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Indice

Hyper Activity Books for Children: How Technology Can Open Books to Multisensory Learning, Narration and Assessment

Michela Ponticorvo, Orazio Miglino**

Abstract

Together with books, tangible educational materials are widely used in formal and informal contexts, as they improve learning, especially in children. Marrying tangibles with traditional books through digital technology can enrich both materials, making them a powerful tool. In this paper, we describe an approach to design and build Hyper Activity Books (HAB) that allows transforming books in multisensory materials, bonding books with tangible materials. To show the effectiveness and the wide viability of this approach we describe some examples of HAB implementation, applied to mathematics, storytelling, science, and assessment. These examples indicate that HAB can be very useful to produce educational tools.

Keywords: Tangible Educational Materials, Multisensory Learning, Formal Educational Context, Assessment.

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1. Introduction

In formal education contexts, starting from kindergarten and primary schools up to university and life-long education, it is possible to find a wide choice of educational materials. These materials, whose use is proposed to learners, obviously derive from specific pedagogical approaches and educational practices, even if this aspect is not always explicit.

For example, if the pedagogical approach is case-based teaching, students develop knowledge by reading and discussing complex, real-life scenarios.

The Montessori method (Montessori, 2013) proposed a wide variety of materials that favor active exploration and try to stimulate all children potentialities. In more detail, Montessori-like educational materials are manipulatives, physical objects specifically designed to foster learning that promote a multi-sensorial experience. These materials include Logic Blocks, cards, teaching tiles, etc. Many manipulatives are mathematical manipulatives, that is to say concrete objects which facilitate children's understanding of important math concepts such as the relation between quantities and numbers (pattern blocks, interlocking cubes, and tiles), but manipulatives can be employed to teach a wider range of relevant subjects, including soft skills (di Ferdinando, di Fuccio, Ponticorvo & Miglino, 2015).

The revolution of the Montessori method, passed also through the stimulation of all senses: specific materials, named Montessori sensorial materials are widely used in the Montessori classroom to help a child develop and refine her five senses.

More generally, physical manipulatives offer the chance to engage the child with sight, touch, sense of smell, taste and hearing, always promoting action, which is especially important in the first phases of human development (Kontra, Goldin-Meadow & Beilock, 2012).

Together with manipulatives, another kind of material that is widely used in the first steps of formal education is the activity book. Activity books are particular books, mostly addressed to children, which own an interactive content. The content is defined interactive as it requires the child to perform a certain action in response to a precise order/question. For example, it can be required to color a figure in the page, to complete a sentence, or a calculation in the book itself. The interactive content can be very varied, depending on the subject and can include games, puzzles, pictures, etc. (Ponticorvo, Di Fuccio, Di Ferdinando & Miglino, 2017a).

Activity books can be designed for different goals, such as entertainment or teaching/learning. In this latter case, the child's natural involvement in games is used to promote learning, as the game-based learning approach suggests (Dabbagh et al., 2016).

In later school cycles, the activity book becomes an exercise book for a specific subject, for math, physics, foreign languages, etc. The exercise books can be labeled as workbooks, that is to say a book where the student can directly work on, by writing, drawing, underlining, etc.

Both workbooks and activity books share the interactive dimension, which derives from the teacher and learner interactions. In fact, in these kind of materials, the ask-reply interaction is reproduced in a kind of turn-game where the learner wins when she provides the right reply and acquires knowledge and the teacher wins if the learner learns.

1. Teacher/learner interaction mediated by educational materials

The relationship between teacher/learner is fundamental and is universally recognized as the key for successful outcomes. Teachers and learners are components of a communication system: the teacher sends messages through the whole interaction with the learning child who, at her turn, gives feedbacks that orient the teacher effort.

The teacher/learner interaction is mediated by the educational materials that, in many cases, replicate some elements of this interaction. To clarify this concept, we will explain how teacher/learner interaction is replicated in activity books with two examples.

The first example is about a formal school context where a math teacher is dealing with simple arithmetic. The first step foresees the teacher explaining the subject to be transferred. This is the first action where the pedagogical approach can be recognized; it is the so called "learning by being told" model (Bourne, McMaster, Rieger, & Campbell, 1997).

Then the child, or the children, must try to solve some exercises at the presence of the teacher. This action is inspired by the "trial and error model" (Young, 2009) and a crucial role is played by the feedback provided by the teacher. The third action, reproduces the second one but without the physical presence of the teacher: the child solves the exercises on an activity/exercise book. As stated earlier, in this educational game both teacher and learner win if learner knowledge increases.

