Block Magic: A Prototype Bridging Digital and Physical Educational Materials to Support Children Learning Processes

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Abstract Block Magic is a prototype for educational materials developed in a successful European research project under the framework of LLP-Comenius programme. It aimed at creating a bridge between physical manipulation and digital technology in education. Block Magic developed a functional prototypal system that enhanced the Logic Blocks Box. The prototype is made up of an active desk/board able to recognise concrete blocks equipped with the RFID passive tag and to communicate with a PC, an augmented reality system. Preliminary trials with Block Magic prototype were run in various schools in Germany, Greece, Italy and Spain, involving children aged 3 to 7. Results confirmed Block Magic educational platform effectiveness in educational context.

Keywords Augmented reality systems · Embodied Cognition · RFID/NFC Technology · Hybrid educational materials · Technology enhanced learning

1 Introduction

A considerable part of learning/teaching processes that involve humans is based on technology. For example the book, the pen, the blackboard that belong to our everyday environment and are used as our mind and body extensions, are indeed technologies designed in the latest periods of human evolutionary history. Technology is a mirror of the times, in education too: evolution (and update) of didactic methods run in parallel with technological evolution. This undeniable fact is even more evident in our historical period. The current acceleration in technological development offers new opportunities to support learning processes in those life periods, as infancy, which are, at present, only partially involved in the systematic application of innovative learning technologies.

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V.L. Uskov et al. (eds.), *Smart Education and Smart e-Learning*,
Smart Innovation, Systems and Technologies 41,
DOI 10.1007/978-3-319-19875-0_16

1.1 Background

Children know the world around them using their body even before their motor functions (walking) and cognitive functions (logical and linguistic) are fully developed. Every action, touching, moving, pointing, matches and supports their learning processes. Along the growth process, concrete manipulative acts are gradually simulated in human mind and become symbolic and cognitive acts. However the body use, in particular hands use, is a latent and fundamental resource in learning processes that strongly emerges when the environmental conditions allow it. In recent years, the Embodied and Situated Cognition Theory, ESCT, [1] proposed an explanation of how our sensory- motor interactions with the environment structure our neuro-cognitive organization. The ESCT approach, in our opinion, focuses on another fundamental aspect too: these sensory motor interactions happen, especially for humans, in a social and cultural context that proposes objects, artefacts, technologies and concrete or abstract cultural substrates [4].

Well-established psycho-pedagogical approaches (such as the Montessori approach) have proposed well- structured didactic methodologies which focus on children active involvement. These methodologies rely on learning materials (educational toys), which foster both learning and teaching processes by stimulating the manipulation of concrete objects and peer group cooperation. As a result, such approaches stimulate active education, particularly fit for cognitive and social skills acquisition, such as cooperation, collaborative learning, creative and critical thinking, problem solving, digital literacy and so on. These psycho-pedagogical methodologies use structured materials, such as logic blocks, teaching tiles, abacus, physical representations of letters and numbers, etc., aimed at training specific perceptive, cognitive and motor functions. Inside the learning environment, such didactic materials are disposed and used according to specific didactic criteria which foster their spontaneous use by pupils, in order to empower the proactive function in learning processes. In these environments natural cooperative dynamics tend to emerge. However, because the above-mentioned psycho-pedagogical practices are aimed at empowering learning/teaching processes focusing on pupils active participation, as well as on customizing educational interventions, they tend to be extremely expensive. These educational practices imply constant supervision by adults (educators, trainers, teachers, parents, caregivers, etc.), that carry out (discretely) the educational play, and play a role as directors, as well as mediators in the learning processes. Therefore, mass diffusion of this kind of practice is considerably limited.

Some technologies, e.g. augmented reality, RFID/NFC sensors [10] are natural candidates to represent the bridge paradigm [7] to unite the manipulative approach and touchscreen technologies, as widely explored by the Block Magic project [6], from now onwards BM that took place in four European countries. BM is an example of what we can call STELT: Smart Technologies to Enhance Learning and Teaching [8] that links physical and digital applications [9], reported in Fig. 1.

