In: Vom interaktiven Werkzeug zu kooperativen Arbeits- und Lernwelten,
Berichte des German Chapters of the ACM, Mensch & Computer 2002, Bd. 56, S. 115-124

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

Thomas Winkler, Huberta Kritzenberger, 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 contribution introduces a collaborative and constructive learning space for elementary school children designed along the virtuality continuum. It was designed through recent teaching experiments with elementary school children. The learning space itself is actively, collaboratively and constructively designed by the children themselves and allows making semiotic learning experiences during interaction with each other and with elements of the learning space along the virtuality continuum.

1 Introduction

Learning is a constructive and collaborative activity of people, where they construct knowledge from physical experiences in the world. This holds especially true for children's learning. This basic understanding of the learning process 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 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/Kinsho 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

3.1 Situation as Interface

In the aforementioned project ArtDeCom we use a collaborative mixed reality learning environment approach, which is sketched in figure 1. It was designed by the children themselves around a musical revue "World of Dragons". It consists of an animation, which shows a wild landscape with mountains, trees, a watercourse, an active volcano, a cave and several moving dragons. On the stage within the physical world, 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 music of 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.

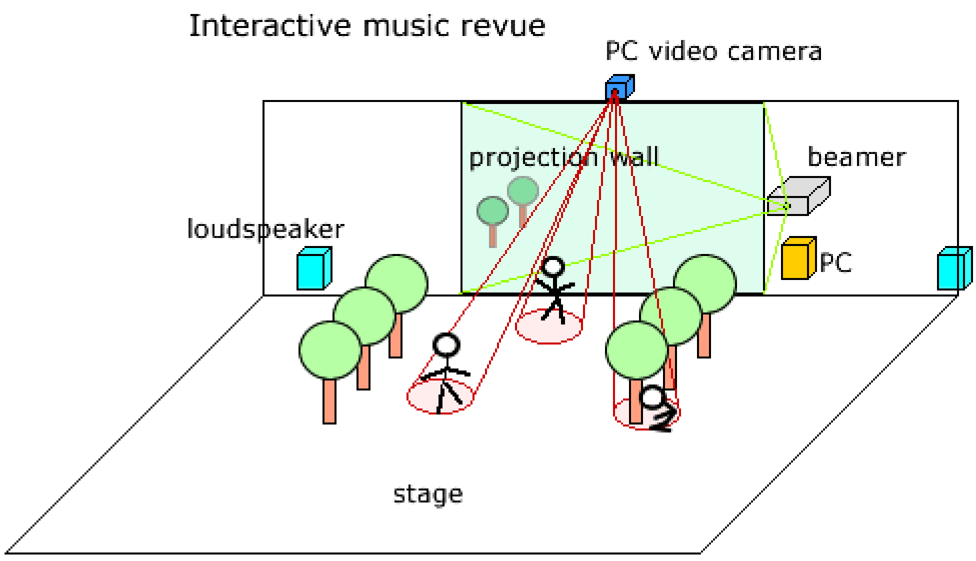

Figure 1: Sketch of the collaborative mixed reality environment for the musical revue

Figure 2: Performance on stage (Lightning releases a thunderstorm)

There are sounds like the blowing of the wind, the rolling of thunder, the volcanic eruption, the sound of an avalanche, the shouting of dragons, as well as the recurring sound of a stumbling little dragon. Other sounds are triggered by the children's movements, e.g. by the colors of their costumes the children trigger different pre-recorded sound files, 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.

Figure 3: Children learn a system of expressions to code and arrange data spatially

The children learn how space can be used to structure virtual worlds, meaning that one could organize data like one organizes choreographic actions. 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. Communication and interaction is not experienced as conveying known meanings using a given system of expressions. Movement and gesture connect the participant with each other not directly, but through their effects on the environment The effect is not to understand the relationship between one's actions and the effects perceived. It becomes more interesting what one is creating than how one is doing it. Participants don't think how they are going to move - they simply move, guided by the impression of the resulting landscape and their bodily experience of space and of other participants. Therefore, the children meet a situation in which they discover their mutual interdependence in exploring and perceiving the world. Through their interaction within the real space they interact with each other and with the digital world of the computer programs.

3.2 Mixed Reality Boundaries

In order not to separate the learner from their the real world and their traditional tools and their senses the alternative approach with a mixed reality environment is used. As mixed reality (MR) is the overlaying of virtual objects and the real world, it allows the users to see each other and the real world at the same time with the virtual world, facilitating a high bandwidth of communication between the learners and intuitive manipulation of the digital world. This conditions of mixed reality boundaries are very promising for constructive and collaborative learning experiences in the classroom, although there are hardly any examples for using mixed reality learning environments as learning spaces in other contexts. Single-user MR interfaces have been for computer-aided instruction (Feiner/MacIntyre/Seligman 1993) or for medical visualization (Bajura/Fuchs/Ohbuchi 1992), where virtual ultrasound images overlay images onto a patients' body allowing doctors to have X-Ray vision while performing a needle biopsy task. These applications have shown that MR interfaces can enable a person to interact with the real world in ways never before possible. We believe that MR is ideal for collaborative interfaces. Modeling the mixed reality is done by the children with respect to setting and story, as well as visual and auditory environment. The children digitally record sounds and specify the possible use and behavior of sound files.

