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The Impact of Mind Game Playing on Children’s Reasoning Abilities: Reflections from an Experience

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Abstract: The paper aims at contributing to the understanding of whether digital games can be considered suitable and effective tools for enhancing learning. It thus aims at providing grounds for reflecting if their school use can provide a significant added value with respect to traditional school activities. The paper draws on a long-term research experience carried out in primary schools with the specific aim of studying the impact of the use of mind games (puzzles, brain teasers...) on children’s reasoning abilities and problem solving skills. Early activities in this field at primary school level, appear to be particularly important since reasoning and problem solving abilities are universally acknowledged to be “key skills”, transversal to any kind of learning and there are grounds for believing that improving such abilities will impact on the global school achievement.

The hypothesis that a teacher driven and well focused use of carefully selected mind games can have a positive impact on students’ reasoning abilities is put forward. A number of reflections and observations are outlined, based on both the analysis of the quantitative results of students’ performance and on the teachers’ opinion on the impact of the experimental activities on pupils’ school achievement. From a quantitative point of view, the results of a standardized test carried out at national level, revealed, in fact, that students who had undergone three years of experimental activities with games, performed better at the mathematics test (which also included logic items) with respect to those of two matched classes. Such results also showed that high achiever students seemed to have benefited from the work with games more than low achievers. Beside the encouraging test results, from a more qualitative standpoint, personal opinions and individual findings of the school teachers involved in the project seem to confirm that, following the extensive use of logical games, positive effects were observed both on the students’ attitude towards learning and on their global school performance.

Keywords: Games based learning, mind games, reasoning abilities, primary school.

1. Introduction

The research field of games based education appears to be promising: many authors acknowledge, in fact, that games have a great potential to foster learning (Kriemuir & McFarlane 2004; Mitchell & Savill-Smith 2004; de Freitas 2006). Nevertheless, the assumption that games can have a potential for enhancing learning, taken as such, is much generalized and more in-depth analyses seem to be required. Many different types of digital games, in fact, exist and, what is more, they can be used for a number of different educational purposes (Pivec 2007). In order to analyze the educational potential of games, specific studies are required to assess if and to what extent clearly identified educational objectives can be attained through the use of games and which types of games best serve such objectives. In this paper we consider the use of those games that are usually defined as “mainstream” in that they are explicitly designed for entertainment and not for training or for instruction (Garris et Al. 2002, Dondi & Moretti 2007).

In particular, the use of mainstream games for developing reasoning abilities in primary school children is addressed. More specifically, those games that are usually called mind games, puzzle games or brain teasers (Mitchell & Savill-Smith 2004) are considered. The use of mainstream mind games is studied from the point of view of their potential for supporting students’ reasoning abilities and problem solving skills in clearly identified tasks.

There is a debate among researchers whether and how reasoning and problem solving skills can be enhanced by specific instructional methods, since there is a lack of empirical evidence at this regard (Wolcott et Al. 2002). Nevertheless, many authors point out the importance of improving the design of research studies and intervention methods in this field (Cotton 1991) in order to enhance students’ abilities and to elicit complex thinking patterns (Lohman 2005). Early activities in this field at primary school level appear to be particularly important and there are grounds for believing that improving such abilities will impact on global school achievement, and on results in traditional subjects such as mathematics. The research question whether mind games can be considered as suitable tools for
supporting reasoning abilities has not been yet fully addressed. As a matter of fact, if, from one hand, the fact that logical and reasoning skills can be developed by playing games is generally accepted (see, for example, McFarlane et al. 2002; Kilili 2007), from the other hand, very few research studies explicitly focus on the use of mind games to this end. In the same way, mind games are not frequently studied from the point of view of the learning outcomes (Facer et al. 2007), even if it has been far-back recognized that they can be used in schools to foster learning (Griffiths 1996). In the following, drawing on a small-scale, long-term research project focused on the use of mind games with primary school students, considerations are proposed as to the suitability of such tools to enhance reasoning and problem solving skills. The discussion of some data collected during the project complements these considerations.

