. Because the hypermedia addresses children, a special category of user, design and development have been carried out following a learner-centred methodology (Quintana et al., 2001), in order to build a system that satisfies clear usability objectives. The work has been carried out in collaboration with primary school teachers, with the aim of creating educational software for use by teachers and students in primary school classrooms, integrated in the school curriculum (Roselli et al., 2000; Roselli et al., 2000a).

The paper is organized as follows. In the following section, the current scenario of the development of the interactive system exploiting Artificial Intelligence in the learning context is described. Then, the hypermedia system, Logiocando, is described. After that, Logiocando learning effectiveness is evaluated. Finally, some conclusions are drawn.

RELATED WORK

The accelerated growth of computer and communication technologies in education and the development of educational systems are attracting growing attention of researchers both in Computer Science and Education, although the question of whether hypermedia environments enrich student learning is still debatable. There is conflicting evidence about learning by means of such environments (Becker & Dwyer, 1994; Benyon, Stone, & Woodroffe, 1997; Thuring, Manneman, & Haake, 1995). Bagui (1998) refers to several studies showing that computer-based hypermedia can help people learn more information and learn it more quickly than classroom instruction. The author states that “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.

In (Aedo et al., 2000), the authors have a similar opinion. They claim 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. Cybulsky and
Linden (2000) showed that MATE (Multimedia Assisted Teaching Environment) is a valid complement to traditional teaching based on lectures, tutorials, and practical sessions. In (Busby et al., 2000), it was demonstrated that students were favourably impressed by the use of a computer-based system for learning expert engineering practices. They preferred the computer system to books, because it was on their desks, immediately accessible, personal, and not rationed. Instead, they associated paper-based material with something in a remote store, not integrated and shared, thus not readily accessible on demand.

Other authors are more sceptical about the use of hypermedia learning systems. For example, in (Hegarty et al., 1999) no differences were reported in learning between a group of students who used a hypermedia manual to learn about mechanical systems and a control group, who used a traditional printed manual.

The introduction of Artificial Intelligence techniques helps build more efficient hypermedia, since such techniques provide the learner with a control that can guide them through personalised learning paths (Schank, 1993; Schank, Korcuska & Jona, 1995). The pedagogical value of this solution has been demonstrated elsewhere in (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 literature, there are examples of the effectiveness of the AI techniques in the development of educational systems of different domains. In (Lesgold et al., 1992), Sherlock is a computer-based coached practice environment for Air Force trainees learning a complex troubleshooting job. In (Anderson & Reiser, 1985), an Intelligent Tutoring System is developed to teach the basic principles of programming in LISP. In the Lisp Tutor, the expert model was created as a series of correct production rules for creating LISP programs and a learner model was built as a subset of these correct production rules along with common incorrect production rules. Another example (Koedinger et al., 1997) reports a large-scale experiment introducing and evaluating intelligent tutoring in an urban High School setting. The intelligent tutoring system, PAT (Practical Algebra Tutor), supports an algebra curriculum and has been made a regular feature of 9th grade Algebra in 3 Pittsburgh schools. In (Cheung et al., 2003), SmartTutor, an intelligent tutoring system is implemented for distance learning in Hong Kong. This system integrates the concept of personalization and educational theory, incorporated in a single Internet-based e-learning system. In these cases, users were university undergraduate students, i.e., a special highly motivated category of user. Pillay (2003) asserts that ITSs have successfully been used to tutor novice programmers, and that the intelligent programming tutors are a more effective and economically viable means of assisting novice programmers to overcome learning difficulties.

On the contrary, Logiocando users are children at 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 below.