Another example is about an informal context where a child plays by manipulating, for instance Dienes (1971) Logic Blocks, by under adult supervision. The first turn lets the child freely manipulating the material while the teacher observes the child behavior and stimulates her to examine the blocks. This step is based on a "learning by doing" approach (Schank, Berman, & Macpherson, 1999).

At the second turn, the adult proposes an activity, for example to build a train with all the squares (in this case, the material has been employed to improve categorization abilities).

These different educational models and some possible materials are pictured in Figure 1.

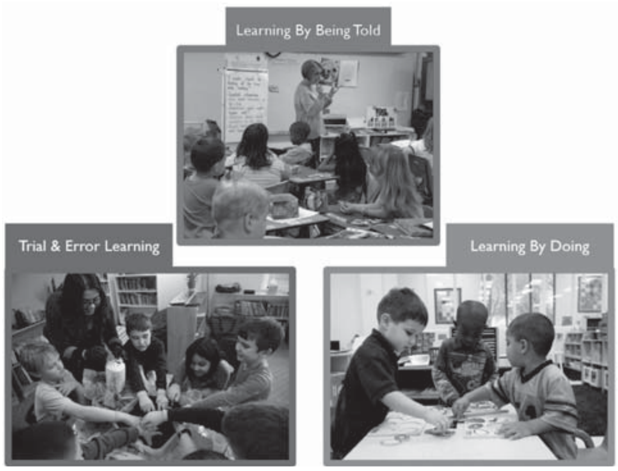

Figure 1. Different educational models with some possible educational materials

In a formal context, all these educational models imply supervision by the adults (educators, trainers, teachers) managing the educational play, explicitly or discretely, covering the role of directors and mediators in the learning processes. The perfect ratio to guarantee an efficient educational pathway is one to one, which is quite far from the real situation in schools. At European level, relevant published data (Organization for Economic Co-operation and Development [OECD], 2010) indicate that ratios of students to teaching staff at pre-primary school level have an average equal to 13, ranging from 22 pupils on average in France to six pupils in Sweden. These data give a clear idea of how difficult, if not impossible, is to offer a personal pathway to each child and to customize educational experiences in such a context.

The situation is even worse in underprivileged situations. In that contexts, educational materials, especially books, can be brand new materials together with technology. Technology, indeed, offers features that can help to overcome the constraints and can prevent the described educational models to fully express their potentialities. Technology – in these cases – could support teachers and learners in the educational enterprise, offering new tools to mediate in teacher/learner interaction. In what follows, a general architecture to design and build such materials will be described, together with examples of its implementation.

2. How to build Hyper Activity Books

In this section, we will introduce a general architecture to design and implement augmented educational materials, namely Hyper Activity Books (HAB). This architecture exploits Technology Enhanced Learning (Goodyear & Retalis, 2010; Mayes & De Freitas, 2013), described elsewhere in detail (Ponticorvo et al., 2017a).

The main goal of this architecture is to connect together activity books and manipulative educational materials, in order to open books to multisensory learning and related benefits (Shams & Seitz, 2008). In a similar vein, Osmo, the commercial system for iPad, has been employed for designing tangibles for children (Antle, Warren, Cramer, Fan & Matkin, 2016). HAB, the system we introduce, is less expensive and can run on already owned devices, so, it can have, in principal, a wider diffusion, also in contexts where few resources are available.

We now describe the architecture in detail. The database hosts numerous and varied learning activities or exercises. It can be conceptualized as activity book pages with every page representing a single activity. Every activity is meant to address a particular knowledge domain; for instance exercises about basic math and logic or to develop vocabulary.

The selection of the activities is made by T_0, an intelligent tutoring system (Corbett, Koedinger & Anderson, 1997), whose task is to choice the activity relying on two information sources: teacher hints and previous results. Teacher hints derive from her work experience as well as from the child observation. Previous results are available from earlier experience with HAB platform that collects data along the sessions, available at a later stage.

Once the activity is chosen, the child interact with the physical materials, manipulating them. At this level, T_1 acts as a tutor whose aim is to maintain the child at a high level of interaction. This is possible through a multisensory interaction whose primary goal is to fully engage the child with all her senses. This system is implemented with natural interfaces (Liu, 2010), invisible to the user and usable without previous training. These interfaces can be implemented exploiting various technologies such as RFID/NC, Smart Objects and Leap Motion.

