Interim reflections on Theory and Practice of integrated Arts and Computer Science - lessons learned at German schools

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Abstract
The paper is based on interdisciplinary school scenarios which have been developed to embedd the computer in a multidimensional education involving a variety of senses of a human being. The school scenarios intend to link the haptical activities of pupils with informatic thinking by means of selfdependent and self-acting programming. They have been realised, tested and evaluated in the framework of the interdisciplinary model-project "Theory and Practice of integrated Arts and Computer Science in Education" (ArtDECom)[1] which aims to bring together the disciplines arts and computer science in order to facilitate the development of a broader concept of computational literacy of pupils, students as well as teachers. ArtDeCom is one of twenty-two model-projects funded by the German Bund-Länder-Commission (BLK) under the program strand of "Cultural Education in the Media Age" (KuBiM) which investigates innovative approaches concerning the use of digital media in cultural education.
The paper looks at the *scenarios* realised using robotic and sensor technologies, image recognition software as well as networked virtual worlds on different school levels such as first and second part of academic secondary schooling as well as at primary school.
The *evaluation* including the methodological approach, and the criteria being used as well as key issues of first findings will be outlined. In conclusion the paper reflects *first findings* and lessons learned in the framework of different schooling scenarios at the different schools and age levels and its meaning for responsive curriculum development.

[1]The ArtDeCom Web site can be accessed on: http://ArtDeCom.mesh.de

0. Introduction

The interdisciplinary model-project[2] "Theory and practice of integrated studies of arts and computer science in education" (ArtDECom) is funded under the program strand of "Cultural Education in the Media Age" by the German Bund-Länder-Commission (BLK)[3].
The model-project aims to bring together arts and computer science in general education. It is realised in the framework of a collaborative development of integrated scenarios for different age levels and diverse types of schools.
According to the Greek term for technology - *tekhné*- which originally meant art or craft, and *logia* which meant "the study of"[4] the project was initiated to overcome splitting of computer science and arts. The interdisciplinary approach of the project aims to bring together the separately organised disciplines which are of increasing importance in the context of growing digitalisation and visualisation - arts and computer science. Art is *the* subject at school dealing to a wide extent with shaping and experimenting with images, icons, processes, events, aesthetic objects, the shaping of interfaces, and the like. Computer science is *the* science in the back of digitalisation, interaction and multimadia. The project investigates common points of contact and possible synergies. Different work methodolgies are supposed to be brought together in the framework of an integrated arts and computer education.
Therefore the variety of material of the real world and the semiotic nature of material processed with the algorithmic machine – the computer – are brought together in the framework of school scenarios. The project investigates what kind of scenarios need to be developed to improve computational literacy in the long run. What are challenges, problems, constrains and solutions following from the practice at school? How can those models be embedded and linked to teacher training at university level?

The model scenarios developed are part of the results of the model project. They aim to contribute to the development of interdisciplinary appraoches for learning with digital media. We are promoting the computer as a shapale medium pupils can manipulate self-actingly. At most schools the computer is still reduced to the tool metaphor (the simulation of a type writer or paint brush), rather than being investigated as a media machine. The interdisciplinary approach promoted is being supported in media arts where a lot of hybrid systems are being developed using analog and digital media. It is in contemporary arts where we find the experimenteal use of the computer. At the same time we want to explore the concepts of computer science. We intend to make transparant and the digital media as programmable media opn to digital manipulation.We aim to embedd the computer in multidimensional education processes, rather than reducing computer education scenarios to the work in front of thw screen.

1. Computers in education processes– some general remarks

The use of computers at school is currently perceived critically in Germany which is not a surprise, given the fact of missing didactical concepts as well as the widespread idea of computers mainly being used as tools for data processing. Critique is often driven by traditional school scenarios of science education with computer based training environments, that is pupils working at single work place systems on their own in front of the srceeen most of the lessons. They would learn how to handle a particular software.[5]
The ArtDeCom model-project has a *different approach* concerning the computer use in education, that is to get away from the concept of *applying software* realized with computer systems based on single work systems. We think that the computer needs to be embedded in collaborative learning processes and the real environment of the pupils with all the dimensions linked to it, such as the senses linked to perception of a human beeing, e.g the haptic sense.