THE HYPERMEDIA LOGIOCANDO

The hypermedia system Logiocando is an educational software developed at the Department of Computer Science of the University of Bari (Italy). It has been implemented by the authoring system ToolBook Instructor and the programming language Open Script. The idea of building Logiocando stemmed from indications by primary school teachers who felt the need for a software product to support the teaching of logic, a topic which is often difficult for children to understand but it is also
very important as the basis for mathematics. The teachers were actively involved in the design and evaluation of Logiocando, providing suggestions and materials for the hypermedia, in accordance with the objectives of primary school programs as specified 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. Aside from the User-Centred Design (UCD) methods (ISO, 1998), we need Learner-Centred Design (LCD) methods (Quintana et al., 2001) in order to develop a usable and accessible system to make new learning domains accessible in an educationally effective manner. LCD should start by understanding the learner’s background. In this context, we do not need interfaces that support “doing tasks” but interfaces that support “learning while doing tasks” (His & Soloway, 1998). While designing learner-centred systems, the emphasis is on the learner’s competence and proficiency in specific areas of knowledge, skills, and understanding. Thus, it is crucial to understand the differences between typical software users and learners. While moving from UCD to LCD we have to identify the unique needs of learners, that go beyond those of typical users. Whereas UCD assumes that users have a common culture and similar experiences in the application domain, in LCD a variety of learner categories must be considered, as well as personal learning strategies, different experience in the learning domain, and different motivations.

In accordance with this methodology, a lot of effort has been devoted to collecting user information by interviewing teachers and observing children at school. In the design of Logiocando teachers were actively involved, providing definitions, hints on the presentation of the theoretical concepts, and examples of exercises. They also helped to revise the system throughout the design cycle. Early prototypes of Logiocando, starting with paper prototypes, were evaluated using several methods, primarily expert inspections, observation of users working with prototypes, and contextual interviews (Nielsen, 1993; Nielsen & Mack, 1994; Dix et al., 2003). Evaluations involving teachers and children proved to be extremely useful to select the language, icons, and presentation layout of the hypermedia.

Once Logiocando was finished, an experimental evaluation with the objective of assessing its learning effectiveness was carried out (Costabile, De Angeli, & Roselli, 2001), described in the section “The evaluation of Logiocando”.

An overview of the educational content and of the architecture of Logiocando is provided in the rest of this section.

**Logiocando Educational Content**

Logiocando aims at helping pupils to master logic. It covers basic logic 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 the title and is divided into 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 “esempi” (“example”), as illustrated in Figure 1 that presents the concept of Set in Unit 1, or Sets.
Pupils navigate forward and/or backward in the Explanations section using arrows. Other buttons are available. The button “Aiuto” is the Help facility. The button “Ricerca” gives users the possibility to check the meaning of a word. The button “Unità 1” allows users to go to the general index of the unit they are navigating (Unit 1 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 choose the right sentence explaining the situation illustrated in the picture, selecting from 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 they 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.

The Tests section (Figure 3) allows users to assess their knowledge. It includes ten questions of various types. At the end of this section, the sum of the score for each question is computed and a comment about the pupil’s knowledge level is reported.
The two sections Logic Games and Tests were designed considering the taxonomies of the educational objectives defined in (Bloom et al., 1986), while the number of games and questions was established by applying the formula reported in (Priore, 1995).

**The Logiocando Architecture**

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 et al., 1993). Intelligent Tutoring Systems (ITSs) integrate learning systems with Artificial Intelligence techniques and hypermedia to offer students better support. ITSs offer considerable flexibility in presentation of material and a greater ability to respond to distinctive, idiosyncratic and characteristic student needs. These systems achieve their "intelligence" by representing pedagogical decisions about how to teach as well as information about the learner. ITSs are computer-based instructional systems that have separate data bases, or knowledge bases, for instructional content (specifying what to teach) and for teaching strategies (specifying how to teach), and they attempt to use inferences about a student’s mastery of topics to dynamically adapt instruction. ITSs’ design is founded on two fundamental assumptions about learning. First, that individualized instruction by a competent tutor is far superior to classroom-style learning because both the content and style of the instruction can be continuously adapted to best meet the needs of the situation. Second, that students learn better in situations which more closely approximate the situations where they will use their knowledge, i.e. they “learn by doing”, learn via their mistakes, and learn by constructing knowledge in a very individualized way. ITSs use techniques that allow automated instruction to come closer to the ideal by more closely simulating realistic situations and by incorporating computational models (knowledge bases) of the content, the teaching process, and the student’s learning state (Jerinic & Devedzic, 2000).