What we have described up to now is HAB first level, that is to say the activity experience. This platform holds also another level that is invisible to the child, but is very important for the teacher and it is based on T_2 work. This tutor builds an individualized report about the child interaction, it records achievements and failures, activity preferences and so on, in order to obtain a detailed user profile. This report goes to the teacher who can further customize HAB/child interaction with a personalized choice from the database and to T_0 that can better adapt itself to the child. This way the cycle can start again.

It is evident that tutors role is fundamental: they rule the interaction and implement what are called learning analytics (Baker & Inventado, 2014) that measure, collect, analyze and report data about learning during the activities and support the learning processes.

This architecture offers various advantages:

- Learning/teaching processes are personalized and customized: intelligent tutoring systems and authoring tools allow teachers to build individualized learning experience;
- Personalized learning materials can meet children special needs, such as learning disabilities;
- Learning can happen in every context;
- Teachers can overcome standardized books by tailoring educational experiences on child's, small groups', and classes' needs and goals.

On a technological level, this architecture is implemented through Smart Technologies to Enhance Learning and Teaching – STELT (Miglino et al., 2013), an integrated, software and hardware environment that links physical and digital applications.

These features will be better illustrated in the next sections where some examples are reported to illustrate how HAB architecture can transform different kind of books.

The HAB architecture is very flexible and it can be used for any type of educational content, for example in logic and storytelling, for specialist training and even for assessment.

3. Block Magic: an example of Logic Blocks HAB

The first example of HAB architecture implementation modifies math books for primary school by connecting them to blocks tangibles. Digital version of manipulatives have been already introduced, for example Resnick and colleagues (Resnick et al., 1998) developed a new generation of digital manipulatives, computationally-enhanced versions of traditional children's toys to allow children to explore. These materials were blocks, beads, balls, and badges.

Zuckerman, Arida and Resnick (2005) proposed a computationally enhanced version of manipulatives, in the form of enhanced building blocks: physical, modular interactive systems that serve as general-purpose modelling and simulation tools for dynamic behavior. Finally, Block Magic (Miglino, Ponticorvo & Sica, 2015) is an augmented version of Logic Blocks by Dienes (1971).

Block Magic has been implemented and tested in the European project Block Magic (Di Fuccio, Ponticorvo, Di Ferdinando & Miglino, 2015). It consists of a set of magic blocks (48 traditional Logic Blocks), a magic board/tablet device and a dedicated software.

Block Magic transforms the traditional Logic Blocks by Dienes: the Logic Blocks are tangible interfaces, 48 plastic pieces categorized in four classes: geometric shape (triangular, squared, rectangular and circular), thickness (thick and thin), color (red, yellow and blue) and dimension (big and small).

Block Magic proposes various learning activities for children between three and seven years old. The exercises cover different fields: logic, mathematics, language; and some soft skills like problem solving, cooperation and leadership. Block Magic can be used in formal and informal contexts.

This HAB was tested in extensive trials that involved four different schools, 257 students, two children with special needs and 10 teachers. Schools were located in four countries (Italy, Germany, Spain and Greece). Children involved were between two and a half and seven years old, attending the early years of primary school and kindergarten (see Figure 2).

Figure 2. A girl interacting with Block Magic platform and the physical Logic Blocks

4. STTory: An example of narrative HAB

The second HAB example derives from the transformation of a narrative book by adding multisensory materials. Children learn better if caregivers and teachers tell them stories. Narration in educational contexts has be declined as storytelling (Coulter, Michael & Poynor, 2007). This has the key feature of putting together the learning dimension with the emotional one. For this reason, storytelling is able to appeal the cognitive and the emotional dimension simultaneously, which is, especially in the first years of life, very important to guarantee children harmonic growth (Susman, Feagans & Ray, 2013).

Through storytelling, children can develop skills and knowledge, especially related to language and creation of "connections", this latter skill being useful in many other knowledge domains. Narration and storytelling represent an educational approach largely suitable for the development of cognitive abilities and knowledge in an active context.

In storytelling, books play a central role, so the effect of hyperactivity books can be outstanding. In recent years, technological and digital tools have been applied to storytelling, generating digital storytelling considered an even more powerful instructional tool. Moreover, in the storytelling context, multisensory elements have been introduced producing multisensory storytelling, widely used to support children and adults with special needs (Fornefeld, 2012).