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[2] According to the German Bund-Länder-Comission the aims of *model-projects* at school are the targeted on innovation and transfer of the findings. They have an experimental character as they investigate innovative ideas and approaches.
[3] The program strand of 'Cultural Education in the Media Age' (KUBiM) was launched in spring 2000 to develop and test ground-breaking models for the creative and competent use of new media-technologies and other innovations in the field of cultural education and training. It is a program under the umbrella of the Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung (BLK), a joint body of the Federal Government and the Länder for educational planning and research funding. The KuBiM program is linked to the larger context of concepts and programes in Germany to help building the global "Information Society". Cp. http://www.kubim.de
[4] cp.Kurzweil, Ray: "What is technology?", p.76 in: "The age of Spiritual machines – when computers exeed human intelligence", New York, 2000
[5] Further the current discussion in Germany concerning the use of computers for educational purposes is strongly being influenced by the results of the PISA study in which German pupils got low scores in the context of international comparison[5]. Following from the study there grew the misgiving that computers at school may support bad reading and writing skills of German pupils. Another aspect influencing the discussion was the desaster of Erfurt where a 19 year old pupil has shot sixteen teachers and himself at a Gymnasium[5]). According to the inverstigations he turned out as a user of computer games such as "World Craft", a strategic shooting game based on creating three-dimensional worlds, networked via the Internet. As a consequence of the desaster, a whole range of computer and video games were permitted for non-adults or called illegal. However, in the end "world craft" was not indicated as "jugendgefährdend" in the framework of the German law (Jugendmediengesetz). However, those are issues influencing the discussion about using computers at school in Germany.

Further, it seems to be most important to help to develop computer skills based on an understanding of the semiotic and algorithmic machine. We believe computers can contribute to creative learning processes based on a collaborative approach which intends to make transparent the inside of the machine, that is, to mediate what we call *informatic thinking*. The pupils are asked to translate abstract mental models into a software programme, that is, to visualize them.

The model-scenarios at school

What kind of scenarios do we need to develop for such integrated courses? What are skills required for both teachers, pupils and students? Is it possible to make transparent informatic thinking and acting and what kind of software has to be developped to support such processes of understanding? In the framework of the model-project scenarios have been realised and tested at different types of schools in Schleswig-Holstein, North-Germany such as primary schools, initial schools[6], intermediate schools[7], academic secondary schools[8] as well as comprehensive schools.[9]

The scenarios developed had to meet the following particular criteria: They were targeted to link reality to virtual worlds in the computer in the framework of a multidimensional[10] art and computer education. The computer had to be embedded into the conception of a particular and individual schooling sequence developed in co-operation with art and computer (science) teachers. It were the teachers contribution to decide about the software which fitted best with their particular ideas and previous learning contents of the class involved.

Further the scenarios had to address informatic thinking and programming, that is, to make such informatic models to a huge extend transparent.

The starting point for the scenarios is based on works of contemporary media artists using both digital and traditional media.[11]

The overall aim was to test the computer as an indepandent artictic medium linking digital spaces with the objects of the physical world. It was aimed to embedd the computer in *multisensual*[12] and multidimensional creative processes in art education reflecting challenges, losses and added values opening up when linking various media.

Further it was intended to get away from a work place system fixed in the typical computer classroom at an average German school. In consequence mobile equipment has been used in both work phases at the studios and in the class rooms.

According to the various needs of diverse courses, the project has developed different ***models of scenarios*** to integrate art education and computer science at ***school level as well as on the university level***[13]. Each learning sequence is linked to a particular Hard- and software package selected within the project according to the projects aims[14]. We have chosen technologies we think point the way ahead towards a human-machine interaction adapted to the human being being focussed on the body and its' senses. According to recent technological developments and predictions of scientists[15], there will be stronger links between biotechnology and arts in the future.[16] The two-dimensionality of the medium soon will be outdated. New sensor technologies will allow for human-machine interaction without visible interfaces.

