IEEE computer society

2012 12th IEEE International Conference on Advanced Learning Technologies

Reasoning on reasoning through serious games

R.M Bottino, M. Ott, M. Tavella

Istituto Tecnologie Didattiche (ITD) - Consiglio Nazionale delle Ricerche (CNR) Genova, Italy

Abstract — This paper, based on a long term experience conducted in primary schools, investigates the cognitive abilities involved in playing with digital mind games. The experimental work with pupils was first focused on game dynamics and aimed to identify some general cognitive skills required to children to successfully interact with the games. Subsequently, a more detailed investigation was carried out focusing on the actual cognitive abilities required to solve specific reasoning tasks proposed in a variety of selected mind games. The different number of information to be taken into account and processed while tackling each reasoning task appeared to be the key element that differentiates pupils' performance. This finding was in-depth analysed also in respect to the children's level of school achievement and some considerations were drawn confirming the potential of mind games for developing young students' reasoning abilities and also paving the way for better tuning related game-based interventions, from a methodological standpoint.

Keywords—Technology Enhanced Learning; game-based learning; cognitive skills, reasoning abilities, logical thinking

I. INTRODUCTION

Contemporary education is strongly focused on the development of those "horizontal, cross-disciplinary, not subject-based" competences that are also called "transversal" or "key skills". Digital tools (including digital games) are widely considered high-potential educational tools in this respect [1]

Recently, the EU Commissioner Vassiliou [2] has pointed out the actual potential of digital tools to sustain the cognitive abilities related to both "the use of various types of reasoning (inductive, deductive, etc.)" and "the solving of different kinds of non-familiar problems", abilities that are regarded as "crucial transversal competences" necessarily needed nowadays and "requiring the enactment of specific educational actions.

This paper investigates the cognitive abilities involved in playing with digital mind games, with the final aim of shedding light on whether these tools can be used to support the actual development of logical and reasoning transversal skills starting from the earliest stages of formal education

(e.g. primary schools). In doing so, it draws on a long-term experience carried out by the authors in primary schools. In the first phase of the experience, a group of around 40 students was followed for three years and directly monitored by the research group while playing with a variety of different mind games (more than one hundred) with the main aim of understanding the general suitability of the gaming environments in sustaining the children reasoning attitudes and abilities [3]; in the second phase, the research was more in-depth focused on the analysis of the specific reasoning abilities triggered by a set of selected digital mind games and a norm–referenced test (based on results obtained by around 500 students), the LOGIVALI test, was developed [4]

During the two research phases, performance and attitudes of the children were in-depth analysed, and particular attention was given to recognise the cognitive skills involved in playing. A first outcome of the work is that it is important to distinguish between those abilities related to game dynamics at large (contextualizing game features and scope, learning and understanding game mechanics, learning to fruitfully move and act, etc.) and those more specifically related to the actual reasoning process required by each reasoning task at hand.

As an example, in HEXIP one of the mind game adopted (http://www.yoogi.com/hexip.htm), the overall task is positioning all the available ships (on the right) in the hexagonal board (Fig.1); this should be done taking into account the numbers external to each row/diagonal indicating how many ship pieces are to be placed and making hypothesis on possible ships positions. In order to solve this game, the children have to reason on row/diagonal positions and they also need to form a general understanding of the game mechanics and of the overall playing dynamics (e.g. where to start positioning ships, how to get a global view of the ships that haven't yet been positioned, etc.). In the following, we briefly summarize the results obtained so far as to both the general and specific cognitive skills required to solve this type of game.

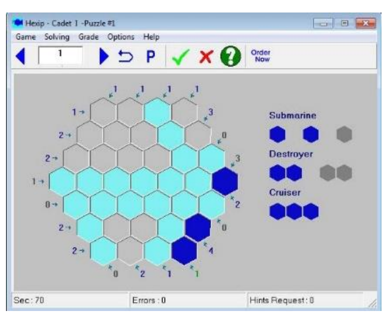


Fig. 1 Hexip: screen shot of one of the adopted mind games

II. COGNITIVE SKILLS AND GAME DYNAMICS

As discussed elsewhere [5], the field experiments pointed out the importance of the following skills:

a) Understanding and mastering the game rules. The amount of cognitive effort required mainly depends on the design and interface features of the game and on the educational approach adopted by educators (e.g. side explanations and context of use).

978-0-7695-4702-2/12 $26.00 © 2012 IEEE DOI 10.1109/ICALT.2012.225

b) Analysing available data and identifying those allowing the game solution to be reached. For example, particular cases can be identified to reduce the complexity of the task. For instance, in HEXIP (Fig.1) the task is much easier if the player first identifies the "peculiar case" of lines marked with 0 (no ships). In most games a careful analysis of the feedback provided by the software is also crucial to solve the task.
c) Mentally anticipating future game events on the basis of current data. In most games the ability to mentally anticipate the consequences of each move is key to reach the solution; this implies considering not only current data settings but also possible future configurations.
d) Formulating and verifying hypotheses. A further step is the ability of making hypotheses and verifying their effectiveness (some games supports this possibility with specific features).
e) Revising the work done. This attitude emerged as being very important in all the games.

