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Developing strategic and reasoning abilities with computer games at primary school level

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Abstract

The paper reports a small-scale, long-term pilot project designed to foster strategic and reasoning abilities in young primary school pupils by engaging them in a number of computer games, mainly those usually called mind games (brainteasers, puzzlers, etc.). In this paper, the objectives, work methodology, experimental setting, and tools used in the project are outlined, together with an analysis of some findings.

In particular, we perform a brief analysis of some of the cognitive processes involved in playing with the computer games considered; we then discuss software features that, in our experience, help children tackle different cognitive tasks. The quantitative data collected during the pilot allow us, also, to take account of children's performance according to a number of different parameters, such as their level of achievement, the game's degree of difficulty and the type of data handled. Moreover, we reflect on the general impact of the project on children's reasoning abilities.

The extent and duration of the study mean that, whilst the findings are not generalizable, they do offer insights into mechanisms underpinning basic strategic and reasoning skills as well as the educational potentialities offered by some of the existing computer games; they also point to some areas for further research.

Keywords: Elementary education; Pedagogical issues; Interactive learning environments

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1. Introduction

It is universally recognized that one of the key tasks of education, at any level, is to foster and support the development of students' thinking skills. Among the more important areas to be developed are logical and strategic reasoning capacities, as well as critical and reflective thinking abilities for problem solving (see, for example: Baril, Cunningham, Fordham, Gardner, & Wolcott, 1998; Van Gelder, 2005). There is a debate among researchers whether and how these skills can be enhanced by specific instructional methods, since there is a lack of empirical evidence in this regard (Wolcott, Baril, Cunningham, Fordham, & St. Pierre, 2002). Nevertheless, many authors point out the importance of improving the design of research studies and intervention methods in this field (Cotton, 2001) in order to enhance students' competencies and to elicit complex thinking patterns (Wolcott, 2003). Early activities in this field at primary school level appear to be particularly important, especially if we consider that critical thinking skills develop slowly (King & Kitchener, 1994). There are grounds for believing that improving such abilities will impact on global school achievement, and on results in traditional subjects such as mathematics. Activities in this field therefore can be used by instructors "to identify building blocks from which further knowledge can be constructed" (Marshall, 2004). Appropriately, teachers are increasingly changing their approach to the teaching of the various disciplines in the curriculum, moving away from information transmission towards the construction and critical analysis of ideas and concepts.

While the fundamental role of traditional subject areas is unquestionable, it may also be interesting to explore other ways of developing logical abilities applied to strategic thinking and problem solving. ICT have proved to be a very powerful tool in this regard since many software products are available which involve abilities of this type (Riel, 1994). Here, we report a small-scale, long-term pilot project aimed at fostering strategic and reasoning abilities in young primary school pupils by engaging them in a number of computer games, mainly those usually called mind games (brainteasers, puzzlers, etc.).

Our work highlights possible pedagogical values of mind games, which appear to be useful tools in cognitive development, especially in fostering transversal reasoning skills; this is in accordance with the extensive state of the art reported by Alice Mitchell and Carol Savill-Smith (Mitchell & Savill-Smith, 2004).

What makes these tools even more interesting is that these can be used not only at school, but also (maybe mostly) in extracurricular and home activities.

2. The research project

The project, which is based on field experiments, is the result of a collaboration among ITD-CNR researchers, psychologists from Genova ASL 3 (Local Health Authority) and teachers from a primary school in Genova. ITD-CNR has a long tradition in the documentation, design and evaluation of educational software; it has also carried out a lot of ICT-based research projects based on field experiments. The specific project described here is part of a long-term research effort aimed at understanding the potential of technology for enhancing mathematical abilities (Bottino, 2004; Dettori, Ott, & Tavella, 2002) at compulsory school level; the focus subsequently shifted to logical/reasoning abilities.

2.1. Objectives

The project has two specific objectives:

- To perform a qualitative analysis, through direct observation, of the cognitive skills involved in playing with the computer games considered and to understand whether and to what extent specific features of these products can support the enhancement of such skills.
- To perform a quantitative evaluation of children's performance with the computer games according to a number of different parameters such as the children's level of achievement, the game's degree of difficulty and the type of data handled.

