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Learning Biology through the Creative Use of Artistic Digital Media: Constructing Phyconic Control for a Video Installation

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Abstract: In this paper, the authors examine why the creative use of artistic digital media is relevant in classroom learning. Fifth graders learn about the existing associations between nutrition, their bodies and sense of well-being. In an inter-disciplinary learning project (biology and art), students learn how to express and reflect upon their knowledge about the biology of food and mood. They build an interactive video installation in a cubical tent. Each tent wall serves as a back-projection for the students' self-made video clips. These clips are controlled by a tangible user interface. The subject of diet, nutrition, and digestion in their biology curriculum is linked with various forms of expression developed in their media art class. Throughout this project, the children are able to reflect upon the aesthetics and scientific facts of their personal eating habits. The major long term learning effects occurs when the children build a tangible interface and an interactive installation, which creates a relation between their ideas and their physical world.

Introduction

Tangible and digitally augmented reality has been successfully used in schools over the years (e.g., Iturrizaga & Falbel 1999; Nobel 2001; Rogers 2002; Price 2003). Closing the gap between the world of bits and the world of atoms (Ishii & Ulmer 1997) seldom leads to cost efficient answers, thus often eliminating schools from being able to work with state-of-the-art technology. However, more and more teachers realize the importance of teaching children in an interdisciplinary approach. The teachers show the students how to augment their learning environment digitally, and how to learn by producing tangible media in an artistic environment. The focus the project "Your Food is Your Mood" was to create sustainable project-oriented learning in biology: a sustainability supported through artistic expression and encouraging the acquirement of media literacy. The students create interactive artistic environments with self-made tangible user interfaces, which influence their long-term learning experiences positively. Then various influences of the students' learning experiences were analysed: e.g., effects of choosing subject material closely related to the high school students' personal interests, degree of difficulty learning to record videos and produce animations, degree of difficulty creating an interactive environment using tangible user interfaces. Does the use of artistic strategy to study biological processes positively affect or support sustainable learning?

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Brief History

The development, testing, and evaluation of the project "Your Food is Your Mood", originated within the KiMM (Kids in Media and Motion) initiative. For more than six years we have developed at the University of Luebeck innovative learning technologies and learning scenarios and transferred them into grade and high school education systems. Initiating learning by using creative wearable, tangible, ambient, mobile and participatory (Web 2.0) media to augment or mix the physical with the digital realm, has proven to be successful for education (Melzer, Hadley, Glasemann & Herczeg 2006; Winkler, Goldmann & Herczeg 2006; Melzer, Hadley, Winkler & Herczeg 2005; Melzer, Hadley & Herczeg 2005). The aim of the KiMM initiative is to establish pedagogical models and technological tools for use in the acquirement of media literacy. The research and transfer initiative promotes holistic, project-oriented, inter- and transdisciplinary learning as well as creative and artistic use of digital media. The new interfaces for human computer interaction (HCI) are developed by the scientists, teachers and school children together. The development of new software and scenarios for learning are pedagogically sound, since the focus of the software is on applicability and the content of scenarios rooted in the school curriculum.

In all of the school projects, the students are the main participators in all aspects of producing the media and systems. It is their responsibility to define, design and realize all the tasks and artifacts in their projects. The teachers act as supervisors to assure that the communication in the work teams functions, mediate any occasional difficulties, and help the students adopt a structured work method.

Related work

Already in 1993, Pierre D. Wellner, Wendy Mackay, and Rich Gold wrote in their paper "Computer augmented Environments: Back to the Real World" about the interaction with accustomed physical/tangible environments, and how to augment the digital world. The augmentation of artifacts for digital interaction (e.g. tangible user interfaces) leads back to the primacy of the physical world and the idea of introducing computing technology unobtrusively. In their paper "Tangible Bits: Toward Seamless Interfaces between People, Bits and Atoms" (1997) Hiroshi Ishii and Brygg Ullmer presented their vision of Human Computer Interaction: "where the user could 'grasp and manipulate' bits of in the centre of users' attention by coupling the bits with everyday physical objects". In the following years many attempts have been made world wide, to close the gap between the worlds of bits (virtual) and atoms (physical) regarding learning at school.