*Logiocando* follows the general architecture of ITSs, which consists of four main modules: *Interface Module, Tutor Module, Student Module*, and *Domain Representation Module*, as illustrated in Figure 4.
Interface Module

Beck et al. (1996) describe the functions of the interface module as controlling interactions with the student. This essentially involves presenting the student with the correct screen layout for the task at hand and facilitating communication between the student and the components of the intelligent tutoring system (Beck, Stern, & Haugsjaa, 1996). Anderson and Skwarecki (1996) state that the effectiveness of an intelligent tutoring system is largely dependent on the design of its interface. The interface must clearly indicate to the student when problems arise and errors made must be clearly visible to the student. The student’s history as well as her/his learning style should be taken into consideration when deciding which of these interfaces to present to the student for the purposes of program construction. Thus, 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. The 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, etc. The interface module allows learners to navigate the content, choosing their own paths with the aid of menus 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 disorientation in the learning environment.

Domain Representation Module

In general, the Domain Representation Module of an ITS, and more specifically of Logiocando, organises the hypermedia content. The content structure is built by an expert in the course domain. In the content structure graph, the relationship among different concepts, topics, and subjects is exhibited clearly. The elementary unit is the graph node. Each node represents a self-contained course session. Since the course can be divided into different self-contained sessions according to the relationship among course contents, the content structure of the whole course is a graph consisting of many nodes.

Paolucci (1995) conducted a study comparing the three different schemas for structuring knowledge domain, namely conventional, hierarchical, and branching schema. The author demonstrated that the conventional schema, in which nodes and links are relatively unstructured and learners can freely access any node, provides a 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 is more boring. 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 alternatives being suggested. In some cases, access to lower level nodes might be blocked until all higher levels nodes are viewed. This organization permits a medium degree of self-direction, but limits the risk of disorientation. Thus, Logiocando provides a balanced approach between guided instruction and opportunities for active self-directed exploration.

**Tutor Module**

The Tutor Module is responsible for deciding how and when the content is to be presented to the student, in other words it emulates the teacher. For example, information about when to revise, when to present a new topic, and which topic to present. The student model is used as input to this module, so the pedagogical decisions reflect the different needs of each student. In Logiocando, the Tutor Module is realized by parameterizing a semantic network of frames, combining several sets of IF-THEN Action rules, organised as diagnostic rules, exercise rules, presentation rules, remedial rules, and others. It is activated when on demand pupils choose the “guided path” from the Interface Module. In this case, the Tutor Module generates links between two nodes automatically according to the information contained in each node and determines the best node to access next from the educational point of view. Each node is associated, for example, with variables which contain information on: the level of difficulty of the exercise, if it has been solved in a previous pupil work session and the score obtained. Simply accessing a node produces instantiation of the variables associated with it.

Several sets of rules are used for adapting the content to the pupil’s knowledge. They are organized as follows:

- **Selection Rules** which select the exercises to propose on the basis of the topics already examined
- **Computation Rules** which calculate the level of difficulty of each proposable exercise
- **Managing Rules** which manage the presentation in sequence: simple or medium-difficult on the basis of the pupil’s previous knowledge
- **Updating Rules** which upgrade the difficulty and the comprehension level, on the basis of the solutions given by the pupil

An example of selection rule is presented below, whereby the system uses rules to present the exercise best suited to the pupil’s knowledge:

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IF the pupil’s knowledge in Unit n is >= 100
  THEN go to theory of Unit n+1
ELSE show the theory of the Unit n
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The pupil’s knowledge is calculated on the basis of the difficulty of the exercise: each exercise has three levels of difficulty: low, attributed a score of 10 per question; medium, a score of 20, and high, a score of 30. If the student has not visited the theory section, the exercise is associated with, the level of difficulty of the exercise proposed increases. A computation rule is implemented in the system to reach this goal:
IF difficulty-exercise = x and not-visit theory is true
THEN difficulty-exercise x = x+10

Instead, if the pupil decides not to take advantage of the Tutor Module, but chooses the “free path” option, s/he can freely visit any unit. Pupils do not need to follow the learning schedule and they can select the topics they want to learn.