Moreover, the project tries to understand whether and how this kind of activity can help children develop some general reasoning abilities that could, in turn, impact on their school achievement. The extent and duration of the study mean that, whilst the findings are not generalizable, they do offer insights into the mechanisms underpinning basic strategic and reasoning skills as well as the educational potential offered by existing computer games; they also point to some areas for further research.

2.2. Working methodology and experimental setting

The field experiments were carried out in two primary school classes, which were followed from the second grade (age 7–8) to the fourth grade (age 9–10). Currently the project is continuing at fifth grade level. The primary school is located in an area of Genova affected by urban degradation, recent immigration, and unemployment; the children had little or no previous experience with computer games and none of them owned a computer. Thus, we considered it important to offer pupils an opportunity that they would have little chance of experiencing otherwise.

Each pupil had a computer at his/her disposal and used software games individually in the school's computer laboratory during class hours. Each working session lasted approximately 1 h per week, and pupils were divided into three groups (high, medium and low achievers) according to a general evaluation made by their teachers.

During the sessions, researchers and teachers followed the pupils. Their work was monitored and data were collected on performance with the different software products, i.e., the results obtained, the capacity to operate the software on one's own without outside assistance, and the attitude towards logical reasoning. For each child and for each session, a data sheet was compiled which included both quantitative and qualitative evaluation.

Different computer games were selected for each ability group according to the level of difficulty, with particular attention paid to the children's potential and to the need not to frustrate lower achievers. These products were empirically classified according to the cognitive workload of exercises proposed (very easy, easy, medium, difficult).

When a software package was composed of a number of different exercises, each single exercise was evaluated separately. Most exercises could be undertaken at different levels of difficulty, which were evaluated separately. Often the same exercise was proposed at increasing levels of difficulty, that is, a more difficult level was tackled when the child had clearly mastered

the game at the previous level. We recorded the score each child obtained in each game and also the difficulty level reached (low achievers rarely managed to reach difficult levels in most games).

2.3. Tools: the games used

The wide range of software currently available (commercially, for free, or as open source products obtainable from the web) allowed us to choose products, which are mainly, centred on basic skills, without involving subject matter abilities.

In choosing computer games, we favoured products requiring the user to devise reasoning and strategies for the solution of specific problems (Muller & Perlmutter, 1985). In particular, we selected those mind games classified in Mitchell and Savill-Smith (2004) as brainteasers or puzzlers. For example, some versions of well-known games like Mastermind, Minefield, Battleship, Chinese Checkers, Labyrinths, etc., were used as they have features and functions able to support the progression of pupils' thinking. As pointed out by Griffiths (1996), games of this type can have educational components, can be used in school in order to foster learning and can also help in overcoming some of the negative stereotypes that many people have about computer games (Okan, 2003).

Fig. 1 shows PappaLOTTO[1] a version of the classical Mastermind game where players are required to guess the exact position of parrots of various colours sitting on the hidden perch. At each attempt the player makes, the program tells the player how many parrots s/he has managed to place in the right position (black pellet) and how many are of the right colour but are sitting in the wrong position (black and white pellet). The degree of difficulty is determined by the number/colour of the parrots to be placed on the perch (here 5) and by the number of positions available on the perch (here 3).

Fig. 2 shows Hexip[2] a game similar to Battleship but with different rules. The objective of this single-player game is to find the position of ships within the hexagon-shaped board (dark boxes contain ships, light boxes are empty). The game provides information on the number of boxes occupied by ships both on the horizontal and diagonal rows of the board (the numbers outside the hexagon). The player can make inferences on the content of each box by colouring it either with light colour or with dark colour, in this case a small pellet appears in the box. Clicking on the tick in the toolbar validates the player's inferences: when an attempt has been validated, the small pellet disappears if the inferred content is correct; otherwise the system provides an error warning.

Since our data showed that performance changed according to the type of information made available to the pupils, software products were chosen to allow pupils to work with computational objects in different ways (shapes, images, moving objects, numbers, symbols, indexes, etc).