Unlike the mere execution of tangible media mentioned above, our more pedagogically driven approach helps teachers to teach school children to create tangible user interfaces in an artistic process by themselves. This approach is borrowed from contemporary art. It encourages students to look different at their own world (Eco 1989). Thus, they attain an intensification of perception (Seel 2005) about their surroundings that is pedagogically meaningful (Parks 1992; Strauss 2004). The examination and reflection of media art plays a primary role for both teachers and students.

Artists have used tangible user interfaces in media art since the beginning of the 1990s. These interfaces allow the user interaction with computers via graspable objects. It was possible to implement cost efficient tangible media with graspable user interfaces, e.g. objects with attached barcodes. A computer, with a barcode reader, could then easily identify a large range objects. One of the best well known media artwork, which used barcodes is the interactive environment "Bar Code Hotel" by Perry Hoberman, 1994 (Fig. 1). Hoberman recycles the ubiquitous symbols (barcodes) found on every consumer product to create a multi-user interface to an unruly virtual environment. The installation uses a number of strategies to create a casual, social, multi-person interface. The public simultaneous influences and interacts with computer-generated objects in an oversized three-dimensional projection, scanning and transmitting printed bar code information instantly into the computer system. The objects, each corresponding to a different user, exist as semi-autonomous agents that are only partially under the control of their human collaborators. Different from Hiroshi Ishii and his colleagues, who implemented tangible media for non professional users, Hoberman creates his own tangibles. Due to the fact that these tangibles are abstract, he works without the richness of associative mental models users already have, due to their own experiences of real world objects.

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Figure 1: "Bar Code Hotel" by Perry Hoberman

Our concept of learning theory regarding the development of specific software to realise tangibles with barcodes, is based on the premises of pedagogical reformers, critical constructivism, the idea of holistic education and discrete learning. We are particularly inspired by Friedrich Fröbel with his "gifts" for his "kindergarten" and Maria Montessori with her graspable learning materials for her "Casa dei Bambini". Both of these educators' works improved cognitive development in linking thoughts to sensory perception.

Furthermore, our concepts of learning theory are based on concepts of pedagogy, regarding critical constructivism in the sense of the psychologist and mathematician Seymour Papert (Papert 1980) and his followers. Papert determined that it is essential for children to dominate the computer and not vice versa. Children should not be trained to be answering machines. Instead, they should be enabled to experiment and build new things with computers. This leads them to a deep understanding of technical principles, enables them to make their own decisions and to take responsibility in everyday life; one that is interspersed with digital media. Papert's concept boosted scientific thoughts and acting by researching independently, linked to the richness of multimodal perception. His concept was carried on at the MIT through to the late 90th by Mitchell Resnick, Robbie Berg, Michael Eisenberg and others.

Our approach regarding the creative, experimental exposure to computers by Papert is expanded by new concepts of holistic and interdisciplinary learning. In our approach, the learning process encourages competence of acting, based on responsibility. Using such didactic methods is important when teaching with digital technology: learning in relations, ethical responsibility, developing autonomous competence to act, work against the disembodiment of the structures and processes at school, phenomenological consideration of physicality, learning linked to our present world ("Lebenswelt": Moegling 1998).

The Project "Your Food is Your Mood"

The subjects of the project "Your Food is Your Mood" are food and digestion. The project is a cross disciplinary collaboration between biology and art classes. The children study how food acts as fuel for their bodies and how the choice and balance of nutrients is determining healthy bodies. They study how food impacts on their physical, intellectual, and mental well-being. They experiment with food and drink as a sensual experience. And they learn the importance of food as an energy source, as well as enabling their bodies to function properly.

A central aspect of the project attempts to present the knowledge that has been acquired during the course of the biological process in an interactive environment in a way that an interaction between sender, receiver and media is possible. Thus, through a creative usage of computers, a broader perspective of the topic is initiated. School children become skilled directors, designers, and actors due to the multi-layered approach of the project. The interactive environment as a multi-sensual event is realized by the children themselves. First, they create a series of videos about food and the biological process of digestion. They pay attention to the digestive process with regard to its detailed and abstract meaning for the human body. Secondly, the students create an interactive experience with the support of a phyconic Tangible User Interface (TUI) (Fig. 2).