Commercial products for storytelling have been packaged with a notable success; consider for example interactive books such as LivingBooks or authoring tools such as StoryMaker. These tools are indeed effective, but they miss the interaction with the physical world. Some solutions have been proposed to overcome this limit; consider, for example, the Interactive Storytelling Spaces for children proposed by Alborzi et al. (2000) where room-sized immersive storytelling experiences for children is realized, or the I-theatre (Muñoz, 2011), a collaborative storytelling system that allows children to draw on paper their own characters and scenarios and see them animated in a digital story.

Starting from these experiences and combining them, a HAB for narration was conceived and implemented: STTory (Di Fuccio, Ponticorvo, Ferrara & Miglino, 2016). It is a hardware/software system for digital and multisensory storytelling with smell, taste and touch. These senses, usually neglected in digital applications, are strictly connected, also at the neural level and the emotional dimension. A good example is STTory, displayed in Figure 3, is made by: 1) an active board able to recognize real objects enhancing the physical materials using the RFID technology; 2) a software with the intelligent artificial tutor that manages the feedback; 3) the tangible objects; 4) the smelling jars; 5) the tasting jars.

Figure 3. STTory: a HAB for narration

Tangible objects, smelling and tasting jars allow the child to be involved in a narration which stimulates, together with sight and hearing, also touch and chemical senses. This has a positive effect on engagement and cognitive processes such as memory.

5. Skeleton Magic: An example of scientific HAB

The third example of HAB application is the transformation of a scientific book, for the introduction of anatomy. Teaching anatomy has been completely renewed by technological tools, models and simulators have replaced the cadaver lab to teach anatomy and to perform procedures and operations (Jones, 2015). Some tools employ tangibles materials, for example ARnatomy (Seo et al., 2014), a tangible augmented reality app for learning gross anatomy or FlexAR (Saenz, Strunk, Maset, Seo, & Malone, 2015), a system based on kinetic tangible augmented reality for anatomy education. In this case, the HAB architecture has been applied also for introducing anatomy to children: Skeleton Magic (see Figure 4).

Figure 4. Skeleton Magic

Skeleton Magic proposes a game where the goal is to re-build a plastic human skeleton that is initially in pieces. Every time the child selects a bone, the game gives some relevant information about it and asks the child to select another bone connected with the first one. This way the child can learn some basic information about anatomy, relying on touch together with sight and hearing.

6. LogicART and SNIFF: Examples of HAB for assessment

HAB architecture can be used to build assessment tools as well (Cerrato, Ferrara, Ponticorvo, Sica, Di Ferdinando & Miglino, 2017; Cerrato & Ponticorvo, 2017). In this case, the materials for the test is a transparent assessment tool. The test is administered in a setting that resembles real life, for example a game situation, preventing some well-known biases such as social desirability. This approach has great potential for implementing HAB. It has been used with LogicART (Ferrara, Ponticorvo, Di Ferdinando & Miglino, 2016), an assessment tool where tangible interfaces are employed for cognitive assessment. This tool allows gathering information to identify the learner starting level and monitoring progresses. Traditionally assessment uses tests often based on verbal materials that are not suitable for populations' as such young children or people with special needs, severe cognitive disabilities or sensory impairment. On the contrary, LogicART can be used in assessment and training of cognitive abilities, such as reasoning, memory, categorization, etc. in the widest possible population.

In the same vein, SNIFF (Ponticorvo et al., 2017a; Ponticorvo, Ferrara, Di Fuccio, Di Ferdinando & Miglino, 2017b) is an assessment tool test that stimulates and trains the sense of smell in the form of a quiz game. The player interacts with 30 different aromas (fruit, flowers, plants and other items). The game asks the user to recognize them and, at the end of the interaction, SNIFF proposes an assessment of the smelling performance, showing a complete report of the results achieved (Di Fuccio, Siano & De Marco, 2017).

7. Conclusions and future directions

Today education is a fundamental challenge for society and educational materials are essential elements. Books have undergone to great transformation and more changing will occur under the technological pressure. We do believe that this changing pathway will not lead to pure digitalization, but rather to a joint use of digital and physical materials which will keep the advantages of both, mitigating their drawbacks. The HAB architecture we have described with related examples, show that it is possible to exploit the significant opportunities offered by novel ICT tools and applications without neglecting the multi-sensory and physical side of education materials.

The HAB project is still at its starting phase and the described prototypes, except Block Magic, have been not tested on wide samples. The next step will be to evaluate and validate these tools in different contexts, including schools and science center, in order to have feedback on various aspects, including usability, acceptance by teachers and students, and efficacy in stimulating cognitive and learning processes.

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