**Student Module**

The intelligence of an ITS is assessed on the basis of its ability to adapt to the specific student during the teaching process. Obviously, the adaptation depends on the individual student’s knowledge of the subject and other relevant student features, so that the system can give the student a personalized treatment. The student model contains and manages all the data needed to identify each student. It includes personal information such as student name, age, sex, etc. But, more importantly, it keeps track of the student’s learning history during the interaction, including units explored, exercises performed, and performance achieved.

Logiocando can record each step in the student’s learning path, and provide a personalized learning instruction schedule.

The student’s initial learning level is decided by checking her/his grades in prerequisite courses and previous experience data, if available. The learning result of each session is dynamically updated at each interaction.

**THE EVALUATION OF LOGIOCANDO**

Any educational instrument to be used by children must be properly evaluated (Bucktleiner, 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 the classroom, the selection of software for children is taking on ever greater importance. However, despite the need for information reviewing software, the number of evaluation studies is still low.

According to Bucktleiner (1999), the evaluation of software for children should address the following questions: 1) What is the intended purpose of the software and where is the software intended to be used? 2) What is the developmental level of the intended audience? 3) How does the software under evaluation compare with competitive products?

As regards question 1, 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 an 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. From this viewpoint, a major role is played by the tutor module, which should ensure that pupils acquire accurate and systematic knowledge.

With reference to question 2, 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, music, and choice of characters influence children’s reactions
to a software product (Bucktleiner, 1999). For this reason, Logiocando design has been supported by both teachers and children.

Finally, as regards the comparative evaluation required by the third question, Logiocando has been evaluated in an ecological setting. To assess its learning effectiveness, 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, we predicted that Logiocando had pedagogical potentialities that could equal those of a human teacher. Indeed, we believe that Logiocando has 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 allow pupils to organise their own learning paths in a non-linear, yet controlled way. Moreover, like every computer-based learning tool, Logiocando relies on a one-to-one relationship which in a traditional classroom is seldom possible. To test this hypothesis, a user evaluation was run. First, a pilot study was performed. Then, on the basis of the results an experimental study was carried out.

The pilot study, conducted in 2000, consisted in having groups of pupils working with the system in order to observe their interaction with the hypermedia (Roselli et al., 2000a). This study demonstrated that Logiocando has the potential for facilitating learning in a sample of 9-10 year old children. However, contrary to our expectations, the hypermedia was not found to be as effective as the human teacher. Despite this disappointing result, the study turned out to be very useful since it gave us the opportunity to observe the behaviour of children in the two learning settings. This provided a few insights into the reasons for 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 the work with Logiocando seriously enough, considering it as a game to play with rather than as a learning tool. 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. 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.

Therefore, in the experiment we carefully controlled pupils’ attitudes, making them feel responsible for the work they had to perform and stressing the educational value of the experiment, apart from its game content.

The Experiment

Method and results of the controlled user evaluation of Logiocando are described herein.

Participants

Participants were selected and recruited from pupils attending the fourth class at the primary school “E. De Amicis” of Bari. Initially, 71 children were administered a pre-test to evaluate their knowledge of logic. The test was designed by the teachers of the school according to the pedagogical requirements 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. Pupils had to solve the problems individually in one hour as part of their class work. Then, the teachers evaluated each test individually. Final scores ranged from 0 to 10. Since the teachers considered all the scores below 7 as insufficient, 40 pupils that obtained less than 7 (range 1-7, mean 5.12) on the pre-test assessment were selected to participate in the study. So, they all qualified as students who might benefit from revising and doing further exercises related to the logic. All pupils were familiar with the use of PCs, primarily for playing games and for browsing the Internet, but nobody had previous experiences with learning hypermedia.

**Design**

The experiment is based on a pre-test/post-test control group design. After recruitment, participants were randomly assigned to one of two groups, balancing gender and pre-test scores. 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 pre-test with post-test grades.

**Procedure**

The evaluation was carried out in February 2001. It consisted of two experimental sessions: theory revision and practice. Each session lasted an hour, with a 2-day interval in between. During the theory revision session, pupils assigned to the CA condition were required to individually revise two units of the hypermedia, namely Set Operations and Diagrams. These two units were chosen since they illustrate concepts that were more problematic for the pupils, as indicated by the pre-test results. Interacting with Logiocando, pupils revised the basic operations and the graphical representations of sets. The TA group was introduced to the same didactic material as the CA group, during a 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 post-test (see Figure 5) as part of their class work. They had to answer a set of questions designed by the teachers, of a similar nature to the pre-test ones.