2. The research project

2.1 Aims

The research project was carried out over the last five years in Italian primary school classrooms. The project was primarily aimed at fostering students’ strategic and reasoning abilities by introducing systematic use of a number of selected computer-based mind games in classroom activities. The basic idea underpinning the project was that of investigating, from a qualitative point of view, which games and methods are better suited for developing children’s reasoning abilities (outside the development of disciplinary content and knowledge).

Aims of the project were to identify a number of suitable mind games, to analyse which specific reasoning abilities are supported by the use of such games and to understand which software characteristics and functions better support students in the enactment of their reasoning and problem solving strategies. In (Bottino & Ott 2006) we have analyzed some of the cognitive abilities involved with the use of a selection of mind games used during classroom experiments while in (Bottino et al. in progress) we have discussed mind games’ interface and design characteristics that make them more or less fruitful for educational purposes. In this paper we provide some indications on the possible impact of mind game playing on children’s scholastic performance drawing on data collected during classrooms activities.

The study of the impact of mind games use on students’ general scholastic performance was not an explicit objective of the project. Nevertheless, since the school in which the project was run was included in a national assessment plan, we had the opportunity to analyze the results of such assessment as to the students of the two fourth grade classes involved in the project and to compare these with the results obtained by the other two fourth grade classes of the school which had not taken part in the experimental games activities. As a matter of fact, the school had four fourth-grade classes following the same curriculum implemented by the same team of teachers, but attending a slightly different number of weekly school hours. The two experimental classes were those that followed the longer weekly timetable, no significant difference among the four classes was pointed out by the teachers, in particular as far as curricular results are concerned. In this paper we present data on such comparison and make some initial considerations regarding the results obtained. Preliminary to this, we also briefly describe the main features of the first phase of the project, the work methodology adopted and the type of games used.

The project was carried out by a group of researchers involving educational technology researchers (from ITD-CNR), psychologists from Genoa ASL 3 (Local Health Authority) and primary school teachers. It is subdivided into two phases. In the first phase two classes (involving around 40 children) of the primary school Dante Alighieri in the Genoa district used mind games in computer sessions carried out during school hours. The second phase of the project, which is still in progress, involves a larger sample of children (around 300 pupils) belonging to different primary schools and districts. In the following, we mainly refer to the first phase of the project where approximately the same children (with a few new arrivals and withdrawals each year, in each class) were followed over a period of four years, from the second grade (age 7-8) to the fifth grade (age 10-11).

2.2 Working methodology

A number of different games were selected taking into account the different abilities required by each game, its general appropriateness with respect to children’s age, and the its specific interface features. This means that during the whole duration of the project each child played individually with a
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A significant number of different games. As said above, around 40 children (belonging to two fourth level classes of the same school) participated to the experiment. The students were divided into three groups (high, medium and low) according to a general evaluation of their school achievement made by teachers. Each group (composed of 5-6 pupils) attended in turns a computer session of approximately one hour per week, during a six month period for each school year. The computer sessions were carried out in the school computer laboratory during normal class hours. At the outset of each session, one of the researchers explained the game at hand to the whole class. Each pupil had a computer at his/her disposal and played with the game individually. The pupils played with the same game for the duration of the session and each game was used by the same child for at least two sessions. The children were, thus, engaged in repetitive play over time, thus tackling each game according to a multi-trial and multi-level approach. This approach was important because it allowed involvement of the pupils in a game cycle in which the recurring judgment-behaviour-feedback loops can lead to better acquisition of target skills (Garris et al. 2002).

During the work, each pupil was followed individually by a member of the research team, whose task was that of monitoring his/her activity, intervening where necessary, and completing observation sheets after each session. The observations sheets included both quantitative and qualitative evaluation of the child performance and of his/her behaviour. The quantitative data were different for each game but, generally speaking, accounted for the score obtained (if any), the difficulty level reached, the number of attempts made. The qualitative data included evaluations (made on the basis of a Likert scale) of child’s autonomy (in playing the software game), attitude (interest, attention, motivation), and of the number and kind of hints received. The observation sheets also reported the researcher’s observations on the specific difficulties/abilities demonstrated by each pupil, the solution strategies used, and the ability to verbalize the undertaken solution procedure.

