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Exploring Teachers' Acceptance of Tangible Enhanced Educational Materials in Education. The Block Magic Case

Franco Rubinacci, Fabrizio Ferrara**

Abstract

This study aims at investigating teachers' acceptance of Tangible Enhanced Educational Materials, namely hybrid materials that link physical and digital contents in pre-school and first years of primary schools. It examines teachers' approach to Block Magic, a functional prototypal system that enhances the Logic Blocks Box. Data were collected through semi-structured interviews with 17 teachers in schools located in four different countries (Italy, Germany, Spain and Greece) about four different trials involving four different schools, 257 students and two children with special needs. Results indicate that this kind of material is well-accepted by teachers as a complementary material. This implicates that they can be included in every-day school activities supporting learning and teaching processes in a constructivist and embodied cognition theoretical framework.

Keywords: Human-Computer Interface; Improving Classroom Teaching; Interactive Learning Environments; Pedagogical Issues

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1. Introduction

Digital technology has held a very relevant role in education for many years, thus becoming a very discussed issue in education and psychology literature. As technology produces materials to be used in the interaction between students and teachers, it is very important, to build a successful augmented education pathway, that teachers accept technology enhanced educational materials. In fact, a crucial role is played by teachers in every effective integration of technology in teaching and learning processes. Many studies have addressed this question, consider for example Teo (2009, 2011, 2014) whose studies propose to apply the TAM model (Technology Acceptance Model) introduced by Davis, Bagozzi and Warshaw (1989) and widely applied from the business context to education. These studies indicate what factors influence teachers' acceptance of and intention to use technology, stressing the importance of variables such as perceived usefulness, perceived ease of use, attitudes towards computer use, technological complexity, computer self-efficacy (Bandura, 1977; Gong, Xu & Yu, 2004). Moreover, even if teachers are interested in introducing technologies in their classroom, it seems crucial for them to learn how to use technology receiving appropriate support and extensive training (Demetriadis et al., 2003). Even if teachers do not have to become a designer of technology enhanced learning (Kirschner, 2015), they must face the challenge of technology in education. In this respect, teachers' knowledge and competence for teaching with technologies should include what has been called technological pedagogical content knowledge (TPCK and/or TPACK). This includes a comprehensive conception of teaching content with technologies, knowledge of students' understanding, thinking and learning with technologies, knowledge of curriculum and curriculum materials, knowledge of instruction and instructional representations and five levels of acceptance for teaching with technologies which are *recognizing, accepting, adapting, exploring*, and *expanding* (Niess, 2015).

Alongside the ever-increasing use of technology in education has come radical changes in educational paradigms. Recently the flipped classroom (Tucker, 2012) model, which proposes an instructional methodology and a paradigm of blended learning that delivers instructional content outside of the classroom has emerged. For example, accessing multimedia on-line contents at home, and moving activities that were traditionally considered homework and student/teacher interaction into the classroom.

This new trend leads to newer and newer tools whose features must favour an autonomous use at home and a fruitful interaction with teachers, who, as discussed before, should accept this technological innovation to make it effective.

One relevant example of these tools is Breedbot (Miglino, Gigliotta, Ponticorvo & Nolfi, 2008; Ponticorvo, Di Ferdinando, Marocco & Miglino, 2016; Rubinacci, Ponticorvo, Gigliotta & Miglino, 2017), an integrated hardware and software system that allows us to breed a population of robots to teach how to govern complex systems. This tool promotes collaboration between students, as described by Barneva, Kanev, Kapralos, Jenkin and Brimkov (2017), who illustrate how tangible technology-enhanced learning can lead to the improvement of collaboration between students. These new tools have been also addressed to primary school students, indicating that the technologies for children that go beyond the desktop computer and merge the physical and digital worlds can be interesting also for this age (Xu, 2007).

In what follows, we will describe a particular material that fosters spontaneous and unsupervised use by children, and stimulates effective student/teacher interaction thanks to the blended existence of digital and physical contents. We then describe the trials that were run to assess this tool's acceptance by teachers.

1. Block Magic as a tangible enhanced educational materials

Block Magic (BM) exploits the tools provided by technology enhanced learning to transfer traditional manipulation into the corresponding virtual interpretation, thus accessing a wide range of learning opportunities both on the teacher and student side.