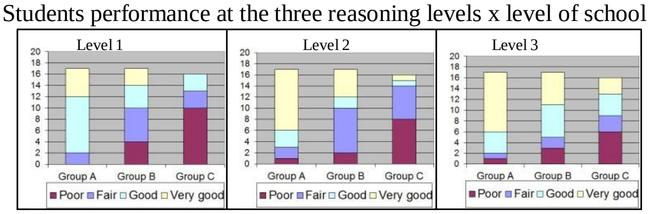
The research work allowed to point out that even if some of these abilities are initially mastered by few children the extensive and pedagogically focused use of selected mind games supports their development and positive effects were observed both on the students' attitude towards learning and on their global school performance [3].

III. COGNITIVE SKILLS AND SPECIFIC REASONING TASKS

During the second phase of the experiment, which involved more that 500 primary school children (age 8-10) playing digital mind games an hour per week for a 4 months period, a standardized test called LOGIVALI was produced. This test is based on the hypothesis that different levels of reasoning ability are required to perform specific reasoning tasks, and that the difference among the levels mainly depends on the number of different elements to be taken into account to make inferences. Three different levels of reasoning were, then, identified and tested:

- level 1: making inferences taking into account one information or game constraint
- level 2: making inferences taking into account two information and/or game constraints
- level 3: making inferences taking into account more than two information and/or game constraints

Table 1 Students performance at the three reasoning levels x level of school achievement



During the standardization procedure of the LOGIVALI test, it emerged that the number of correct answers of the children progressively decreased from tasks involving level 1skills up to level 3, thus allowing us to argue that the three levels are increasingly complex for the target population and confirming that they are progressive levels of the general ability of making inferences on the basis of given data. This finding had been compared with students' school performance. As the matter of fact, students participating in the research study were classified in three groups based on their school achievement: high achievers (group A); medium achievers (group B) and low achievers (group C). Test results (see Table 1) showed that the performance of high, medium and low achievers, as to the three different skill levels, were scaled and that high achievers always performed better than the other two groups; while low achievers obtained the lowest performance as to all the three levels. This finding allowed us to confirm that there is a correlation between school achievement and ability in solving the reasoning tasks proposed by the selected mind games.

If we look in detail at the results obtained by the three categories of students we are also allowed to hypothesize that: a) the more complex level of ability (level 3) is more difficult for all the three categories of students; b) level 2 ability can be considered as the "demarcation line" between low/medium and the high achievers; c) pupils target age (8-

10 years old) is exactly the age where the "higher order reasoning ability" required at level 3 is getting improved and better structured (as the matter of fact, we obtain a significant difference of positive results between class 4^{th} students (age 8-9) and class 5^{th} students (age 9-10) even in high performance students.

IV. CONCLUSIVE REMARKS

We have put forward some experience-based ideas on the actual abilities required to children to successfully playing mind games. The abilities we have pointed out certainly need to be further explored and are not meant to fully cover the wide spectrum of cognitive skills required; Our findings can, nevertheless, help educators make a fruitful use of games for developing young children transversal reasoning skills by allowing them carrying out well focused, and personalized educational interventions in the field.

REFERENCES

[1] Robertson, D., Miller, D., Learning gains from using games consoles in primary classrooms: a randomized controlled study. Procedia Social and Behavioral Sciences, 1 (1), 1641-1644, (2009)
[2] Vassiliou, A Introduction to the Eurydice report on "Learning and Innovation through ICT at School in Europe" available at http://eacea.ec.europa.eu/education/eurydice/documents/key_data_ser ies/129EN.pdf (2011)
[3] Bottino, R.M., Ferlino, L., Ott, M., Tavella, M.: Developing strategic and reasoning abilities with computer games at primary school level. Computers & Education, 49 (4), 1272-1286. (2007)
[4] Bottino R. M., Ott M., Tavella M. and Benigno V.: Can digital Mind Games be Used to Investigate Children's Reasoning Abilities? In. Meyer B. (ed) Proceedings of the 4th ECGBL Conference on Games Based Learning Copenhagen, Denmark, Academic, Conferences, pp.31-39 (2010)
[5] Bottino, R.M., Ott, M. : Mind games, reasoning skills, and the primary school curriculum: hints from a field experiment. Learning Media & Technology, 31 (4), 359-375 (2006)

978-0-7695-4702-2/12 $26.00 © 2012 IEEE DOI 10.1109/ICALT.2012.225