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Collaborative and Constructive Learning of Elementary School Children in Experiental Learning Spaces along the Virtuality Continuum

Huberta Kritzenberger, Thomas Winkler, Michael Herczeg

Institute for Multimedia and Interactive Systems (IMIS), University of Luebeck

Abstract

Learning is an active, constructive and collaborative process, where people construct knowledge from their experiences in the world. Especially children need to learn through their senses and through physical activity. However, there are few experiental learning environments for school children available, which involve the senses and physical activity. Reasons put forward for this situation are the nature of the concepts to be learned and partly the lack of manipulative learning material. This paper introduces a mixed reality learning space collaboratively constructed by elementary school children during recent teaching experiments. During the process of constructing and interacting with the learning space along a virtuality continuum the children make learning experiences, which can be interpreted in a semiotic way and which allows the children intuitively understand concepts from the two disciplines of computer science and of the arts.

1 Introduction

Learning is a constructive and collaborative activity of people, where they construct knowledge from physical experiences in the world. It holds especially true for children's learning and therefore should be the leading principle in the design of learning environments. Especially new media hold the promise of creating new spaces that can be entered and experienced in a primary sensory way. This is the starting points for considerations at the IMIS in recent teaching experiments with elementary school children creating and acting in a mixed reality environment.

The authors are involved in a project called ArtDeCom ("Theory and Practice of Integrating Education and Training in Arts and Computer Science"). We try bringing together education in the two usually separated disciplines of arts and computer science in school on several levels of education. Pupils should be given an opportunity to explore the relationships of the two disciplines with adequate tools and learning goals for their respective age and learner level. The project is funded by the German "Bund-Länder Commission for Educational Planning and Research Promotion" (BLK) within the general funding program "Culture in the Media Age". It aims at investigating teaching material and situation for a curriculum definition for integrating education in arts and computer science on all educational levels. The IMIS is cooperating with the Muthesius Academy of Arts, Design and Architecture and with the Institute of Art History of the Christian-Albrechts-University in Kiel (Germany) to develop curricular elements for an integrated education of arts and computer science.

This situation is the background for the integrated lessons of arts and computer science in an elementary school in Luebeck (Germany). The teaching attempt is in the 3rd class level, that is for children with an age of 8-9. During several lessons the children work in design projects developing their own mixed reality environment, within which they later perform an interactive musical revue. The children themselves develop the scenes of the mixed reality environment working in groups and using adequate software tools as well as real world materials. Collaborative and constructive learning is practiced permanently during the design process as well as during interaction with the hybrid environments of the mixed reality scenery, where children actively explore the boundaries between the real and the virtual world.

A key focus of our research refers to cross-settings of ways of thinking in arts and in computer science. We think that mixed reality environments are a perfect learning space that enables children to physically explore concepts from both disciplines in an intuitive way.

2 Constructive Learning Spaces for Children

Constructive learning theory addresses learning as a process of actively constructing knowledge from experiences in the world. People construct new knowledge with particular effectiveness when they engage in constructing personally meaningful products, which are meaningful to themselves or to others around them. Furthermore, it is important that the learning environment is authentic and situated in a real-life situation. Learners must get an opportunity to build multiple contexts and perspectives in a social context. This process of experiental learning is especially important in childhood learning, where children need sensual and physical activity to draw knowledge from it. Despite of this common insight into the conditions of effective learning processes, children encounter fewer learning situations where senses and physical activity is involved when they move from kindergarten to elementary school.

Reasons put forward for this situation are that the nature of abstract concepts seem to be very difficult if not impossible to explore by sensual and physical experience. For example, traditional physical media generally do not support children understanding the behavior of dynamic systems or how patterns arise through dynamic interactions among component parts. Such concepts are typically taught through more formal methods, involving abstract mathematical formalisms. Unfortunately, many students have severe problems with this approach, and thus never develop a deep understanding of these concepts (Resnick 1998).

With this background in mind there are several approaches to manipulative, physical and tangible learning environments for children. Resnick (Resnick 1998) has created a new generation of computationally enhanced manipulative materials, called "digital manipulatives", developed at the MIT Media Lab. They expand the range of concepts that children (and adults) can explore through direct manipulation of physical objects and aim to enable children to continue to learn concepts with "kindergarten approach" even as they grow older. As children build and experiment with these manipulative materials, they form mental models and develop deeper understanding of the concepts they enact with. Children continue to learn new concepts with a "kindergarten approach". Resnick assumes that children learn with digital manipulatives concepts that were previously considered too advanced for them.

Other approaches with physical and tangible (graspable and touchable objects) interaction are for example MIT´s KidsRoom (Bobick et al. 2000), Triangles and 'strings' (Gorbet et al. 1998, Patten/Griffith/Ishii 2000), Curlybot (Frei et al. 1999); StoryMat (Ryokai/Cassel 1999) or StoryRooms (Alborzi et al. 2000) in order to enhance collaboration among learners and enable constructive learning experiences for children. Furthermore, there is a growing recognition of the value of design projects as having positive effects on learning and deep understanding (Alborzi et al 2000; Druin/Perlin 1994; Stanton et al. 2001). In these projects children create external artifacts, like animate stories, video games, kinetic sculptures, models, simulations and so on, which they share and discuss with others. These artifacts provide rich opportunities for learning. As children are involved as active participants, they have a greater sense of control over the learning process. As they design artifacts in group work, they experience pluralistic thinking, multiple strategies and solutions. By the way they need to think about how other people will understand and use their constructions. Furthermore, design projects are mostly interdisciplinary and therefore bring together concepts from different disciplines.