Fig. 3 shows an exercise contained in the "Viewpoints" section of the Studio 5[3] software product, which requires the user to detect how each character sitting around the table "sees" the objects placed in the middle. This is done by choosing from the images proposed at the bottom

[1] http://www.iprase.tn.it/.
[2] http://www.yoogi.com/.
[3] Studio 5, Publisher DAINAMIC Software: http://www.dainamic.be.

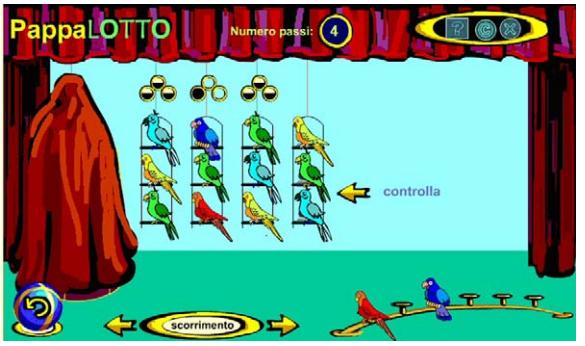

Fig. 1. Screenshot from PappaLOTTO a version of Mastermind.

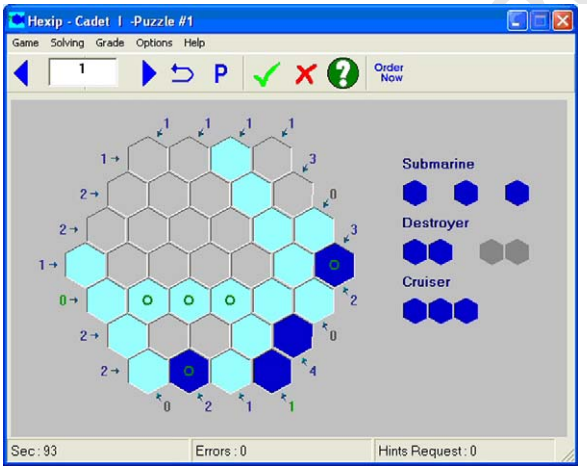

Fig. 2. Screenshot from Hexip.

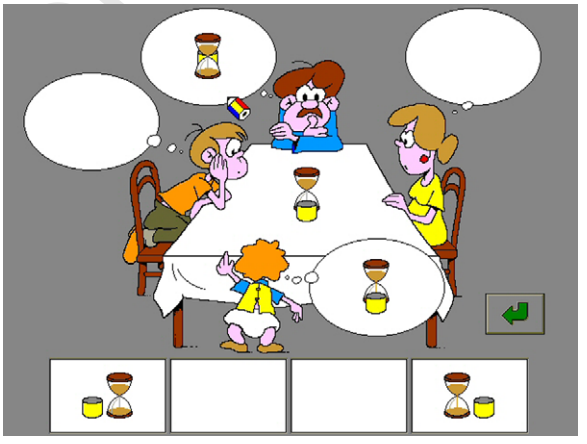

Fig. 3. Studio 5, screenshot from the "Viewpoints" exercise.

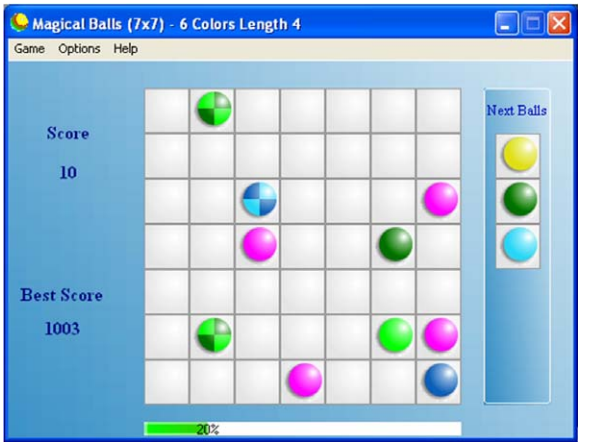

Fig. 4. Screenshot from Magical Balls.

of the screen. In this game, the logic work is strongly based on the perception of the "shapes" of presented objects.