1.2 Research Objectives

In what follows we describe the BM platform and the first trials that were run to test its effectiveness. The research questions that guided our effort were mainly the following: *Is BM tool attractive for children? Does BM contributes to enhance specific cognitive skills? Is BM able to convey social skills learning? Can BM be compared with traditional materials in support children learning processes?*

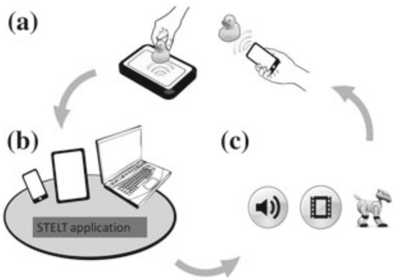


Fig. 1 STELT platform functional representation

In next sections we are going to illustrate how we tried to aswer these questions and what the reply was. In Fig. 2 the BM kit is shown.

Fig. 2 The BM kit including a set of 48 Magic Blocks, Magic Board, Teachers Manual, CD containing all required software and scripts for all learning activities. See text for explanation

2 Materials and Method

In this section we will describe in detail the BM platform and the trials that were run to test it in four different European countries.

2.1 BM Platform

The BM platform consisted of a set of magic blocks (48 traditional logic blocks), a magic board/tablet device and a specific software (see Fig. 3). It is based on STELT platform introduced above and links together smart technologies and physical material to support children learning processes. It unites the manipulative approach and touch-screen technologies. BM materials derive from structured materials, classically used in education. Structured materials have a fixed numbers of n elements, m categories and rules to connect single parts that represent the structure. Logic blocks, cards, teaching tiles, etc. are structured materials typical examples. These materials promote analytical thought, as they segregate single qualities (e.g. dimension, shape, color, etc.) and allow first to focalize attention on an object single part and then to develop clustering and serialization ability in order to understand the objects features.

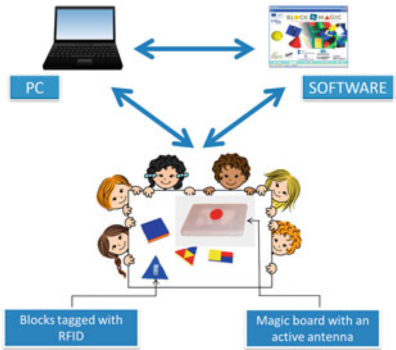


Fig. 3 BM platform functional representation

RFID technology The technology used in the BM project is the RFID/NFC, Radio Frequency Identification/Near Field Communication. RFID system consists of an antenna and a transceiver, which is able to read the radio frequency and transfer the information to a device, and a small and low cost tag, which is an integrated circuit containing the RF circuitry and information to be transmitted. These technologies are simple to be used, so they are interesting for applications rather than on technical level.

Magic blocks and the magic board The BM teaching kit consisted of a set of magic blocks (48 traditional logic blocks), a magic board/tablet device. Magin blocks are dervied from Logic Blocks which are didactic materials used worldwide in kindergartens and primary schools [2]. They are made up of a set of blocks (usually 48 pieces) divided in four groups according to different attributes: geometric shape (triangular, squared, rectangular and circular), thickness (thick and thin), color (red, yellow and blue) and dimension (big and small). The BM project proposed an hybrid version that allows an enhancement of traditional logic blocks, equipping them with RFID tags. This configuration permits to a PC or a table, with BM software installed on, to connect with BM Magic Table, another relevant BM material. The Magic Table has an hidden antenna that recognizes each block, sends a signal to the PC/tablets, and produces a feedback coherently with pupils learning path. Each augmented magic block had an integrated/attached passive RFID sensor for wireless identification of each single block. A specially designed wireless RFID reader device, an active board, is used which could read the RFID of a block and transmit the result to the BM software engine.