Completely different approaches to develop constructive and collaborative learning spaces fertilize virtual reality environments, in which learners collaboratively interact with, create or extend a virtual world. However, there are only a few examples for collaborative learning environments for children, like the Virtual Museum Project (Kirner et al. 2001), NICE (Johnson et al. 1998), Gorilla World (Alison et al. 1997) or AGORA (Hiroaki et al. 1998). These learning environments are at the very end of a virtuality continuum (Milgram/Kishino 1994), that is the virtual world replaces the physical world and therefore prohibits tangible interaction which is a vital learning experience for children learners. From an interaction point of view, virtual reality separates the learner from the real world and from traditional tool use. The statement for virtual reality as a natural medium for computer supported collaborative learning holds true only as far as aspects of the task are concerned.

3 Experiental Learning along the Virtuality Continuum

We consider mixed reality environments as very promising for constructive and collaborative learning experiences in the classroom in order to explore concepts of arts and computer science. As a mixed reality environment does neither separate the learners from the real world, which they can explore with their senses, nor from the known tools. As the learners can see each others and the real world at the same time together with the virtual world, this situation facilitates a high bandwidth of coding and communication activities between the learners and an intuitive manipulation of the elements of the digital world.

From the point of view of the children's learning experiences the process of constructing the mixed reality world is very important for the later understanding the interaction with this world. The mixed reality world was build by the children in a collaborative process (see chapter 3.1) forming first papier-maché objects and then animating the objects with LEGO® software. The animated digital world formed together with the similar looking real world the background and stage for an interactive musical revue (the world of dragons) performed by the children (see chapter 3.2). During this process of construction and stage performance the children got involved in diverse processes of coding, decoding and interaction and thereby understanding concepts from the arts and from computer science.

3.1 Mixed Reality Boundaries

In the first phase of the teaching experience the children created a story (world of dragons), collected and arranged objects of the real world, e.g. they created trees, mountains etc. for a landscape using wires and papier-maché (figure 1). The physical objects of the real formed the building block for the creation of the digital world.

Figure 1: Process of modeling objects in the real world: children's story creation and design of elements of the real world with papier-maché

The children's construction process proceeded by creating computer animations using the real world previously created with papier-maché. For this work they used software like LEGO® -Cam or LEGO® MindStorms Vision Command to program the picture recognition and interactive sequences. Furthermore, the children produce and record sounds from the physical world in order to enhanced the digital world (figure 2).

Later, in another stage of the learning process, the children will interact with this digital world when performing a music revue on the stage. By their actions and partly by their appearance (e.g. dresses, movements) the children will influence the reactions of the computer program (chapter 3.2). In order to enable the system to react this way, the children test the conditions, under which the picture recognition program registers the movements or color coding in the sensitive monitor parts. For this purpose, the children define interactive points in the physical space and thereby create boundaries between the real and the physical world (figure 3). When doing this work the children will learn relevant attributes for coding (e.g. color attributes, like light and color intensity). The children also collaboratively and constructively learn that by coding these attributes they can influence the computer program and they will also learn, that changes in the program states will influence their behavior and interactions in the real world (figure 4 and chapter 3.2).

Figure 2: Process of modeling the mixed reality world by the children: design of sound and video animation

Figure 3: Children define interactive points in the physical space and thereby create boundaries between the real and the physical world

Figure 4: Children express themselves in mixed reality: With movements the children triggersounds - at the same time they react with certain movements to the video projection

3.2 Situation as Interface

In the second phase of the teaching attempt the children use the previously created mixed reality environment for the performance of a music revue (figure 5). The digital world consists of an animation, which shows a wild landscape with mountains, trees, a watercourse, an active volcano, a cave and several moving dragons. In the physical world of the stage there are several trees which have been made from the same material and look exactly like the trees in the animation. Between the projection wall and the video animation the children move and dance on the stage. They wear differently colored dragon costumes and dance to classical music. The rhythm of the music as well as the narrative structures of the animation impose a certain timing of the acoustic and body expression. By certain attributes, e.g. the colors of their costumes, the children trigger different pre-recorded sound files (e.g. blowing of the wind, the rolling of thunder, the volcanic eruption, the sound of an avalanche, the shouting of dragons), creating sound experiences.

That is in this collaborative mixed reality learning environment the real world becomes the interface to the virtual. The physical interaction space is filled with data produced by the children and interpreted by the software. The production of the data is organized spatially (movements and dancing of the children) and perceptually (colors of the children's dresses). Furthermore the children's exploration of the virtual space is connected to the real space. Movements causes the coding and de-coding, arranging and re-arranging of content. The children learn how space can be used to structure virtual worlds, meaning that one could organize data like one organizes choreographic actions (Strauss et al. 1999). During the dancing lesson, which the children were given before, they learned a system of expressions and they use the system of expressions to arrange data (figure 6). Movement and gesture connect the participants with each other and with the digital world of the computer program.