In Montgomerie, C. & Seale, J. (Eds.) *Proceedings of ED-MEDIA 2007*. Chesapeake: AACE. pp.4044-4054.

Figure 2: A boy holds an apple over the barcode scanner

By manipulating physical objects (e.g., apples, hamburgers, sneakers) on a table with a barcode-scanner, four videos are played simultaneously on the four walls of a three-dimensional dice (party tent). The viewer individually chooses a phycon (object) and places it over the barcode reader, which then shows different perspectives of the object in the content of the videos. This is a visualization of the principle of networked thinking in structures.

The school children learn how the biological – not visible – processes of digestion work inside the body, how diet is related to fitness, and how to relate this knowledge to their own actual eating habits. In the course of their artistic endeavors, they utilize various possibilities for an aesthetic visualization of on different levels of perception. They learn to write concepts together, write storyboards, realize filming, make sound files (i.e., soundtracks of the videos), and how to program and build an interactive multi-sensory experience through the installation.

The concept in the intersection of the subjects biology and art

The project is a cross disciplinary collaboration between biology and art classes, where the children study how food acts as fuel for their bodies and influences their mood and well-being. A project-oriented learning environment is created, where collaborative learning is supported by artistic and constructive use of digital media. We studied which factors influence the sustainability of children's learning and whether the students' newly acquired knowledge in the context of physical and digital reality can lead to changes in their thoughts and actions.

First, studies about the children's own eating habits were made, in which the children write down their own food diary and create comparison tables. Next, they experiment with digital technologies (video cameras, editing software and stop motion animation software) in connection with specific processes of eating. By doing this, the students learn the significance of camera angle, perspective and plot axes and how to use these to effectively present the meaning of food and its components. This learning process connects cognitive and affective dimensions of biological processes. The students learn that there are two ways of approaching the topic of digestion: either the students hand build a functioning digestion system plastic model using everyday objects (e.g., a garden hose, bucket) (Fig. 3), or, they create an abstract visualisation, using color coded paper shapes for the food elements in red, green and yellow (Fig. 4).

Fig. 3: Plastic model

Fig. 4: Abstract visualisation

The multi-perspective work and the structuring of the storyboards is focused on four levels: the sensual experiencing of eating (Fig. 5-8), the analysis of biological and chemical processes (Fig. 9-12), the effects of food on the body (Fig. 13-16), and creating scientific tables and holding interviews with experts outside the school (Fig. 17-20). The students then produced over 30 videos and sound clips of 30 seconds length. Each physical object (e.g., apple, hamburger, sneaker) manipulated on the table with the barcode-scanner is associated in space and context with various videos and soundtracks. These videos and soundtracks are carriers of multi-layered perspectives.

In Montgomerie, C. & Seale, J. (Eds.) *Proceedings of ED-MEDIA 2007*. Chesapeake: AACE. pp.4044-4054.

The sensual experience of eating

Fig. 5: Healthy food

Fig. 6: Junk food

Fig. 7: Healthy breakfast

Fig. 8: Healthy food

Analysis of biological and chemical processes

Fig. 9: Experiments

Fig. 10: Collecting facts

Fig. 11: Creating an animation

Fig. 12: Creating an animation

Effects of food on the body

Fig. 13: Running

Fig. 14: Early exhaustion

Fig. 15 and 16: Measuring burned calories

Tables and interviews with experts outside the school

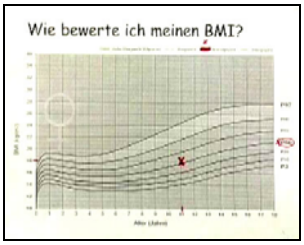

Fig. 17: A student's BMI

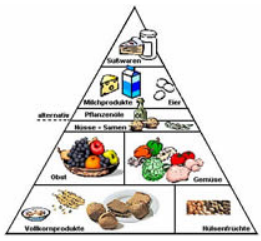

Fig. 18: Food pyramid

Fig. 15: Expert advice

Fig. 20: Expert instruction

In Montgomerie, C. & Seale, J. (Eds.) *Proceedings of ED-MEDIA 2007*. Chesapeake: AACE. pp.4044-4054.