The main groups are as follows:

1. **Robotic and sensor technologies** (programming motion of objects in real space), that means correspondingly to the context of art education to **develop interactive environments**
   - **Image recognition software**[17] linked to performance, that is, the development of a **performance in mixed realities** (real space is becoming an interface caused by the motion of the actors)
2. **Virtual Reality (VR) and the development of three-dimensional virtual worlds networked via the Internet (Online meeting in VR[18])**

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[6] "Grundschulen"
[7] "Realschulen"
[8] "Gymnasien", the secondary stage of academic secondary schooling leads to the leaving certificate "Abitur"
[9] "Gesamtschulen"
[10] and multi-sensual
[11] We see a link to media artists working with computer on the level of the code. Cp the exhibition "Kontrollfelder": "Media artists work in different fields with different interests, for example to develop computer programs that exeed the boundaries of conventional software. He focus is not ont the perfect function of the program, but rather on the programs' disfunctionality. However, artists view the code as fundamental aesthetics material for their creation. Software artists demonstrate all the active and creative possibilities by developing their own programs" (announcement of exhibition)
[12] German term is „multisensuell"
[13]. (Referring to teacher training at university level in Art Education Studies. Currently in Schleswig-Holstein no teacher training is offered in Computer Science at the universities (Lehramtausbildung).
[14] One main criteria was – apart from the issue of expenses of soft-and Hardware packages – that the programmes met the aim of self acting and selfdepandant programming of motion.
[15] Such as Kurzweil
[16] as we can already see in the works by Eduardo Kac, who is experimenting at the interface between genetic technology and arts (cp. Genesis-project)
[17] By means of a Web cam.

In the project different models of scenarios have been realised to test the computer in the context of project oriented learning sequences. One of it was the development of a performance in Mixed Realities in a German primary school.

Scenario 1:
A Performance in Mixed Realities – The real world becomes a haptic interface

Fig. 3 Mixed-Reality stage setting at primary school developed by 3rd graders. The coliseum turned into the location of the presentation

The term of "Mixed Reality" stems from media arts where hybrid sytems of digital and non-digital nature are being developed linking real space with digital spaces of the computer.[19]

We think that the software interfaces need to be adapted to the human's nature addressing the different human senses, rather than reducing interaction with the machine to the key board and mouse click level. There are predictions of future scenarios in the year 2019 when "most interaction with computing [will be] through gestures and two-way natural-language spoken communication" (Kurzweil, 1999). Most of such technological solutions are still high end products, rather than available and affordable for the home user. However, the robotic toys are getting more and more popular as well as affordable on the consumer market. For the project we have selected a software and hardware packages of robotic and sensor technologies including Web camera and image recognition software. As we intend to use robotic toys in creative processes but to initiate creative processes and art works, we selected an indivudual solution.

In the third class of a primary school[20] eighteen pupils have developed a Performance in Mixed Realities[21] based on an interactive scenary linked to an image recognition software*. As shown in figure 1 below, the set on the stage was as follows: Based on the image recognition software a Web-camera, which was placed in front of the screen, identified the actors' speech of movements as well as particular colours during the presentation. At the same time a video delivered multimedia elements technically based on a stop-motion-animation[22] which was projected on a screen as part of the stage.

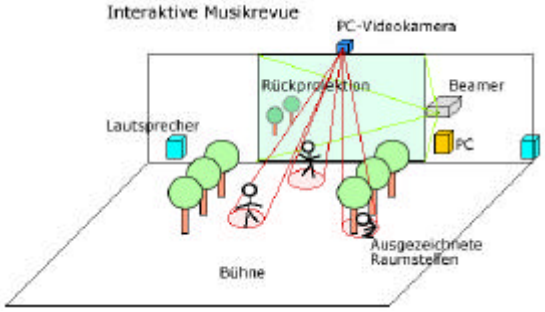

Fig. 4 Scheme of the Mixed-Reality learning environment (stage setting realised at primary school).