The children design the mixed reality boundaries themselves. They model the real world as well as the digital world. During the first production phase they create, collect and arrange the objects of the real world, e.g. they create trees and mountains using wires and papier-maché. Furthermore, during the working process the children create animations or sound for the digital world, but they also create the digital world using software like LEGO-Cam or LEGO MindStorms Vision Command to program the interactive sequences of certain picture recognition sequences. That is they model also the digital world, where elements of the real world are digitized and later on interact in the real world environment using codes that influence not only the real world but also the physical world environment. In order to enable the software to interact with the physical world during the musical revue performance, the children define places on the floor of the stage for the music revue, where a Web Cam and the software is to react on the specific arrangements of the coding (e.g. the rhythmic dancing movements of the children, the colors of the dresses) with generation of specific sounds or music.

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. During this process the children experience relevant color attributes for coding, e.g. light and color intensity. During the music performance vice versa the program influences the children's coding and therefore enable an intuitive understanding of the nature of human-computer-interaction processes.

Figure 4: Process of modeling the mixed reality world by the children: story creation and design of elements of the real world for video animation

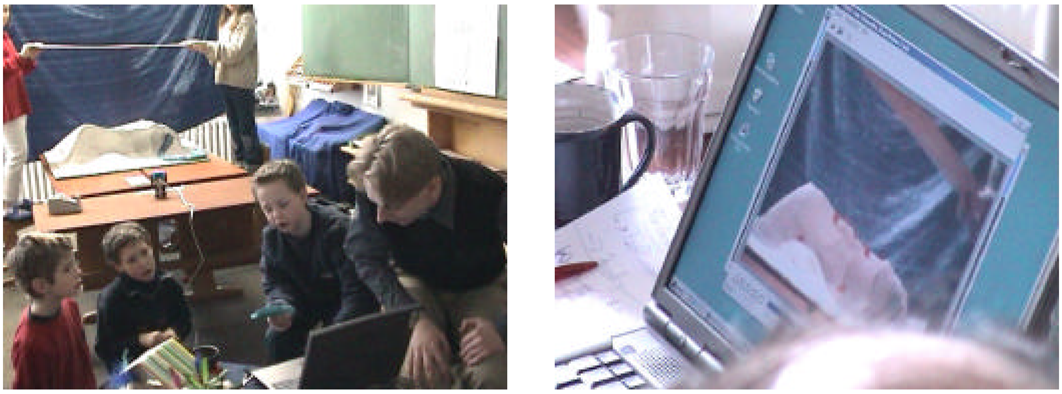

Figure 4: Process of modeling the mixed reality world by the children: design of sound and video animation

Figure 5: Children define interactive points in the physical space and thereby create boundaries between the real and the physical world

Figure 6: Children express themselves in mixed reality: With movements the children release sounds - at the same time they react with certain movements to the video projection

3.3 Seamless Collaboration and Construction

When people talk to one another in a face-to-face learning environment while collaborating on a real world task there is a dynamic and easy interchange of focus between the shared and the speakers' interpersonal space. The shared learning space in the classroom is common task area between collaboration, while the interpersonal space is the common communication space. Normally, CSCL interfaces introduce seams and discontinuities into the collaborative 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). There are functional seam as discontinuities between different functional workspaces, forcing the learner to change the mode of operation, for example the seam between shared and interpersonal learning space. There are also cognitive seams as discontinuities between existing and new worlds or between the real world and the digital world (as far as our subject is concerned) or between (traditional) real world and computer-based tools. Therefore, the seams cause the learning curve experienced by users who move from physical tools to their digital equivalents and permanently change the nature of interaction (cf. 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: Allows the use of intuitive interfaces based upon real world experience and skills. Therefore, a seamless interface between the physicality and virtuality is possible.
- 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. The mixed reality environment meets all requirements for a constructive learning space for children, 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 however different interpretations 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, attributes of their dresses or spatial movements), information coding and processing (e.g. conception and development of picture recognition with LEGO RIS Vision Command.

Acknowledgement

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". The official title of the project is "Theorie und Praxis integrierter ästhetischer und informatischer Aus- und Fortbildung", project number A 6681ASH01. Project partners are the Karl-Albrechts-Universität Kiel (Dr. Ingrid Höpel) and Muthesius-Hochschule Kiel (Daniela Reimann). The authors wish to thank the Grundschule Lauerholz (Luebeck) and the Freie Schule Luebeck e.V.