2.3 The games used

The choice of the games to be used can be considered one of the key aspects of the project. In principle, the basic idea underpinning the project was that of employing tools requiring the user to genuinely exercise reasoning skills and to design/enact solution strategies in order to solve specific problems (Muller & Pearlmutter 1985).

As to the type of games to be used, mainstream mind games were chosen, that is software not specifically designed for educational purposes, and deeply involving reasoning skills. Among the products selected, were versions of well-known mainstream games such as Mastermind, Minefield, Battleship, Domino, Labyrinths, etc. Such games are classified by Mitchell & Savill-Smith (2004) as ‘brainteasers or puzzlers’. In particular, those games were considered that Prensky (2005) calls "mini-games", (namely, "games that take less than an hour to complete (often far less), and whose content is simple and one-noted"). These characteristics are, in fact, important when the use of games takes place during school hours. Other types of games can require a substantial and prolonged time investment which stretches play well beyond the span of a typical single-class unit (Becker 2007).

Globally, more than one hundred mind games (mainly freeware, shareware and open source products) have been analyzed for the project and about half of these were actually used by the children. The selection process also required a careful analysis of software interfaces and contents. Although belonging to the same category (that of mainstream mind games), the games examined, in fact, presented significant differences as to the type of activities in which they engage pupils, the type of user interface, the modalities of interaction and the type/level of cognitive abilities required to perform the proposed tasks.

Since it is unquestionable (Bottino et al. in progress) that some intrinsic features (related both to the way in which the computer game has been designed and to the way in which the interface is implemented) can support and foster students' cognitive effort while others can hinder or slow down the cognitive process, only games presenting a number of characteristics that make them more suited for educational purposes have been chosen. The possibility of graduating the required cognitive effort, the availability of hints aimed at concretely supporting cognitive effort and the lack of elements potentially producing interferences with the main cognitive activity, were all considered important features together with the presence of facilities orienting the cognitive effort towards verification activities and fostering users' performance self-evaluation. Attention has also been given to select games appropriate for the target population, clearly understandable for new players and offering a...
reasonable degree of challenge (Ang et Al. 2006) where users do not perceive the role of luck as predominating over their own effort (Dondi & Moretti 2007).

3. Reflections from the experience

An analysis of the cognitive skills required to “solve” the selected games was performed during the project (Bottino et Al. 2007; Bottino & Ott 2006). We cannot provide account here of such detailed analysis since, to describe the specific abilities involved, it is necessary to explain the way in which each game works, and this it is not possible for space reasons. Nevertheless, in Table 1, we have summarized some general cognitive abilities and skills that are subsumed by the use of the chosen mind games.

Table 1: Some reasoning and problem solving skills that can be fostered by the use of mind games

<table>
<thead>
<tr>
<th>Reasoning and Problem Solving Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysing given data to reach a goal</td>
</tr>
<tr>
<td>understanding the goal of the game and its rules (how it is to be played)</td>
</tr>
<tr>
<td>individuating peculiar or specific cases that can be used to reduce the complexity of the task</td>
</tr>
<tr>
<td>matching available information and constraints in order to make inferences.</td>
</tr>
<tr>
<td>Adapting to different situations according to changing data and constraints</td>
</tr>
<tr>
<td>learning to rearrange previously conceived strategies according to changing data and constraints.</td>
</tr>
<tr>
<td>Formulating and verifying a hypothesis</td>
</tr>
<tr>
<td>making inferences on the basis of a hypothesis/validation process</td>
</tr>
<tr>
<td>reformulating a conjecture on the basis of the result of the validation process enacted</td>
</tr>
<tr>
<td>Looking forward and anticipating</td>
</tr>
<tr>
<td>taking different possibilities into consideration</td>
</tr>
<tr>
<td>mentally anticipating the consequences of a move by considering not only the current data setting but also possible future configurations</td>
</tr>
<tr>
<td>evaluating the role played by a single move in the general frame, that is, learning to go beyond the contingent and, where possible, optimise efforts in view of the expected result.</td>
</tr>
<tr>
<td>Conceiving a solution strategy</td>
</tr>
<tr>
<td>going beyond trial and errors strategies</td>
</tr>
<tr>
<td>generalizing from concrete and specific cases</td>
</tr>
<tr>
<td>understanding that working at random, even when playing, is unproductive</td>
</tr>
<tr>
<td>understanding that in order to solve a problem it is necessary to establish a working strategy and to apply it correctly, even though this activity might be quite demanding in terms of attention and effort.</td>
</tr>
<tr>
<td>Using the feedback provided</td>
</tr>
<tr>
<td>reasoning backward, and considering all the feedback already obtained in order to identify if any incongruence has occurred.</td>
</tr>
<tr>
<td>Revising the work done</td>
</tr>
<tr>
<td>developing attitude to reconsider and modify the work done</td>
</tr>
<tr>
<td>identifying the key points to be revised</td>
</tr>
<tr>
<td>Orienteering in the space and discriminating visual stimuli</td>
</tr>
<tr>
<td>mentally manipulating two or three dimensions figures</td>
</tr>
<tr>
<td>perceiving and individuating visual patterns and clues</td>
</tr>
</tbody>
</table>