Work process

Firstly the children of age 8-9, class level 3 at a primary school[23] have been introduced to the overall idea of a performance in Mixed Realities[24]and its co-ordination. Therefore the project was parted in three work groups working together on a collaborative project and one common theme entitled "the world of the dagons", which allowed for integrating the pupils art works (dragons) of the previous school year. The work process was characterised by a mixture of haptic, auditory and programming activities. During the work process the children developed artifacts of diverse nature and material such as digital and non-digital objects. Firstly they created a real (miniature) model out of paper and paste, based on a wired framework[25]. It served as the general basis of the digital animation for the screen projection. The children developed

1. The model landscape and elements required for the stage setting

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[18] Therefore a digital communication platform including a media archive has been developped in order to realise collaborative Internet-based art projects – such as collaborative art works using different media (images, video, story-telling, sound) linking different communities, such as classes, schools and pupils. It is is a rich environment for archiving, learning and collaborating providing a resource for archiving art works as well as software tools. It can be accessed by teachers, pupils, students and the project researchers.

[19] Cp. the works of Fleischmann and Strauß at the Mars Media Lab at the Fraunhofer Institut.

[20] The elementary school is linked to the Verein „Freie Schule Lübeck" which is a society for the common good (e.V)

[21] The overall project was running for one school year. (October 2001 to April 2002)

[22] A digital video made coping less than 25 frames per minute, so that it allows the children for linking motion to static objects.

[23] Third year at the primary school

[24] The term addresses the bringing together of real and virtual spaces in a hybrid environment.

[25] Pappmaché

2. The multimedia stage setting (based on a self-made Stop-Motion Animation)
3. Self-made individual sound files required in the framework of the dramaturgy of the event driven performance
4. The story and choreographie of the performance
5. Last not least a concept of the overall project co-ordination

According to the variety of work tasks, the *whole physical body* of the children including their different senses became involved in the learning process. The human being was addressed as a *holictic creature*.
In co-operation with three teachers for arts, computer and performance, the class was parted in three thematic work groups, such as computer, arts and Performance with each five to six children attending. Those work groups were organised in paralell sessions. According to a particular time frame the participating children were rotating from one group to the other to make sure all children had joined all the thematic groups.
In the **art work group** pupils were **modeling** a miniatur edition of a vulcany landscape including dragons and vulcany using all sorts of material. In order to make the scenary alive and therefore move the static objects such as dragons and vulcany, the children learnt to programme Stop-Motion-Animations using a Web-cam including related software package[26].
The art work process was strongly characterised by haptical acting, using hands to build the basis of the scenary. The model landscape was then the basis for the multimedia elements of the stage setting. It was filmed and projected on a screen on stage during the presentation.

Fig.5 Miniatur model of landscape as bases for stop-motion animation developed by 3rd graders at primary school

In the **computer work group** children were concerned with the development of all multimedia elements needed for the overall performance- presentation, such as the development of the **Stop-Motion-Animation**, an overall film to be presented during the presentation, showing the vulcany landscape with an erupting vulcany and moving dragons. Apart from getting familiar with soft- and hardware the children have learned that each video film is based on single pictures. The learned that static objects can be moved in the framework of Stop-Motion-Animations. The produced self-made sound files which were required by the dramaturgy of an event-driven performance, that is, the pupils made the sounds by themselves deciding for the particular means chosen.

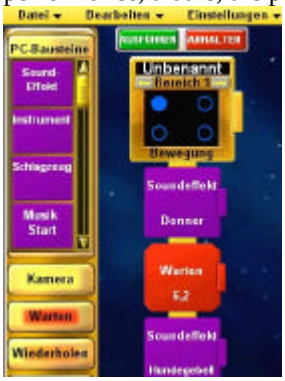


Fig.6 Example of programming line used at primary school level

[26] by LEGO Vision Command

Apart form that, this work group was in charge with the programming of a camera by means of an **image recognition software**. Therefore a live Web-camera was placed in front of the stage observing the performance of the actors during the presentation. It was the childrens task to develop a programm so that the camera would react on **different speech of movements** as well as on **particular colours.** The children decided on the events which were supposed to happen when the camera was identifying a certain stimulus. In combination with the software programme, the camera is becoming a sensor. The camera position is recognising stimuli such as the speed of movements and particular colours and releases events programmed before and contorled by the software, so that the **real world itself becomes a haptic, tactile and tangile interface**.