Using the Magical Balls[4] software (see Fig. 4), the pupil operates with "moving objects", i.e., pellets automatically placed on the board; each time the player manages to line up at least four pellets of the same colour these are eliminated and the score increases: the longer is the line obtained, the higher the score. The objective of the game is to get the highest possible score before the board is completely filled. Some pellets count as two colours at the same time.

Fig. 5 shows the "Recycling" exercise from Math Blaster: in search of Spot[5]. This exercise requires the user to scroll the various columns so as to obtain an arithmetical equality: numbers that pass the "target area" will either be recycled or lost (bottom line). Once the player has managed to achieve five equalities, s/he moves on to the next level with a fresh supply of numbers. To succeed in the game, it is necessary to bear in mind that the supply of numbers at each level is limited. At higher levels, different types of operation are proposed and the position of the equal sign may change. "Recycling" was proposed to fourth grade pupils in such a way as to focus on the development of strategic skills rather than on numerical ones, which at that age level had largely been acquired by almost all pupils. The software products described above represent only a small portion of the products used during the experimentation.

3. Preliminary findings

3.1. Is it possible to identify some cognitive processes involved in playing the considered computer games?

The children in our study faced two main obstacles when playing with the games: task comprehension and construction of a solution strategy. By "task comprehension" we refer not only to the

[4] http://www.yoogi.com/.
[5] Math Blaster, Publisher Davidson & Associates: http://www.knowledgeadventure.com.

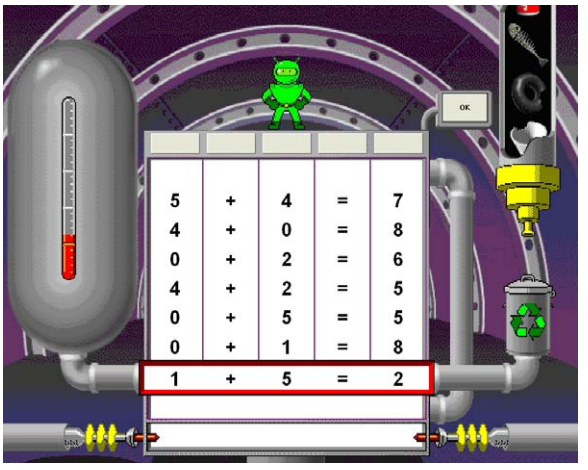

Fig. 5. Math Blaster, screenshot from the Recycling exercise.

objective to be attained but also to comprehension of the functional characteristics of tools made available for this purpose and the ability to use them effectively. For example, in PappaLOTTO (Fig. 1), task comprehension includes both understanding the goal (guessing the right colour sequence) and understanding the interface features needed to perform the task, that is the way feedback is shown (black and white pellets) and the way new guesses can be made.

This way of interpreting task comprehension is related to cognitive accessibility even though it cannot be completely identified with it. Actually, cognitive accessibility corresponds to usability/ease of use, for instance, in the matter of a consistent style of icons and buttons (Brewer, 2004).

According to Squires and Preece (1996), when looking at educational systems, it is inappropriate to consider learning and usability as independent issues. Just because an interface is easy to use, it does not mean that it is designed appropriately from an educational perspective. In this sense, there should be synergy between the learning process and the student's interaction with the software; usability features should not just allow the software to be efficiently manipulated but should also be appropriate for the intended learning task.

In our experience, the understanding and manipulation of interface features represented an important step towards the development of reasoning abilities; the ability to use these features in a coherent way was often considered an educational objective per se. Accordingly, when we selected software products, we paid particular attention to the way they propose tasks, so that we would obtain a range of a range of different possibilities: in some cases the task was presented in an explicit way, in others it was exemplified, in others the task objective was implicit and thus left to the deduction of the user (possibly helped by some features of the interface). The type of interaction with the software product was diverse, ranging from the simple and intuitive to levels of interaction that require rather complex inference processes.