Didactic Aspects

By combing biology and media art, networked and not-linear structures thought processes are used to support diverse approaches in creating media content.

Fig. 21: Film editing

Fig. 22: Group work

Fig. 23: Programming

Fig. 24: Building

The possibility of developing individual and differentiated ways of learning supports a sustainable consolidation of context-related thought and action (Fig. 21-22). Through studying, presenting and designing the sensory world, the children learn a competent way of using media. They get to learn about cause and effect between food, body and well-being. They express their acquired knowledge by programming and building an interactive multi-sensory installation (Fig. 23-24). The production of the multi-perspective is experienced by connecting video and sound sequences to physical objects (Fig. 22-24).

Technical description

The computer application, which controls the installation, was developed in Java, using the Java-QuickTime library to operate the media players. The barcode-scanner acts as a human interface device (HID) via a USB connection (Fig. 25). An event-handler catches the barcode-input (i.e. from an object) and reads out an information string. This string is sent to each of the four computers, which are responsible for projecting the various videos (Fig. 26). The information string is assigned to another string after it has been received in a configuration table. This new string determines which video is played by which computer at what time.

Fig. 22: Combining Videos

Fig. 23: Phycons with barcodes

Fig. 24: Testing the installation

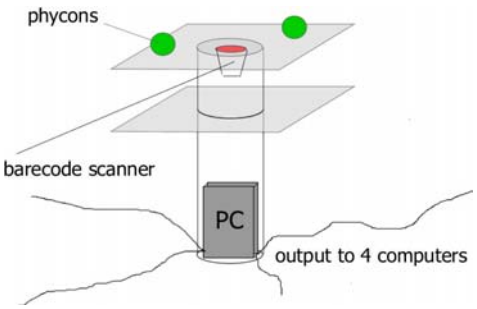

Fig. 25: Sketch of the interface system

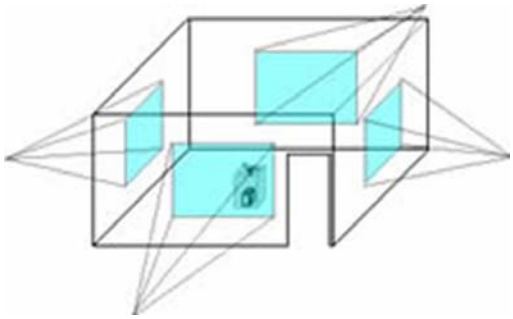

Fig. 26: Sketch of the video installation

The configuration table can be modified, so that new assignments to other videos can be prepared, to be used in another installation. In this case all four tables assign the same string to different videos. The software is free for download and a used multi-directional barcode-scanner is available for less than 50 USD.

In Montgomerie, C. & Seale, J. (Eds.) *Proceedings of ED-MEDIA 2007*. Chesapeake: AACE. pp.4044-4054.

Evaluation

Within the KiMM initiative, we developed an evaluation framework for the multiplicity of the different projects in the schools (Melzer, Hadley & Herczeg 2005). To evaluate the project "Your Food is Your Mood", students, teachers, and parents answered post-project questionnaires.

The students' questionnaires consisted of 30 questions with the following three focal points:

- students' behavior and experiences
- communication and social interaction by other students in the teams
- media diagnostics

The teachers' questionnaires consisted of 32 questions with the following four focal points:

- students' performance, behaviour, and experiences
- media (e.g., usage, applicability)
- expectation and comprehension (concerning the KiMM concept) and judgement of KiMM support
- evaluation of their own behaviour (e.g. treatment of children's teamwork) and their own experiences (i.e., satisfaction, stress)

The parents' questionnaires consisted of 15 questions with the following three focal points:

- changes observed in their child's behaviour
- sustainability of the learned information
- use of digital media in the school

