Towards Hyper Activity Books for Children. Connecting Activity Books and Montessori-like Educational Materials

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Abstract. In the first years of school, activity books and Montessori-like educational materials are widespread. They satisfy children's precise psychological needs and result in funded educational practices based on game activity adopted by teachers. These materials are more effective for promoting learning if used in close interaction with an adult, they cannot be customised and the corrective feedback cannot be provided within the appropriate time frame. In this paper, we aim to overcome these limitations by exploiting a Technology Enhanced Learning (TEL) methodology to connect activity books and Montessori-like educational materials. We propose a general architecture for building hyper activity and exercise books called HAB, with three levels: multimedia, multimodality and computing; we describe a first implementation for validating this architecture, Block Magic, and outline development of the architecture under the INF@NZIA DIGI.Tales 3.6 project.

Keywords: Technology Enhanced Learning · Augmented reality systems · Embodied cognition · Natural interfaces · Hybrid educational materials · Montessori-like educational materials

1 Introduction and Background

In primary schools around the world, children and teachers spend much time playing with activity books and Montessori-like educational materials. A significant number of teaching/learning processes are therefore mediated by these tools. They exploit the child's natural involvement in games to promote learning.

Activity books are specifically addressed to children and include interactive content such as games, puzzles, pictures and other elements that require drawing or writing in the books. These interactive features can be supported by a narrative structure and contain elements such a mascots. In later school cycles, the activity book becomes an exercise book for a specific subject. Montessori-like educational materials [14] are manipulative, physical objects specifically designed to foster learning. These materials, introduced by Montessori, include logic blocks, cards, teaching tiles, etc.

These educational materials emerged among others because they meet important psychological needs of children that lead to educational outcomes for teaching adults.

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These psychological needs are related to action, narration and forms of multiple intelligence. Action and interaction are crucial in children's development, as underlined by Piaget [15] and Bruner [2] and, in recent years, by Embodied and Situated Cognition Theory (ESCT) [3]. Especially for humans, these actions take place in a social and cultural context that proposes objects, artifacts, technologies, concrete or abstract cultural substrates [9] and narrative structures. Children need a narrative structure to understand the world around them [1]. The third need to be satisfied to support children's learning processes is feeding their multiple forms of intelligence [7].

These needs are reflected in educational outcomes, first of all the learning-by- doing [5] approach, that encourages active participation, active choice, manipulation of concrete objects and peer group cooperation. The second outcome is narration in an educational context that brings the learning dimension together with the emotional dimension. The third educational outcome is related to children's multiple forms of intelligence: each child should be seen by the teacher as a *unicum* requiring an individual learning path. These outcomes lead to practices which are aimed at focusing on the active participation of pupils as well as on customising educational interventions: the teacher prepares a tailored teaching approach for each child. Moreover it is important to underline that these practices rely on teacher/learner interaction, a fundamental relation that is universally recognised as the key for successful outcomes. But customisation is quite difficult in everyday school practice and the appropriate feedback cannot be delivered within the appropriate time frame. Moreover, as suggested before, ideal educational practice foresees a one-to-one ratio between teacher and learner. However, realising this educational utopia is quite difficult because it can be extremely expensive.

The psycho-pedagogical approach described implies constant supervision by adults. For this reason, mass diffusion of this kind of practice is considerably limited and the school reality is quite different.

Our proposal, described in detail in the next section, is to exploit technology to overcome these limitations and to support teachers, parents and learners in learning/teaching processes.

In particular, the technological starting point is represented by Game-based learning [18] that exploits the motivational qualities of digital games to create engaging educational and training tools [8]. This interest is motivated by the fact that games are carefully designed to stimulate user engagement [6, 10]. Moreover, games constitute an outstanding example of learning-by-doing, or experiential learning: learning by actually doing and being active in the learning process. This has led to many experiences in applying Technology Enhanced Learning (TEL), to children education. Considering the role of action introduced above, it is important to remember that a huge amount of research has been devoted to tangible interfaces [11, 16, 19] that transfer manipulatives into the digital domain.

2 An Architecture to Build Hyper Activity Books

To overcome the above-described problems, we propose the adoption of a general architecture to design and implement educational materials, namely Hyper Activity Books (HAB). This architecture exploits TEL methodology to connect activity books and Montessori-like educational materials. It is represented in Fig. 1.

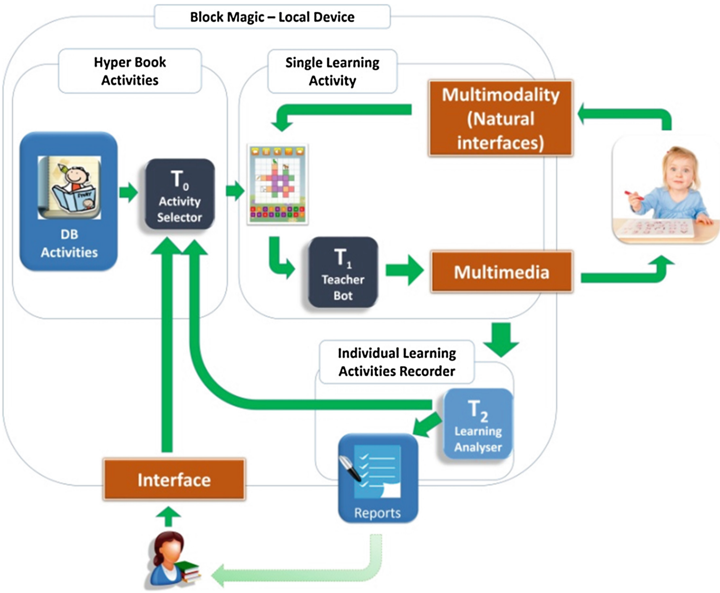

Fig. 1. HAB architecture. Brown boxes represent the three interaction levels of the architecture, where T represents Tutoring systems; the drawing represents the activity based on manipulatives (Color figure online)