Furthermore, in the attempt to control confounding variables related to the participants’ history, no other logic lessons were taught during the period of the experiment nor was any relevant homework given.

**Results**

Comparing the pre-test and post-test results, it was immediately clear that our motivational manipulation was successful. The behaviour of the pupils who used Logiocando was completely different from behaviour observed during the pilot study. Pupils were disciplined and worked very seriously, precisely executing the tasks they were set. This behavioural difference yielded different results (Figure 6) from the ones obtained in the pilot study.
Pre-test and post-test scores were analysed by a 2-way mixed design analysis of variance with Learning as the within-subject factor and Teaching Method as the between-subjects factor. The learning improvement was 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 2-way interaction was absolutely negligible, in both cases $F(1, 38) < 1$. This implies that all the children learnt during the experiment and that this learning was comparable in the two teaching groups. Average values and standard errors of the learning gain (difference between post-test and pre-test scores) are reported in Table 1.
The results of the experiment confirmed our 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.

During the experiment, pupils interacted very easily with Logiocando. After a few minutes, they understood the hypermedia navigational structure and were able to work autonomously.

Many children preferred to navigate in the Logic Games, and Tests section, rather than exploring the Explanations section. In fact, when pupils observed the theoretic concepts they soon wanted to see the example page related to that definition. Moreover, pupils were more attracted by the possibility to interact actively with the hypermedia. For example, when they could not solve an exercise, they quickly clicked on the button “Soluzione” (“Solution”) to see the right way to answer the problem. Moreover, they often asked the system their score to verify their new knowledge.

CONCLUSION

The aim of our study 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 worse than those taught by the teacher. We explain this result by concluding that the pilot study failed to situate Logiocando in a meaningful and realistic learning context. Hence, Logiocando failed to provide the complex and varied role required of a teacher in a primary school, ranging from supportive help to firm control. Because of this, Logiocando did not foster individual responsibility but was simply perceived as a game.

By enhancing pupils’ motivation, the experiment achieved different results. The group who used the hypermedia (CA group) had an excellent performance, equaling that of the pupils who were taught by the teacher (TA group). The post-test score of the CA group improved by an average of 30%, and the post-test score of the TA group by 29%. Several factors can explain these results. Certainly, one is that by interacting with an instructional hypermedia children can personalise their learning path and follow their own learning rhythms. In this way, a child who needs more time for learning a concept can navigate in the hypermedia for all the time s/he feels necessary. Considering the result of the experiment, we do not claim that Logiocando can replace the teacher, but it can certainly be considered a valid support in the process of revising and deepening knowledge on a topic.

Moreover, the experiment demonstrates that motivation affects learning through hypermedia. The motivational role of Information and Communication Technology (ICT) in learning is widely recognised (Gülşehir & Kubat, 2006): adequate resources, sufficient time and technical and social

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<td>Mean</td>
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Discussion

Table 1

Descriptive statistics of the Learning Gain in the 2 experimental conditions
support are important factors for increasing learner learning. The “new” instructional methods (“new” learning) hold that it is crucial to generate learner’s motivation: students with high motivation often outperform students with low motivation (Martens, Gulikers & Bastiaens, 2004). In other words, 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. All the pupils in our experiment had prior experience with computers but mainly in connection with video games, which are normally perceived very differently from the rigorous activity required by formal learning.

More research has been done to learn how to embed this rigour in educational software without decreasing the software’s appeal. Other systems have been developed in two different domains, Mathematics and Geometry, and other experiments have been performed in order to investigate their educational effectiveness (Faggiano, Roselli & Rossano, 2006; Pragnell, Roselli & Rossano, 2006). The results of these further studies confirm the value of our environments in increasing students’ knowledge and competence in these other learning domains. Now these systems are actually used in the classrooms of the schools in which the experiments have been performed.

Our experience certainly stresses the need for carefully controlling motivational factors in the evaluation of educational software, especially if designed for a young population.

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