For the answers to the questions a scale from 1 = "does not apply at all" to 6 = "applies fully and completely" has been used. For children and parents the mean (arithmetic average) (*M*), the standard deviation (measure of statistical dispersion) (*SD*) and the median (relative frequency, not influenced by extremes) (*MD*) was calculated. A presentation of all findings from the questionnaire is beyond the scope of this paper, therefore only the main findings will be reported below:

Main Specific Results of the Inquiry

Students:

- because of the project, 5 out of 6 students can use their knowledge from biology lessons and compare it with their own eating habits (*M* 3,75 / *SD* 1,67 / *MD* 4)
- the production of video films does not have any influence on the students remembering content from biology lessons so far (*M* 3.32 / *SD* 1.52 / *MD* 3)
- compared to other subjects, the students were able to work more independently: planning, experimenting, etc. (*M* 4,0 / *SD* 1.66 / *MD* 4,5)
- except for a few students, all agreed that the teachers liked to work with digital media (*M* 5,07 / *SD* 1,21 / *MD* 6)

Teachers:

- the students can recognize contexts more easily after the teaching unit (*M* 6)
- the students tried different approaches in team work (*M* 6)
- the use of digital media was very useful to reach the goal (*M* 6)
- the artistic use of digital media changes the student's perspective from which they reflect upon their own

thoughts and actions (*M* 6)

Parents:

- after finishing the project, the parents think that their child has experienced the topic of food and digestion comprehensively and closely related to reality (*M* 4,65 / *SD* 1,12 / *MD* 5)
- they think that because of the way in which the content of food and digestion was taught, their child has a better understanding about eating influences their body, well-being and effectiveness (*M* 5 / *SD* 0,96 / *MD* 5)
- they think it is a good thing that their child got used to digital media in the project (*M* 5,5 / *SD* 0,80 / *MD* 6)
- they think that the presentation of the results from the project gave their child a good feeling and a sense of accomplishment (*M* 4,55 / *SD* 1,31 / *MD* 5)

Overall Evaluation Results

- the tangible objects (e.g., apple, sausage, sneaker) are associatively extending (i.e., building a bridge) the content of videos and animation
- the tangible user interface (TUI) gives personal multi-modal experiences by handling the well-known objects and therefore supports a deeper understanding of the content of the self-produced media
- by means of designing and experiencing the complexity of the installation, the students are enabled to apprehend the otherwise individual parts as a whole; while programming interactivity the children themselves are an integral part of the multi-perspective whole
- the students can identify a clear reference to their own personal habits and actions: e.g. eating habits, physical activity, etc.
- the teachers find it easier to teach when the students are highly motivated and working independently from the frontal instructional form practiced frequently in the classroom
- the teachers identified the values of digital media in respect to supporting team work, problem-solving and the learning of aesthetics

Summary and Conclusions

The results from the evaluation show that the functional use of producing videos does not on its own change the children's learning sustainability. A pedagogic increase in value arises when media is used in such a manner that it connects the virtual (e.g., film and animations) and the physical (e.g., multi-sensory perceptible objects) and therefore makes it possible to reflect one's own physical world. The tangible objects used in the installation (e.g., apple, sausage, sneaker) are associatively extending the content of videos and animations. The tangible user interface initiates a personal multi-modal experience and therefore supports a deeper understanding of the content of the self-produced media.

In the artistic environment of "Your Food is Your Mood" the computer, currently a box with keyboard and screen, disappears (Norman 1999; Paradiso 2005). In our project, the computer is almost invisible to the user. This is so because the children dominated the computer's capabilities and they created the interactive multi-sensory experience in the form of an installation. Essentially, by incorporating objects as physical icons (phycons), the children break down the physical boundaries of the computer and mapped its virtual content, back into their physical world. By supporting a collaborative work model that also places emphasis on artistic and constructive use of digital, interactive media, the children's motivation increases and enables them to acquire a better understanding of abstract information. Learning is sustainable if the learning experience incorporates an artistic use of digital, interactive media.

In Montgomerie, C. & Seale, J. (Eds.) *Proceedings of ED-MEDIA 2007*. Chesapeake: AACE. pp.4044-4054.

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