It is worth noting that the development of reasoning and problem solving abilities is also affected by behavioural, affective and emotional factors: attention, concentration, motivation, anxiety, tiredness, need for continuous confirmation from adults, etc.

In addition to these, our experience points to the role played by other factors related to the student’s personal skills and attitudes (Felder & Solomon 2004), 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 analysis of the cognitive skills involved in the use of games and of related factors led to the definition of models and methods for choosing the most effective mind games (Bottino et Al. in progress) and making the best possible use of them for supporting reasoning abilities.
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This type of in-depth analysis proved useful for highlighting the strengths and weaknesses of each child involved in the study and made it possible to set highly personalized tasks for extending and reinforcing their abilities. Consequently, over the duration of the project, it was possible to develop personalized support to foster those abilities that the children lacked or were weak in.

During the project lifespan, the idea emerged that a teacher driven, well focused and structured use of mind games can have a positive impact on students' reasoning capabilities; even so, it is not yet possible to give a definitive answer to the question (which was outside the scope of the project) whether and to what extent mind games can be considered suitable tools for supporting reasoning skills, but some significant steps in this direction have been done.

The hypothesis that the experimental work carried out in the framework of the research project had a positive impact on children's abilities and on their overall school achievement was supported by both the results of a national assessment study and by on-field observations made by the teachers involved in the project.

3.1 Results of a national assessment study

In the last year of the first phase of the project (2004), the school in which the project was run, 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 byINVALSI (www.invalsi.it), the Italian National Evaluation Institute of the Ministry of Education, and, in 2004, it involved more than 71,000 classes and approximately 1,400,000 students.

Specific tests were administered for language, science and mathematics (including logical reasoning items). The results were processed by INVALSI and made available in normalized form.

We considered the results obtained in the INVALSI tests by students in the two fourth grade classes in our project (in the following, "experimental classes", which 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 having the same teachers.

Looking in detail at the scores in the mathematics test of the four fourth grade classes (Table 2), we can see that the experimental classes show better average results than the other two classes.

Table 2: INVALSI Mathematics test - Normalized scores for each fourth grade class of the considered school.

<table>
<thead>
<tr>
<th>Class</th>
<th>Mean</th>
<th>Standard dev.</th>
<th>Min. score</th>
<th>Max score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A (experimental)</td>
<td>72.80</td>
<td>15.87</td>
<td>32.14</td>
<td>92.86</td>
</tr>
<tr>
<td>Class B</td>
<td>53.57</td>
<td>16.86</td>
<td>35.71</td>
<td>82.14</td>
</tr>
<tr>
<td>Class C</td>
<td>56.55</td>
<td>18.99</td>
<td>25.00</td>
<td>89.29</td>
</tr>
<tr>
<td>Class D (experimental)</td>
<td>63.03</td>
<td>21.43</td>
<td>21.43</td>
<td>92.86</td>
</tr>
</tbody>
</table>

Table 3 shows the INVALSI data by students divided into four ranks according to the scores obtained (Low rank: 0<= Score <= 58; Low-Medium rank: 58< Score <= 79; Medium-High rank: 79<Score <= 86; High rank: 86< Score <= 100).