For example, after a short practice, the children found easy Recycling (Fig. 5): the same was true of Viewpoints (Fig. 3). Hexip (Fig. 2), on the contrary, in most cases required additional explanations to help pupils fully understand both the task to be performed and the interface features.

The construction of a solution strategy is not straightforward; rather it implies different cognitive and sometimes interwoven abilities at different levels of complexity. Working in direct contact with pupils allowed us to identify some of these cognitive skills. For instance, it is crucial for children to be able to anticipate, i.e., to formulate hypotheses prefiguring the consequences of an action or of a series of actions. This ability varies according to the type of problem to be solved and may require different levels of abstraction. For example, after making an equality in Recycling (Fig. 5) it is necessary to anticipate mentally which numbers will be left in the columns, so as to ensure there are enough numbers left to make a sufficient number of equalities. Magical Balls (Fig. 4) directly stimulates the activity of anticipating by displaying the pellets that will be positioned on the board in the subsequent move. In some puzzles, like Hexip (Fig. 2), anticipating means that the user should be able to mentally preview the consequences of his/her moves. Other games require the user to foresee the consequences of the opponent's possible moves.

The construction of a solution strategy is also strongly based on inference skills, which allow a pupil to use available information (data, constraints, etc.) to plan future actions. For example, PappaLOTTO (Fig. 1) requires the child to understand and use the feedback provided by the program in order to infer what next move might prove effective. The difficulty of this process is related to the fact that it is necessary to coordinate all the feedback received until a given moment in order to decide what to do next.

All of the games used required the enactment of thinking skills (e.g., information processing, reasoning, and evaluation skills). Success in the games called on the pupils to think logically, take options into account, plan ahead, and consider the interaction of different outcomes (Becta, 2003).

Our experience has shown that the different games can require the user to apply specific abilities such as the ability to identify peculiar cases that can help reduce the complexity of the task. For example, in Hexip (Fig. 2) the task is certainly easier if the player can exploit the "peculiar case" of lines marked with 0 (corresponding to lines where there can be no ships). In Viewpoints (Fig. 3) the player is helped if s/he detects the case where the character is in the same position as the player with respect to the target and begins by positioning the objects as s/he sees them. In other cases, it might be necessary for the user to be able to evaluate the role played by a detail in the general frame, i.e., to be able to go beyond the contingent and, where possible, optimise efforts in view of the expected result. For example, in Magical Balls (Fig. 4) it is important to bear in mind the general picture (the degree to which the spaces on the board are filled and hence the approaching end of the game) rather than aiming to get a high score by lining up a higher number of balls. In the same way, in Recycling (Fig. 5) the general picture is important in terms of the relationship between the number of operations needed to move to a higher level and the consequence of each scrolling movement performed.

Of course, task comprehension and the ability to devise and apply effective solution strategies are not the only elements affecting the general process; a wide range of skills of different nature are also involved, such as the ability to activate working memory effectively.

3.2. Which software features can support children's cognitive processes?

Computer games are not only new and attractive types of game, they also offer a number of functions that are able to support the development of the previously mentioned cognitive skills,

thus bringing value that is unavailable with traditional tools. In particular, our experience has pointed out the crucial role played by the following software features:

- *Direct feedback* on the player's actions. Besides providing a right/wrong assessment, the feedback can support the pupil in error comprehension (Werts, Caldwell, & Wolery, 2003). The feedback can be supplied using different codes (visual, audio, etc.); it can be intended as evaluation of each individual action or of the whole solution process. For instance, the function of validation in Hexip (Fig. 2) allows immediate verification of the correctness of each move, while in Viewpoints (Fig. 3) there is only a final evaluation when the user has positioned all the "images".
- *Backtracking*, i.e., the possibility to retrace one's steps. In practice, backtracking is strictly connected to the type of feedback the software provides to the user. From a cognitive point of view it gives concrete support for anticipating processes as well as those of formulation and validation of hypotheses. For example, in Hexip (Fig. 2) it is always possible to undo a wrong move.
- *Support in the detection of the most favourable cases*. Some software products give explicit tips on how to tackle the task. Hexip (Fig. 2), for example, displays the rows where there are no ships with a zero, which is highlighted through the use of a colour other than that used for other numbers.
- *Support for anticipation*. Here, we mean not only help in activating anticipation but also in stimulating the student's attitudes in developing this skill. For example, by presenting the pellets of the subsequent move in advance, Magical Balls (Fig. 4) invites the student to bear in mind both the current and the future situation.
- *Support for memorization or for performing specific actions*. These functions are made available through various means: the possibility to review previous moves and to visualize useful elements for subsequent moves, etc.
- *Graduation in the level of difficulty*. Progression in the level of difficulty may be determined by the user or teacher, or may be the automatic consequence of user performance. For example, in Recycling (Fig. 5), the user (or the teacher) can choose which of the four operations to work on, or choose to work with all four of them together and to define the order of magnitude of numbers. In some cases, graduation in the level of difficulty simply helps set the exercise to suit the user's potential, while in others it also represents a stimulus for the construction of progressively more complex strategies.
- *Specific tips*. At the user's request, some software products show how to make the next move.

To support cognitive processes effectively, all these software features must be carefully weighed up in view of the type of student and his/her skills. Backtracking and specific tips, for example, are certainly important in the phase of constructing the solution strategy, but can also be used by the student to reduce effort and reach the solution by trial and error. Thus, it would be preferable for the software to provide the teacher with the option of deactivating such assistance.

3.3. How do children perform with the games?

The results from to the third year of the experimentation (fourth grade of primary school) from our structured observations are now discussed. Performance was scored on a range from 1 to 5

(1 for poor performance and 5 for very good); this score was assigned on a single exercise basis and took into account both the results obtained and the pupil's autonomy in performing the task.

The first observation we can make is that pupils' performance closely matches the three ability levels initially suggested by class teachers. In Table 1, the pupils are arranged according to a

Table 1
Pupils' classification according to a global performance index

Pupil's level	Initials	Index score
High	AO	81
H	MF	78
H	CB	75
H	DA	75
H	LU	74
H	VA	74
H	RU	70
H	MR	69
H	JC	68
H	GR	68
Low	CH	63
L	MA	61
L	SP	56
L	SI	51
L	EC	50
L	LA	46
L	AS	44
L	JS	43
L	AX	37
Medium	RO	68
M	XE	65
M	MZ	65
M	AA	65
M	GI	65
M	CP	64
M	VO	63
M	MT	63
M	IS	63
M	AT	62
M	DL	62
M	AM	61
M	FJ	60
M	AP	60
M	GL	59
M	GP	58
M	SM	58
M	SB	57
M	AS	56
M	CL	56
M	OR	55

global numerical index of performance, which is calculated according to how many times each score was obtained at the different difficulty levels.

According to the global performance index, the ability levels that the teachers defined were substantially confirmed even though there are some overlaps: one student in the medium group reached 68 as did two students in the high group, while three low achievers obtained a higher score than some of the medium achievers. This overlap could be ascribed to the difficulty of dividing exactly the children into three distinct ability groups, especially considering that the children belonged to two different classes.

Table 2 shows results obtained by the three groups of pupils according to the difficulty of the software used. Two remarks can be made here:

(a) the only target population showing clear difficulty in performing the proposed activities is that of the low achievers, even though they were given games appropriate to their level;
(b) only high achievers performed well at the difficult level of almost any game.

The data in Table 2 show the pupils' scores divided into three performance levels: high (scores $\geqslant 4$), medium (scores between 3 and 4), and low (score between 1 and 3). The number of children engaged with the software at the different difficulty levels is also recorded. This number varies because in many cases students moved on to more difficult levels only after mastering easier levels.

The high achievers all performed well at the medium and difficult level, while at the easy level two of them obtained a lower score. This fact can be explained in different ways: for example the two students concerned may have initially underestimated task complexity and subsequently tackled the games in a haphazard way, or they may have had initial difficulty in understanding the rules and in figuring out appropriate solution strategies. However, once this moment was overcome, they managed to devise and implement successful strategies and adapt them to suit more difficult levels. On the contrary, medium achievers appear less able to adapt the previously figured out strategies when exercise difficulty increases (column five shows that only three medium achievers and one low achiever played with difficult games).