BM software The BM system aimed to stimulate and teach different skills such as logic, mathematics, languages, etc. therefore the described BM enriched blocks together with the Magic Table are complemented with a software that includes a series of exercise that researchers involved in BM project built on teachers feedback and on their previous experience in pedagogy. The final software was developed through an iterative process: first children and teachers used the exercises and assessed them, then the results were collected together with feedbacks from direct observation and focus groups. This was done by all project partners to define final exercises version. The BM software engine is mainly formed by two parts: the first one is devoted to receiving input from the active board and generating an "action" (aural and visual). These actions implement the direct feedbacks the user can receive interacting with the system. These feedback are regulated by an Adaptive Tutor System embedded that ensures autonomous interaction between the user and the system, receiving active support, corrective indications, feedback and positive reinforcement from the digital assistant on the outcome of the actions performed. Adapting tutoring systems [3, 5] are an Artificial Intelligence application that provides instruction that are tailored on individual learners needs. Traditional applications used in education, indeed, are not individualized to learner needs, but are rather static and rule-based (IF Question X is answered correctly, proceed to question Y, otherwise go to question Z; and so on). The learner abilities are not taken into account. While these kinds of applications may be somewhat effective in helping learners, they do not provide the same kind of individualized attention that a student would receive from a human tutor.

The second software component is devoted to customization too, but it is dedicated to teachers, educators, etc. allowing them to choose the exercises to be proposed to the child, focusing the attention on the skills the child needs to train more. The BM software moreover can collect data about the exercises.

2.2 Participants

Trials involved 4 different schools, 257 students, 2 children with special needs and 10 teachers. Schools were located in 4 different countries (Italy, Germany, Spain and Greece). In detail the trial made in Italy was addressed for children with special needs, with little differences in the protocol and test contexts, described later. Children involved were between 2.5 and 7 years old, attending the early years of primary school and kindergarten.

2.3 Method

To test BM materials in educational context, the BM project included two different scenarios: (1) Individual Game Scenario and (2) Social Game Scenario. In the first one, learners had to solve a task using logical, mathematical, creative, strategic and linguistic skills, whereas in the second one social skills, under group play guise, were required to find game solution. Also teachers were involved with pupils: their role was to create and maintain an adequate environment for BM sessions. The trials were run in a specific setting: a dedicated rooms, different from the classroom where pupils attend traditional lessons. In these rooms large workplaces were prepared with the BM kits, available for free game and manipulation. The teachers, who had already experienced BM platform, set the software choosing the correct level for children in the class. The trials had no pre-defined exercises for children who could skip exercises if they considered it problematic or boring. A trial session typically started with introduction of BM logic blocks and Magic Table device by the teacher, giving pupils the opportunity to play freely with them and use the materials the way they preferred. The trial continuation was different according to the two scenarios introduced above. In the Individual scenario, the teacher acted as an external observer and supported a single pupil when he/she asked for help. This way, the child had to perform exercises autonomously. In the Social scenario groups composed by a minimum of 4 to a maximum of 6 learners were involved and the teacher had a more active role in the session, providing support, observing and/or creating obstacles. Moreover they had to observe children behavior in order to complement these qualitative observations with session results recorded by BM software. This allowed to define a learning curve for each child and to obtain information about intra- group interaction, focusing on team building, leadership, verbal and non-verbal communication. The session had a maximum length of thirty minutes. Data were collected by BM system, including record sheets and videotapes. In the case of children with special needs there was an additional preliminary phase of pre-training that allowed children to understand the task. After each session, the teacher, for all scenarios, had to analyze results using BM software that shows and lists results for each session and for each child. This way she/he could analyze the session and tune the educational goals for every child. For example, if the teacher noted that a pupil lacked in linguistic skills, she/he might modify the proposed exercises to train these skills more intensively. The trial consisted of at least five twenty-minutes long sessions. During sessions, researchers run observations and collected data, without any support role. After sessions, researchers conducted face-to-face interview with teachers based on a semi-structured questionnaire. This questionnaire is formed by 21 items with responses on a Likert scale. Researchers also run collective focus groups with teachers that lasted 60 min. Teachers interviews and focus groups, together with observations were focused on four aspects: BM attractiveness, BM ability to contribute to specific cognitive skills, to strengthen social and working in group skills, BM ergonomics and comparison between BM platform and traditional materials.