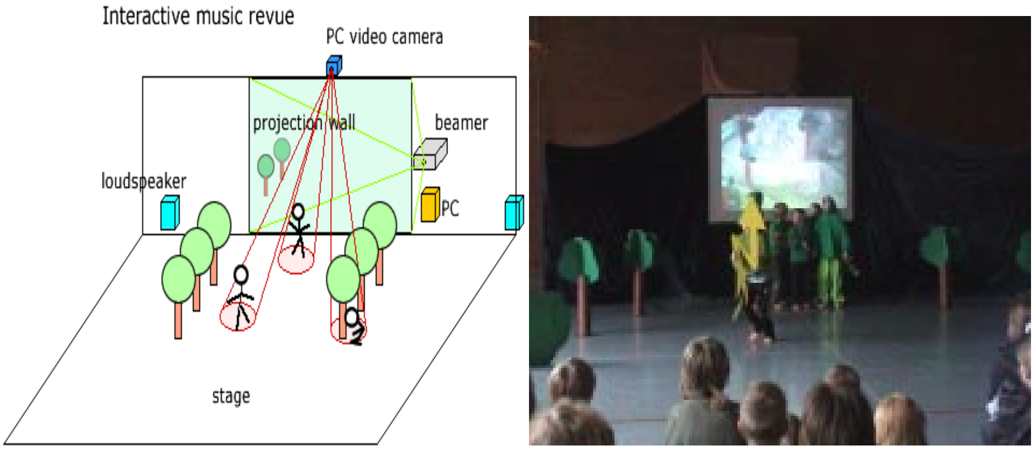

Figure 5: Sketch of the collaborative mixed reality environment and a picture of performance of the music revue on stage

Figure 6: Children learn a system of expressions to code and arrange data spatially

3.3 Seamless Collaboration and Construction

Mixed reality environments have an important advantage putting them near face-to-face-environments. While collaborating with other learners on a task there is a dynamic and easy interchange of focus between the shared and the speaker's interpersonal space. The shared space in the classroom is the common task area and communication space. At the same time this commonly shared space is the interface for coding and encoding in order to interact with the animated computer program. Therefore, no seams or discontinuities are introduced into the collaborative and constructive learning space. Ishii defines a seam as a spatial, temporal or functional constraint that forces the user to shift among a variety of spaces or modes of operation (Ishii/Kobayashi/Arita 1994), for example seams as discontinuities between different functional workspaces. Generally, seams force users to change the mode of operation. For a learning space a seam in this sense would mean to force the learner to change between a shared and a personal learning space and between acting in the real world and the programming the digital world or between traditional real world and digital tools. Studies in other contexts found that seams cause the learning curve experienced by users who move from physical tools to their digital equivalents and permanently change the nature of interaction (Heath/Luff 1991).

However, the concept of mixed reality, as described above, is designed to overcome the disadvantages of current computer interfaces. It widens the computer interface to the environment of the classroom. It merges the real and virtual worlds, providing a single interface to both worlds, and also allows the use of intuitive interfaces based upon real world experience and skills. Therefore, a seamless interface between the physicality and virtuality is possible within the mixed reality. It facilitates collaborative learning and physical and tangible experiences of the children in the classroom interaction.

4 Conclusions

In our teaching attempt we found that mixed reality environments are a very promising learning space for constructive and collaborative learning of children enabling semiotic learning experiences (Kritzenberger/Winkler/Herczeg 2002). The mixed reality environment meets all requirements for a constructive learning space, like learning through senses and physical activity using digital manipulatives. As the children construct their own model of the physical and of the digital world, the children experience a singular event, for which various interpretation levels are possible: bodily experiences (e.g. mimic and dancing expressions, empathy in music and rhythm, feeling physical material), modeling real and digital worlds, arranging data spatially, influencing the physical as well as the digital environment with their bodily expressions or attributes of their dresses or spatial movements), information coding and processing (e.g. conception and development of picture recognition with LEGO® RIS Vision Command).

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Contact Information

Prof. Dr. rer. nat. Michael Herczeg
University of Lübeck
Institute for Multimedia and Interactive Systems (IMIS)
Willy-Brandt-Allee 31a, Media Docks
D-23554 Lübeck
E-Mail: herczeg@imis.mu-luebeck.de

Dr. phil. Thomas Winkler
University of Lübeck
Institute for Multimedia and Interactive Systems (IMIS)
Willy-Brandt-Allee 31a, Media Docks
D-23554 Lübeck
E-Mail: winkler@imis.mu-luebeck.de

Dr. phil. Huberta Kritzenberger
University of Lübeck
Institute for Multimedia and Interactive Systems (IMIS)
Willy-Brandt-Allee 31a, Media Docks
D-23554 Lübeck
E-Mail: kritzenberger@imis.mu-luebeck.de