Table 3 reveals some differences in the performance of the three groups of children (defined by the teachers at the beginning of the experience) when interacting with the games at the easy and medium level (the only two levels common to the three groups).

The percentage of pupils obtaining good (score $\geqslant 4$), medium (score $3 \leqslant <4$) and poor results (score<3), show that when working with medium exercises, all high achievers reach the top level, while only 45% of medium achievers managed to do the same. It comes as no surprise that only 44% of low achievers could manage medium tasks (22% reaching the top level and 22% the medium level), while the remaining 56% could not progress beyond the easy exercises. Our observations suggested that even when low achievers (as categorised by the teachers) had understood the aim and rules of the game, they were not necessarily able to figure out and apply effective solution strategies.

Table 4 underlines that pupils' performance depends not only on exercise difficulty but also on the type of data to be handled. Only some of the games deal with numerical data, while other games are based on shapes, or imply reasoning tasks that do not involve numbers. Actually,

Table 2
Scores obtained by the three groups of pupils, according to the difficulty of the SW used

SW difficulty level	Number of pupils with score $\geqslant 4$	Number of pupils with $3 \leqslant$ score <4	Number of pupils with score <3	Number of pupils engaged in the level of SW difficulty
Results obtained by the 9 high achievers				
Easy	7	2	0	9
Medium	9	0	0	9
Difficult	9	0	0	9
Results obtained by the 22 medium achievers				
Easy	17	5	0	22
Medium	10	12	0	22
Difficult	1	2	0	3
Results obtained by the 9 low achievers				
Very easy	2	6	1	9
Easy	2	5	1	8
Medium	2	2	0	4
Difficult	1	0	0	1

Table 3
Percentage results according to achievement group

Children by ability level	Percentage of pupils with score $\geqslant 4$ (%)	Percentage of pupils with $3 \leqslant$ score <4 (%)	Percentage of pupils with score <3 (%)
Results for easy exercises			
High achievers	78	22	0
Medium achievers	77	23	0
Low achievers[a]	22	56	11
Results for medium exercises			
High achievers	100	0	0
Medium achievers	45	55	0
Low achievers[a]	22	22	0

[a] When considering the percentage of low achievers, it is necessary to take into account that some pupils in this group did not use the exercises at the considered levels.

Table 4
Results of high achievers by software difficulty level and type (numerical and non-numerical)

Software type	Very easy	Easy	Medium	Difficult
Average score results of high achievers				
Numerical SW	–[a]	4.5	4.4	3.8
Non-numerical SW	4.7	4.2	4.5	4.7

[a] High achievers did not use the exercises at the very easy level.

Table 5
INVALSI mathematics test – normalized scores for each fourth grade class of the considered school

Class	Mean	Standard deviation	Minimum score	Maximum score
Class A (experimental)	72.80	15.87	32.14	92.86
Class B	53.57	16.86	35.71	82.14
Class C	56.55	18.99	25.00	89.29
Class D (experimental)	63.03	21.43	21.43	92.86

the ''numerical'' exercises used involve working with numbers and basic calculations but were chosen for the required reasoning skills and not for the computational abilities required.

The ''numerical'' games appear to be more difficult even for high achievers, as shown in Table 4: high achievers at the difficult level obtain an average score of 3.8 with numerical software and an average score of 4.7 with non-numerical ones.

3.4. Does the use of logical games impact on pupils' reasoning abilities?

The school in which the project was run in 2004 was included in a national assessment plan in which individual students from each class were tested using the same set of tests. This plan was carried out by INVALSI[6], the Italian National Evaluation Institute of the Ministry of Education, and in 2004 involved more than 71,000 classes and approximately 1,400,000 students. Specific tests were administered for language and science, and also for mathematics, including logical reasoning items. The results were processed by INVALSI and made available in normalized forms.

We considered the results obtained in the INVALSI plan by students in the two fourth grade classes in our project (in the following, ''experimental classes'' who had undergone three years of experimental activity) and compared these with the results obtained by the other two fourth grade classes at the same school.