5 References

Alborzi, H. et al. (2000): Designing Story Rooms: Interactive Storytelling Spaces for Children. In: Symposium on Designing Interactive Systems. Conference Proceedings on Designing Interactive Systems: Processes, Practices, Methods, and Techniques. New York: ACM Press, pp. 95-104

Alison, D.; Wills, B.; Hodges, F.; Wineman, J. (1997): Gorillas in the Bits. Proceedings of the IEEE Virtual Reality Annual International Symposium, March 1997, pp. 69-76

Bajura, M.; Fuchs, H.; Ohbuchi, R. (1992): Merging Virtual Objects with the Real World: Seeing Ultrasound Imagery Within the Patient. In: Proceedings of SIGGRAPH 92. New York: ACM Press, pp. 130-145

Billinghurst, Mark; Kato, Hirokazu (1999): Collaborative Mixed Reality. In: Proceedings on the First International Symposium on Mixed Reality (IMSM 99). Mixed Reality - Merging Real and Virtual Worlds. Berlin: Springer, pp. 261-284

Bobick, A.; Intille, S.; Davis, J.; Baird, F.; Pinhanez, C.; Campbell, L; Ivanov, Y.; Schutte, A.; Wilson, A. (2000): KidsRoom: A perceptually-based interactive and immersive story environment. *Presence Teleoperators and Virtual Environments* 8 (4), pp. 367-391

Druin, A.; Perlin, K. (1994): Immersive environments: A physical approach to the computer interface. In: Companion of CHI 94. Boston, MA, April 1994, ACM Press, pp. 325-326

Feiner, S.; MacIntyre, B.; Seligmann, D. (1993): Knowledge-Based Augmented Reality. *Communications of the ACM*, Vol. 36, No. 7; pp. 53-62

Frei, P; Su, V.; Mihak, B.; Ishii, H. (1999): Curlybot: International Conference on Computer Graphics and Interactive Techniques. Proceedings of the Conference in SIGGRAPH 99. Los Angeles, California. New York: ACM Press

Gorbet, M.; Orth, M.; Ishii, H. (1998): Triangles: Tangible Interfaces for manipulation and exploration of digital information topography. Proceedings of CHI 98, ACM, pp. 49-56

Heath, C.; Luff, P. (1991): Disembodied Conduct: Communication Through Video in a Multimedia Environment. In: Proceedings of CHI '91. New York: ACM Press, pp.99-103

Hiroaki, H. et al. (1998): Space Sharing Architecture for a Virtual Three-Dimensional Virtual Community. *IOP/IEEE Distributed Systems Engineering* 5, pp. 101-106

Ishii, H.; Kobayashi, M.; Arita, K. (1994): Iterative Design of Seamless Collaboration Media. *Communications of the ACM*, Vol. 37, No. 8, pp. 83-97

Johnson, A.; Rousson, M.; Leigh, J.; Barnes, C.; Vasilakis, C.; Moher, T. (1998): The NICE Project: Learning Together in a Virtual World. Proceedings of IEEE Virtual Reality Annual International Symposium, Atlanta, Georgia, pp. 176-183

Kirner, T. et al. (2001): Development of a Collaborative Virtual Environment for Educational Applications. In: Proceedings of WEB3D 2001, Paderborn, Germany, pp. 61-68

Milgram, P.; Kishino, F. (1994): A Taxonomy of Mixed Reality Visual Displays. *IEICE Transactions on Information and Systems. Special Issue on Networked Reality*. December 1994

Patten, J.; Griffith, L.; Ishii, H. (2000): A tangible interface for controlling robotic toys. Proceedings of CHI 2000, ACM

Resnick, Mitchel (1998): Technologies for Lifelong Kindergarten. In: Educational Technology Research and Development 46 (4), pp. 1-16

Ryokai, K.; Cassel, J. (1999): Computer Support for Children´s Collaborative Fantasy Play and Story Telling. Proceedings of CSCL 1999. Stanford, CA

Stanton, Danae; Bayon, Victor; Neale, Helen; Ghali, Ahmed; Benford, Steve; Cobb, Sue; Ingram, Rob; O´Malley, Claire; Wilson, John; Pridmore, Tony (2001): Classroom Collaboration in the Design of Tangible Interfaces for Storytelling. In: Proceedings of the Conference on Computer-Human Interaction CHI 2001, pp. 482-489

Strauss, W.; Fleischmann, M.; Thomsen, M.; Novak, J.; Zlender, U.; Kulessa, Th.; Pragasky, F. (1999): Staging the Space of Mixed Reality - Reconsidering the Concept of a Multi-User Environment. Proceedings of VRML 99. Fourth Symposium on the Virtual Reality Modeling Language. Paderborn, Germany, February 23-26, 1999. Also: GMD Report 79, December 1999

Contact Informationen

Dr. phil. Thomas Winkler
University of Luebeck
Institute for Multimedia and Interactive Systems (IMIS)
Ratzeburger Allee
23538 Lübeck
E-Mail: winkler@imis.mu-luebeck.de

Dr. phil. Huberta Kritzenberger
University of Luebeck
Institute for Multimedia and Interactive Systems (IMIS)
Ratzeburger Allee 160
23538 Luebeck
E-Mail: kritzenberger@imis.mu-luebeck.de

Prof. Dr. rer. nat. Michael Herczeg
University of Luebeck
Institute for Multimedia and Interactive Systems (IMIS)
Ratzeburger Allee 160
23538 Lübeck
E-Mail: herczeg@imis.mu-luebeck.de