3 Results

In this section we report the results we obtained in the four European trials both from teachers (questionnaire and focus groups) and from children.

3.1 Indications from Teachers

BM attractiveness, emerged strongly: the tool is very attractive for children for many reasons. They especially liked to use the tablet and the computer, and were attracted by visual and aural stimulation as well as the mascot Block. It is motivating for the students to use a computer-based system and that the manipulation of real objects makes it even more fun. Teachers think that children found both visual and aural presentation of the tool attractive and the use of text, graphics, sound, and pictures was perceived as balanced so the children didnt get bored. They stayed happily until the end of each session and even wanted to continue playing. Teachers also noticed that children liked to hear their names from the computer and felt like participating in a real game (in the single player scenario). Also receiving an appropriate feedback was crucial to keep an high motivation level. The researchers noticed that in all cases teachers support and encouragement was essential, otherwise when children couldnt solve an exercise and find the solution wanted to abandon their task. Teachers intervened and tried to increase childrens motivation in case they failed in an exercise. This is especially true for 4 years old children and for the social game scenario. Children with special needs find the tool attractive too. In the Italian trial, in fact, teachers stated that the tool is appropriate for children with special needs mainly because they are motivated on activities with multisensory stimulation. Indeed, children were highly motivated. They stayed on their tasks until it finished and none of them appear to be frustrated. In their opinion BM is an interesting tool as it reduces prompting of the teachers and the engagement with BM produces a large increase in stimulation level. Moreover, teachers stated that computer based learning materials enables students with special needs to learn more effectively because they prefer to play independently and they can increase the quality of life through input and output opportunities: as the other children involved in the trials, children with special needs found the verbal reinforcement that encouraged them to play very appealing.

The researchers investigated BM use in relation with specific skills: in teacherss opinion contribute to develop specific cognitive skills: in particular it is fit to improve mathematical and logical skills. All teachers accepted that the tool offers a variety of activities that encourage children to develop mathematical skills. However, in order to find the solution to mathematical problems children, especially the younger ones, needed teachers help. Besides that, teachers believe that children at this age cannot develop and follow a strategy to solve a problem. For this reason, they underlined that children often used a trial-and-error strategy. Also imagination is stimulated by BM. In detail the Creative Drawing, Logic Train and Slice the Shape were identified as the exercises that motivates children to use their imagination. On the other side, this tool doesnt seem to be effective about creativity. The social scenario provide effective stimuli to improve social skills and the ability to work in groups, even if teachers believe that BM platform is less effective in this respect.

Another point that was treated was BM ergonomics: children are able to interact autonomously with the tool, but there is some difference about age. There are some problems with 4 years old children, as they better interact with BM when they are 5 years old. Younger children need a lot of work with a real adult, either teachers or parents. On the other side, teachers suggest that some exercises could be fit even for children above the age of 7, especially those that have problems and/or special needs. Some students cannot follow the pace of the others and such system can be a suitable additional support for their learning.

About BM ergonomics, many teachers suggested to improve game instructions that were often too long or complex to be fully understood, to solve the problem with noise in the classroom and to fix some technical problems the prototype had.