The traditional materials BM rely on are Logic Blocks by Dienes (1971). These blocks are manipulative materials consisting of 48 pieces, that vary according to some variables, namely, colour (yellow, blue, red), shape (triangle, square, rectangle and circle), thickness (thick and thin) and size (big or small). The related exercises are aimed at training logical skills such as classification based on one or more qualities, Boolean connectors, seriation etc. The materials are used worldwide in pre-school and primary schools.

In the BM project, these materials are enhanced by equipping them with RFID tags (Shepard, 2005). This configuration permits to a PC or a tablet, with BM software installed, to connect with the BM Magic Table, another relevant BM material. The BM system is shown in figure 1.

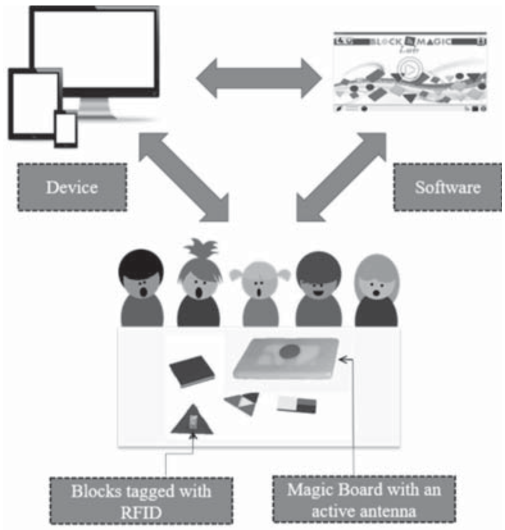

Figure 1. A functional representation of Block Magic architecture

The Magic Table has a hidden antenna that: recognizes each block; sends a signal to the PC/tablets; and produces a feedback coherently with pupils' learning path. It is a specially designed wireless RFID reader device, an active table, which could read the RFID of a block and transmit the result to the BM software engine. The BM software engine receives input from the active table and generates an "action" (aural and visual) based on the direct feedbacks collected by the user interaction with the system. The BM system has 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. If deprived of the digital component, the traditional learning activities require a constant interaction effort and supervision by an adult (teacher or parent) for a single child or small groups (two-three children at a time). This produces a considerable increase in operating costs, which is one of the reasons why methods such as the Montessori approach have not achieved widespread diffusion in public schools. This is one of the motivations inspiring this project.

With BM, the teacher or educator role is considerably reduced, becoming an *ex ante* planner and non-directive monitor and supervisor.

Adapting tutoring systems (Freedman, Ali & McRoy, 2000; Larkin & Chabay, 1992) 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. Whereas 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.

On the contrary, the BM system allows each learning experience personalization: teachers can choose the exercises to be proposed to the child, focusing the attention on the skills the child needs to train more.

The BM engine, moreover, includes a series of exercises that researchers involved in the BM project built on teachers' feedback and on their previous experience in pedagogy.

The BM system can be considered the first implementation of a more general architecture (Di Fuccio, Ponticorvo, Di Ferdinando & Miglino, 2015; Ponticorvo, Di Fuccio, Di Ferdinando & Miglino, 2017) with three levels of interaction, represented in figure 2.

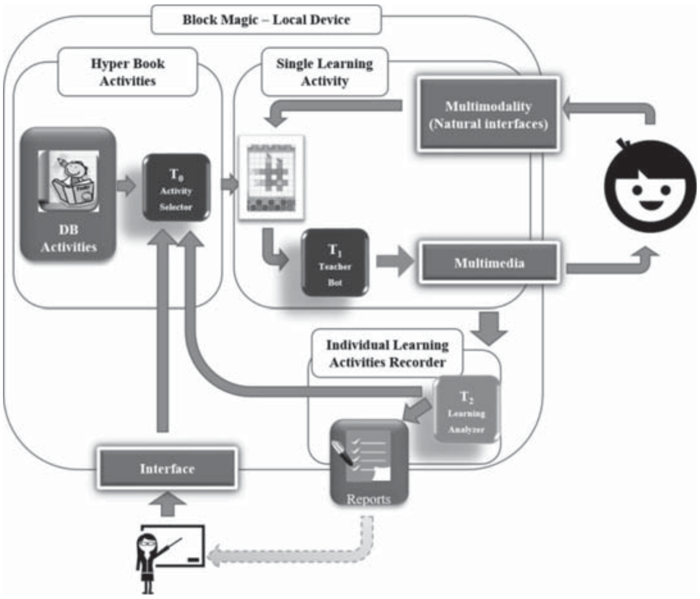

Figure 2. The general architecture Block Magic is built on. It includes three levels of interaction. For explanation, see text.