The results in math tests obtained by the fourth grade classes at the school (four classes) are lower (average score: 60.75) than those at regional (average score: 70.02) and national (average score: 72.29) level.

Looking in detail at the scores of the four fourth grade classes (Table 5), we can see that the experimental classes show better average results than the other two classes.

Table 6 shows the INVALSI data by students divided into four ranks according to the scores obtained[7]

It can be noted that in both experimental classes we find a meaningful percentage of students in the highest rank (23.08% and 23.53% against 0% and 5.56%). Moreover, in the experimental classes there are fewer students in the low rank (in percentage) than in those of the other classes (7.69% and 52.94% against 75% and 55.56%).

If we sum the results of the two higher ranks, the difference between the experimental classes and the others is equally evident (summing up the data of the two high ranks of the experimental

[6] http://www.invalsi.it.

[7] Low rank: $0 \leqslant$ score $\leqslant 58$; low-medium rank: $58 <$ score $\leqslant 79$; medium-high rank: $79 <$ score $\leqslant 86$; high rank: $86 <$ score $\leqslant 100$.

Table 6
INVALSI mathematics test – percentage of students in the four ranks for each fourth grade class of the considered school

Class	% Low rank students	% Low-medium rank students	% Medium–high rank students	% High rank student
Class A (experimental)	7.69	53.85	15.38	23.08
Class B	75.00	12.50	12.50	0
Class C	55.56	27.78	11.11	5.56
Class D (experimental)	52.94	17.65	5.88	23.53

348 classes we find that 38.46% and 29.46% perform at these levels against the 12.50% and 16% from
349 the other classes). Analysis of the global percentage of lower ranks provides a similar picture.
350 INVALSI data can be read as a confirmation that well structured and long-term activities based
351 on the use of logical games can have a positive impact on pupils' reasoning abilities. Of course,
352 this is only a preliminary finding that requires further investigation and research.

353 **4. Additional remarks**

354 The results so far obtained, lead us to be confident about the positive impact of the proposed
355 activities on pupils' logical and strategic reasoning skills. In addition, from a pedagogical stand-
356 point, it can be noted that, in general, pupils have understood that working at random, even when
357 playing, is not productive, and that in order to solve a problem, they have to establish a working
358 strategy and apply it correctly, even though this activity might be quite demanding in terms of
359 attention and effort. By evaluating the behaviour of pupils involved in the experience and compar-
360 ing it with that of other pupils, the teachers have also observed that the work done affected their
361 global attitude even towards tasks pertaining to other curricular subject matters. Moreover, the
362 use of software packages effectively mediates the relationship between pupil and teacher, a rela-
363 tionship that, despite the introduction of technological tools, still plays a fundamental role. When
364 the teacher asks the pupil to explain what they are doing and how they think they will solve a
365 problem, the empirical knowledge used when playing becomes a strategy that can be expressed,
366 transmitted and discussed.
367 The positive evaluation of this experience by teachers is confirmed by its extension to other clas-
368 ses of the school without the intervention of the research team.
369 In this paper, the research project has been analysed mainly in terms of cognitive aspects
370 involved in problem solving. However, it has also been highlighted that the children's cognitive
371 activity is strongly affected not only by personal skills and attitudes (Felder & Soloman, 2004)
372 but also by behavioural, affective and emotional factors (Apollonia, Micheletto, & Seletti,
373 2000). We refer to factors like attention, concentration, motivation (both when connected to play
374 and to computer use) which are universally considered important, and also to transitory factors
375 such as anxiety, tiredness, need for continuous confirmations by adults, etc.
376 In addition to these, our experience points to the role played by other factors related to the stu-
377 dent's individual make up, such as the need for order, the wish to attain good local results even to

the detriment of global performance, concern for aesthetics, the degree of familiarity with the computer, the tendency to underestimate or overrate the task, etc.

The links between cognitive processes and "affective" factors call for a more in-depth investigation not only at the theoretical level, but also at the practical level to plan and manage effective educational itineraries aimed at developing reasoning skills.

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