Let us start from the database, on the left, where the various activities or exercises reside. It can be conceptualised as activity book pages, with every page representing a single activity. These activities stimulate a particular knowledge domain: to cite just a few, there are exercises about maths and logic, as well as activities to develop imagination and creativity. The activities to be played are chosen by T_0, that is to say the tutoring system with the task of selecting the activity to be proposed in accordance with two information sources: teacher hints and previous results. In the activity layer, the playing child interacts with physical materials, Montessori-like educational materials and T_1. T_1 it is the tutor who aims to maintain a high interaction level from the child. This is achieved through a particular kind of interaction that is multimedia and multimodal-based. In fact, HAB has three features - multimedia, multimodality and computing which govern interactions during activities.

2.1 Multimediality, Multimodality and Computing

During activities, children interact with the tool named T_1, both the trainer who proposes the task with a multimedia output (screen presentation, voice, images, pictures, videos, songs, etc.) and the child who interacts with it in a multimodal manner, using voice, hands, typing text. The answer from the child is tracked by T_1 which replies with a feedback based on the exercise performed and on its own artificial intelligence, the computing level. Feedback is fundamental for increasing child involvement in the activity. T_1 can offer various rewards for specific tasks, can name the child thus keeping him/her immerged in the activity layer. Feedback could be a success phrase like "Good! Well done! Play again" if the exercise is performed well or tips/suggestion in other cases. Multimediality is functional to the narrative and, by 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 which are invisible to the user and allow continuous interactions without using artificial control devices whose operation must be acquired. These interfaces can be implemented by exploiting various technologies such as RFID/NC, Smart Objects and Leap Motion.

What we have described up to now is HAB Stage 1, the activity experience. This platform also holds another stage, Stage 2, which is invisible to the child user, but is very important for the teacher. Stage 2 is based on T_2 work. This third tutor builds an individualised report on child interaction, records achievements and failures, and activity preferences in order to build a detailed user profile. This report comes back to the teacher who can further customise HAB/child interaction with a focused choice from the database and to T_0 that can better adapt itself to the child. In this way, the cycle can start again. It is evident that the role of tutors is fundamental, and for this reason we will describe them in more detail in the next subsection. We should stress that, in the HAB architecture, both Stages 1 and 2 run on a personal device.

2.2 HAB Tutoring Systems

In the HAB architecture, we have three different tutoring systems with different roles, implemented by Intelligent and Tutoring Systems [17] which exploit artificial intelligence techniques to provide instructions that are tailored to learners needs. They give the chance to customise didactic paths through the identification of specific goals for each pupil, and tracking of every child's learning achievement, which, in turn, offers feedback that can be used for redefinition of the didactic path along the path itself. They implement learning analytics by measuring, collecting, analysing and reporting data about learning in the activity layer, thus supporting learning processes. In HAB, Intelligent Tutoring Systems represent the computing level.

3 HAB Architecture Applied to Logic Blocks: Block Magic

Block Magic, for now BM, is a prototype for educational materials developed in a successful European research project under the framework of the LLP-Comenius programme. It builds a bridge between physical manipulation and digital technology [12] in education because it is an example of what we can call STELT (Smart Technologies to Enhance Learning and Teaching) [13] which links physical and digital applications. The project recovers above-mentioned Montessori-inspired psycho-pedagogical approach, based on active learning and teaching, exploiting current technology facilities to build a hybrid educational material. In particular, Block Magic has developed a functional prototypal system which has enhanced the Logic Blocks Box, a Montessori-like educational material widely used in kindergartens, primary schools, rehabilitation centers, homes, etc., dedicated to support learning and teaching processes in children aged 3 to 7.

Learning blocks were introduced by Dienes [4] and are a structured material formed by 48 classic pieces that vary in shape, color, thickness and size. BM is the first implementation of HAB architecture. At the single learning activity layer, the child runs an activity interacting with physical educational materials and T1, which is Blocki, the artificial trainer. The physical material consists of a set of magic blocks and a magic board/tablet device. A specific software implements multimediality, multimodality and computing. The first trials which involved 4 different schools, 257 students, 2 children with special needs and 10 teachers, and were devoted to an evaluation of BM impact, indicated that BM attractiveness emerged strongly. These preliminary trials indicate that HAB architecture can produce powerful tools to complement curricular activities. Block Magic has been accepted well by children and teachers because it is very appealing for children. This general architecture is currently inspiring an ongoing research project, INF@NZIA DIGI.Tales 3.6, the goal of which is to promote learning/teaching process, increasing hands-on practice with TEL methodologies.

4 Future Directions

Starting from the general HAB architecture and its first implementation, two pathways will be followed in the future. The first will be to develop HAB further. In particular, the platform will be extended by adding an authoring tool that will become an Open Educational Resource (OER). Moreover, a new tutor will be introduced with the specific task to build collective reports. These reports will contain data about children's groups with different characteristics: class, school, study course, region, nation.

The community will implement activities that are played individually or collectively by children on personal devices. The data collected by the personal devices are fed to the community to analyse learning achievements in a virtuous cycle. The second pathway will be devoted to deepening analysis about the effectiveness and usefulness of the HAB architecture in an attempt to understand which factors are relevant for improving learning and teaching processes.

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