These three levels refer to multimedia, multimodality and computing. During activities, children interact with the tool named T1, the trainer bot that proposes the task with a multimedia output (screen presentation, voice, images, pictures, videos, songs etc.) and the child interacts with it in a multimodal manner, using voice, hands, typing text. The answer from the child is tracked by T1 that replies with a feedback, based on the exercise performed and on its own artificial intelligence, the computing level. Feedback is fundamental to increase child involvement in the activity. T1 can offer various rewards for specific tasks and can name the child so to keep him/her immerged in the activity layer. Feedback could be a success sentence like "Well! Well done! Play again" if the exercise is well performed or tip/suggestion in other cases.

Multimediality is functional to the narrative level described above and, relying on appealing graphical solutions, it keeps the child in the fiction dimension, for example with a mascot character introducing and commenting on activities.

Multimodality leads to natural interfaces that are invisible to the user and allow continuous interactions without using artificial control devices, whose operation must be acquired.

It is evident that the tutor role is fundamental: they implement learning analytics (Elias, 2011; Siemens & Baker, 2012) that measure, collect, analyse and report data about learning in the activity layer, to support learning processes. These tutors are Intelligent Tutoring Systems. This interaction level is based on automatic computation and is what we have called computing.

It is important to underline that every activity is conceived as an interactive game, that can be framed in game-based learning (Tobias, Fletcher & Wind, 2014) exploiting the motivational qualities of digital games to create engaging educational and training tools (Gee, 2003). This interest is motivated by the fact that games are carefully designed to stimulate user engagement.

Moreover, we can affirm that games constitute an outstanding example of learning-by-doing, or experiential learning: learning by actually doing and being active in the learning process. Considering the role of action introduced above, it is also important to underline that tangible interfaces allow preserving the manipulative issue that is crucial in learning by doing by children.

About the narrative point, the BM system and the more general architecture, with each interactive game, enter the child in a fictional dimension where the characters, the goals, the game dynamics are designed to keep the child engaged.

The last educational outcome, personalization, is reached by using Intelligent Tutoring Systems that, as described before, propose the fittest path for children, according to their learning curves and learning styles (Honey & Mumford, 1992).

2. Teachers' acceptance of Technology Enhanced Materials

A number of studies have indicated that the successful pedagogical use of technology depends on teachers' attitudes and acceptance towards technology (Yuen & Ma, 2008). In fact, even if the role of ICT in education is becoming more and more relevant, there is still a high resistance by teachers, especially in public schools, to adopt such tools (Afshari, Bakar, Luan, Samah & Fooi, 2009). A wide number of models have been proposed to explain what factors may determine teachers' acceptance of (Technology Enhanced Materials) TEL materials in education (Ertmer & Ottenbreit-Leftwich, 2010). Many findings suggest that an individual's intention to accept a technology is likely to be affected by attitudinal, cognitive, and normative factors pertinent to technology, social system, the task and the implementation (Legris, Ingham & Collerette, 2003). For example, theories have been proposed to explain different user technology acceptance scenarios; the theory of reasoned actions (Ajzen & Fishbein, 1980), the theory of planned behaviour, and the technology acceptance model (TAM) cited in the introduction, that is specifically conceived to explain individual technology acceptance decisions. It applies to a wide range of technologies, user populations and contexts and includes variables such as perceived ease of use, perceived usefulness and computer self-efficacy (Hu, Clark & Ma, 2003). Moreover, the analysis of individual technology acceptance has explored other relevant dimensions, including target users, implementation context, and technology attributes.

In summary, it is possible to say that a teacher's decision to accept a technology is affected by multiple key factors or considerations pertinent to the technology, the user, and the organizational context.

As underlined before, the present study is focused on the acceptance of the specific material described above. The specific research questions are: can Block Magic be effectively introduced in school curricula? Does it give advantages compared to classical Logic Blocks?

3. Materials and method

The study was conducted in schools from four different European countries during the school year 2011-2012, under the Block Magic project, a research project funded by European commission that involved 5 partners from 4 European countries. The project was specifically devoted to implement a novel, IT-based teaching methodology, especially meant for learning activities involving manipulation of physical objects and learning pathways personalization.