Table 3: INVALSI Mathematics test - Percentage of students in the four ranks for each fourth grade class

<table>
<thead>
<tr>
<th>Class</th>
<th>% low rank students</th>
<th>% low-medium rank students</th>
<th>% medium-high rank students</th>
<th>% high rank student</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A (experimental)</td>
<td>7.69</td>
<td>53.85</td>
<td>15.38</td>
<td>23.08</td>
</tr>
<tr>
<td>Class B</td>
<td>75.00</td>
<td>12.50</td>
<td>12.50</td>
<td>0</td>
</tr>
<tr>
<td>Class C</td>
<td>55.56</td>
<td>27.78</td>
<td>11.11</td>
<td>5.56</td>
</tr>
<tr>
<td>Class D (experimental)</td>
<td>52.94</td>
<td>17.65</td>
<td>5.88</td>
<td>23.53</td>
</tr>
</tbody>
</table>

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 classes we find that 38.46% and 29.46% perform at these levels against the 12.50% and 16% from the other classes). Analysis of the global percentage of lower ranks provides a similar picture.

Considering the results at the language test of the four fourth grade classes (among which the two experimental ones) we saw that there were not meaningful differences among the experimental and non-experimental classes; moreover, looking at the corresponding distribution of students in the four ranks (low, low-medium, medium-high, high) according to the scores obtained, we did not find a meaningful percentage of students in the highest rank correspondingly to what happened for the mathematics test.

3.2 Teachers' observations

It is worth noting that teachers gave a positive evaluation of the experience as it is confirmed by the fact that most of them, after the project end, autonomously extended the use of games to other classes.

From a qualitative point of view, during classroom experience, researchers and teachers agreed that most of the children, irrespective of their own level of ability, seemed to have grasped the importance of:

- Studying the problem at hand by identifying and carefully analyzing their key elements.
- Revising the work done before finalizing it.
- Trying to mentally anticipate the actual consequences of actions, predicting forthcoming events.
- Performing a task by giving the priority to precision and correctness with respect to execution velocity.
- Making explicit (even orally verbalizing) actions to be done.

In addition it was noted that almost all the students had understood that working at random, even when playing, is not productive, and that, in order to solve a problem, they have to establish a working strategy and apply it correctly, even though this activity might be quite demanding in terms of attention and effort.

4. Conclusions and open questions

The data presented above and the opinions expressed by teachers seem to support the idea that students involved in the experimentation benefited from the long-term school activities based on the use of specific and carefully selected mind games.

Further experimental confirmations are nevertheless required for providing evidence that a well focused use of specific mind games can foster students' reasoning and problem solving abilities and that these abilities may have, in turn, a positive impact on students' school performance.

As to the first aspect - that is if specific mind games can foster students' reasoning and problem solving abilities - the second phase of the project will, hopefully, provide more detailed answers and ground for more in-depth reflections. Following the second phase of the project, in fact, a more fine grained analysis of the reasoning abilities required for playing with mind games will be made available as well as the quantitative analysis of students' performance with such games. This analysis will be done on the basis of a wider number of involved pupils with respect to the first phase of the project. The validation of related tests will allow to properly "rank" the actual difficulty levels of the abilities involved.

As to the impact of reasoning abilities on students' school performance, the question is still open whether cognitive skills are transferable and which are the conditions for this "transfer" (Billing 2007).

Billing pointed out that such transfer is not automatic but should be supported by the pedagogical context in which such skills are developed. At this end, a crucial role is played by teachers and by the way in which the activities are designed and managed. For example, it is important to fix learners' attention on how afforded problems and tasks resemble each other and on the underlying structure of comparable problems. It is also necessary to make students' aware of how to apply similar strategies in different contexts and to stimulate their verbal explanation of enacted strategies.
The teachers' role is crucial both in planning and managing the activities with games and in integrating them in a wider educational plan. In such a plan the use of games needs to be supported and backed by other activities (both ICT-based and not) that necessarily have to be more strictly related to disciplinary content and curriculum objectives.

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