Then the questionnaire and the focus group compared the use of BM with traditional blocks: teachers agreed that the most relevant aspect was the feedback provided by BM system that allowed many children, especially the older ones to interact autonomously with exercises. Block Magic meets the new IT generation and is an interactive tool but there are constraints in terms of creativity and imagination, that, on the contrary, are better stimulated by traditional blocks. Moreover teachers underlined that Block Magic creates more possibilities for the teachers than the traditional logical blocks: there is a wider variety of exercises, some of which are more difficult to play in traditional settings. With Block Magic children can work (almost) unattended and they can spend more time with it. It is useful to underline that these aspects emerged in all trials, thus meaning that children interact with BM platform in a similar way across different countries and cultures.

3.2 Children Improvement Along Sessions

Children interacting with BM get better along the sessions, both in individual and social scenario. The preliminary data we present refer to all trials.

Figure 4 shows childrens performance during the first and the last day sessions. This comparison is complicated by the fact that children didnt play the same exercises the first and the last days, but it is possible to see the improvement tendency. Both the group and a single example child have increased the rate of perfectly solved exercises along sessions over the time. The group increased the rate of perfectly solved exercises from 45.0 % to 80.0 % and the single child increased it from 54.0 % to 71.0 %. In the social game scenario we have compared the group means in the first and the last day sessions: the difference is statistically significant $t(15) = 2{,}537$; $P > 0.05$.

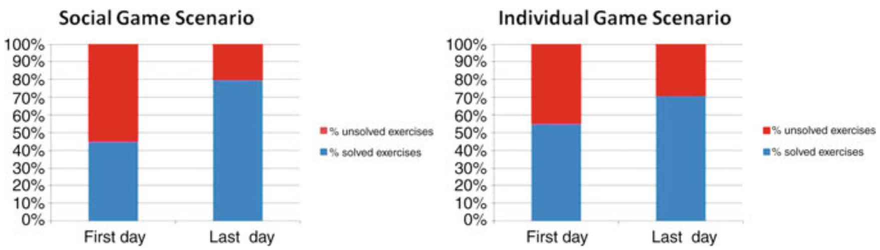
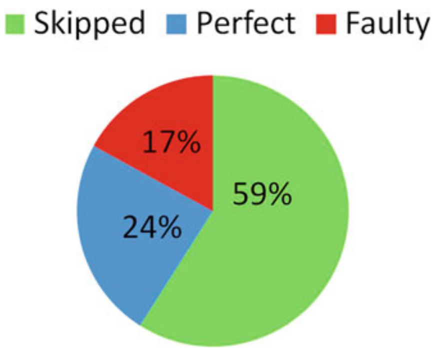


Fig. 4 Percentage of solved and unsolved exercises in first day and last day sessions. On the left results about groups and on the right results about single child are reported

The BM system also allows to record how many exercises have been completed or skipped during the trials by children. Children skipped the exercises either because they failed to solve them or did not listen to the instructions again. As underlined before, some instructions were not fully understood by children. Among the exercises that children played completely some were solved perfectly (without any mistake) and some others were solved faulty (1–9 mistakes). Figure 5 shows the distribution of skipped exercise, faulty and perfectly solved exercises.

Fig. 5 Distribution of skipped exercise, faulty and perfectly solved exercises



4 Discussion

In this paper we have described the BM platform, its concept and implementation and the results coming from the first trials with children. These data indicate that BM can be an interesting and effective tool to be integrated in school curricula. Even if it is clear that an help from the teacher is still needed, especially for younger children, it is nevertheless true that BM allows to run activities with logic block in a more autonmous and therefore economic way. Moreover BM is very appealing for children and this aspect cannot be neglected in a school context where capturing children attention is a challenge. The BM system exploits Augmented Reality in order to building-up hybrid educational materials (physical and digital) that link together well-known psycho-pedagogical practices based on the direct manipulation of concrete objects (not just touching a screen) with technology thus enhancing the overall learning/teaching processes for children in early ages. In next phases, our goal is to test the prototype on a wider sample and in comparison with traditional materials to better clarify its educational potential.

Acknowledgments The Block Magic project has been funded with support from the European Commission under Life Long Learning programme Comenius.

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