3.1 Participants

The study involved 17 teachers that were administered a semi-structured interview. Teachers were selected on the basis of their involvement in the Block Magic project. The interview was relative to trials in four different schools with 257 students and two children with special needs. Schools were located in four different countries (Italy, Germany, Spain and Greece). Specifically, 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 pre-school.

3.2 Procedure

To verify the effectiveness of Block Magic, the BM project included two different scenarios: 1) Individual Game Scenario and 2) Social Game Scenario. Results from these scenarios are reported in Di Ferdinando, Di Fuccio, Ponticorvo and Miglino (2015).

In this paper, we focus on BM acceptance by teachers, during the two scenarios. 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 necessary to find the game solution. 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: dedicated rooms, different from the classroom where pupils attend traditional lessons. In these rooms, large workplaces were prepared with the BM kits, freely available for 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 an exercise if they considered it problematic or boring.

A trial session typically started with the introduction of BM Logic Blocks and the 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 of a minimum of four to a maximum of six 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 the children's behaviour in order to complement these qualitative observations with session results recorded by the BM software. This produced a learning curve for each child and obtained information about intra-group interaction, focusing on team building, leadership, verbal and non-verbal communication.

In the case of children with special needs, there was an additional preliminary phase of pre-training meant to make clear the task.

After each session, the teacher, for all scenarios, had to analyse results using BM software that shows and lists results for each session and for each child. This way she/he could analyse 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. During sessions, researchers ran observations and collected data to compare the BM system with the traditional methods, without any support role.

3.3 Data collection

After the sessions, researchers conducted face-to-face interviews with teachers based on a semi-structured questionnaire. The questionnaire was based on a comparison between BM and traditional methods and was the starting point for interviews that had the goal to assess if teachers accepted BM as an educational material. The first questions were meant to collect information about school profile and teachers, namely about age, education and work experience. Finally, five questions explored specifically the use of classical Logic Blocks and Block Magic (for the complete questionnaire see Appendix 1).

Teachers aged in average 35.88 years, they all had a bachelor degree and one of them a Master Degree in ICT in education. They were from Greece (7), Germany (4), Spain (4) and Italy (2). Two of them were males and 15 females. Nine worked in pre-schools and eight in primary schools.

They had different working experience in the educational field, ranging from one to 24 years with an average of 11.05 years. Twelve of them were already familiar with traditional Logic Blocks and employed them in everyday school activity. Some of them used common technological tools to support learning, but for the whole sample, the average level of technological tool incorporation in teaching methods was 2.88 (with 2 meaning "Almost never" and 3 meaning "Occasionally"). That means present sample was not very used to technology enhanced educational tools.

3.4 Data analysis

Simple frequencies and cross-tabulations were calculated. Interviews were transcribed and coded using NVivo. In table 1, are reported some details about interview participants and where quotes are reported they are identified with their code.

Table 1. Interview participants details

Part.	Nat.	Sc.	St.Age	Gender	Age	W.Y.
1	GR	1	4	F	26	4
2	GR	1	5	M	45	24
3	GR	2	7	F	39	17
4	GR	2	7	F	25	6
5	GR	1	4	F	45	18
6	GR	1	4,5	F	32	7
7	GR	1	5	F	40	11
8	GE	1	4	F	36	22
9	GE	1	4	F	36	13
10	GE	1	5	F	36	1
11	GE	1	5	F	36	5
12	SP	2	6	F	31	6
13	SP	2	6	M	28	5
14	SP	2	7	F	37	13
15	SP	2	7	F	29	6
16	IT	2	13	F	58	20
17	IT	2	15	F	31	10

Part. = ID participant; **Nat.** =Nation: GR Greece; GE Germany; SP Spain; IT Italy

Sc. = School type: 1 pre-school, 2 primary school; **St.Age** = student age **Gender** = F female M male; **Age** = teacher's age; **W.Y.:** working experience in years

4. Results

The coding categories and related example gathered from the interviews are reported in table 2.

Table 2. Interview coding categories and examples

Coding categories	Examples
Block Magic attractiveness	Connected to the fact that the exercises are personalized
	Related to the use of technology
	In terms of usability
Block Magic ability to contribute to specific skills	Contribution to specific cognitive skills namely logic, reasoning but also imagination and creativity
	Contribution to specific soft skills namely work-group and cooperation
Comparison with traditional blocks	Increasing of motivation
	Increased time-on-task
	Chance to play during free time and at home
	Integration with other tools
Block Magic ergonomics	Strengths and weakness

About Block Magic's attractiveness, interview respondents identified different elements that were attractive for children involved in the study. The most commonly cited elements were the use of the kit itself, with the PC, the tablet and the blocks that were very attractive for children (n = 8), followed by personalization (n = 6) and BM usability (n = 4).

"I find it interesting and useful tool. I also see it a good opportunity to support the school innovation" (respondent 14).

About Block Magic's ability to contribute to specific skills, many interviews underlined the contribution to specific cognitive skills (n = 12) but only 5 respondents also appreciated its impact on soft skills and working in group skills. It is also interesting that teachers are convinced that this tool can promote these skills not like the traditional methods.

"It seems an interesting tool that might help children develop logical and mathematical skills in a different way " (respondent 17).

During the interviews, Block Magic was compared also to traditional blocks. Ten respondents believed that these enhanced version of traditional blocks can increase motivation, Fifteen interviewed, noticed that it increased the time-on-task, in other words the time children spend involved in the activities and this had a positive effect on learning. Moreover, 8 of the respondents underlined that this kit offers the chance to play during free time and at home.

"I like that it provides a big variety of exercises. It looks like something children will enjoy to do in their free time and it is great when they learn while they play" (respondent 13).

One of the respondents considers it a very attractive tool, but also suggests that it may become addictive.

"Might be catchy for some kids, I can see potential for challenging students on different level, but it could also become too addictive for some students" (respondent 8).

All the respondents had great expectations about Block Magic and many of them (14) say that they would like to use Block Magic in the future because they found the tool interesting and think that it encourages children to develop a number of skills.

Nevertheless, one respondent underlined that it is a technological tool that could be used as a complementary tool but cannot replace the traditional teaching methods.

We should also note that educators in primary school are more familiar with the use of computer-based materials, compared to teachers in kindergarten. They responded positively to the question about incorporating Block Magic in their teaching methods because they would like to enrich their teaching methods and they found the tool motivating.

The overall data revealed that the Block Magic Teacher Kit was positively accepted by teachers and students and, based on specific comparisons (Di Ferdinando et al., 2015; Di Fuccio, Ponticorvo, Di Ferdinando & Miglino, 2015), proved Block Magic's effectiveness in promoting learning processes.

These results indicate that BM is a powerful tool to complement curricular activities, both for teachers in formal educational context and parents and caregivers in informal ones.

5. Discussion and conclusions

In this paper, we have described the BM platform, as a Tangible Enhanced Educational material, its concept and implementation and the results about teachers' acceptance. Our data indicate that materials with tangible interfaces can be an interesting and effective tool to be integrated in school curricula. Even if it is clear that help from the teacher is still needed, especially with younger children, it is nevertheless true that enhanced materials, thanks to the embedded tutoring systems, allow running activities in a more autonomous and therefore inexpensive way. Moreover, the joint use of digital and physical materials, thanks to tangible interfaces, makes these materials very appealing for children; this aspect cannot be neglected in a school context where capturing attention is a continuous challenge. Therefore, these materials exploit technology enhanced learning in order to build-up hybrid educational materials (physical and digital) able to link together well-known psycho-pedagogical practices based on direct manipulation of concrete objects (not just touching a screen) to technology, enhancing the overall learning/teaching processes for children in early ages. In next phases, the goal is to test the prototype on a wider sample and in comparison with traditional materials to clarify the educational potential of this approach, both in formal and informal contexts.

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Appendix 1

SCHOOL PROFILE	TEACHERS PROFILE/QUESTIONS		TEAC. A	TEAC. B	TEAC. C
Number of classes:	Name:				
Number of students per class:	Age:				
	Education:				
	Working Experience:				
	Do you use logical blocks?				
	Do you incorporate in your teaching methods technological tools?	1 Never 2 Almost never 3 Occasionally/Sometimes 4 Almost every time 5 Every time			
	Do children work in groups in your class?	1 Never 2 Almost never 3 Occasionally/Sometimes 4 Almost every time 5 Every time			
	Why are you interested in using Block Magic?				
	Implementation:				