Fig. 7 Interface of image recognition softwareprogrammed by 3rd graders at primary school

The **performance work group** is concernend with the development of a **story** as well as with the **choreographie**, the events such as a variety of **sounds** as dramaturgical. The work in close co-operation with the other groups who are in charge of delivering the required digital and non-digital materials according to the requested needs.
The scenario strongly supported the overall co-ordination between the groups. It made sure the transparency of the overall project and how the three work groupes work together . The communication between the groupes

Scenario 2: Developing Interactive Multimedia Environments in the second stage of academic secondary school

Fig.8 Example of interactive environment reflecting the issue of nature and the concept of landscape developed by 13th graders at academic secondary school

The development of hybrid, interactive multimedia environments involving the spectator in the process of interacting with the exponated work is current practice in contemporary media arts. Most of these technologies available for home pc use are either toys developed for children or tools for science education purposes (such as the Lego Mindstorms Robolab Investigation system) rather than being developed for art ecuation purposes.
Accordingly, only little research has been made world widely investigating the opportunities opening up using sensor technologies and robots in art education, such as the "Sensa-Table" by the research group "Team Matrix" (Nagamori, Shiomi, Fukomoto and Matsumoto)[27] based on touch screen technology; or the works of Patten, Griffith and Ishii, who have developed tangible interfaces for controlling robotic toys[28] for children.

[27] see: "Sense and Media in Art Education, in: "Matrix – studies in Basic Art Education No.3, Wakayama (Japan) 2002"
[28] Patten, James; Griffith, Laurie; Ishii, Hiroshi: "A tangible Interface for controlling robotic toys", paper presented at the CHI'00, April 1-6, 2000, The Hague, The Netherlands

In the ArtDeCom-project we have experimented with soft- and hardware tools in tems of investigating opportunities they provided for creative work processes:
The fifteen pupils of a project course[29] in their last year of accademic secondary schooling have developed interactive, multimedia environments according to the theme of "natural - artificial". They produced perceptions of what they saw as representations of "nature" including the clicheés and social problems linked to it.
In order to provide a studio-like work atmosphere which allowed for working in and outside the timetable of the course (45-minutes-rythms for the variety of subjects), a studio was offered placed on the roof of the school.

Sensor technology and icon-based programming[30]
The scenario is technically based on robotic and sensor technology**,** so that a variety of sensors such as those responding to temperature, haptic click or light have been given to the pupils to experiment with. The pupils were asked to develop scenarios of event-driven programm features. Controling motion which allows for moving static objects in real space, is realised by means of an authoring tool. Transfering the area of robotic toys to the context of art education it offers the opportunity to develop **interactive environments.**[31]
Robots (Micro computers) and sensors are represented as icons on the desktop which are connected by pieces of physical string to the micro computer[32]shown in figure 9.

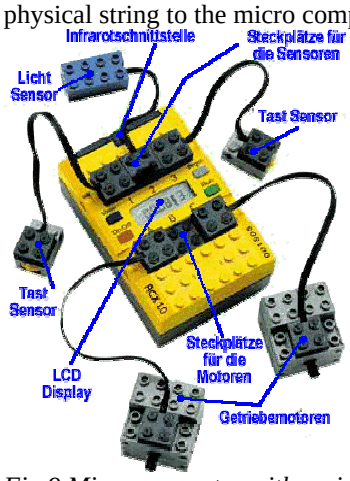


Fig.9 Micro-computer with an infrarot interface

Representations of mental models
Mental models are the bases of the human's activities. Especially in the context of man-machine-interaction they are of increasing importance.[33] We believe that the relation between those mental models and its representation – the metaphor – has to be made transparent in order to initiate processes of understanding of the algorithmic machine and its' underlying model the code is based on: ***informatic thinking***. The use of metaphors, that is, visualized ones - icons on the desktop - each representing single programm features, allows children at primary school level to link behavior to static objects in their real environment. By developing artefacts of different nature and material, such as digital and non-digital objects, the different senses of the pupils get involved in the creative process and the link between reality and virtuality is realised. The latter is of growing importance in the context of learning processes and creativity support. It allows to overcome the separation between virtual and real environment. From a multidimensional art education point of view the later provides the opportunity to integrate existing art works realised with other – e.g. non digital media. Haptic and auditory dimensions get involved under the overarching roof of the integrating medium computer.
Apart from the function of knowledge mediation, metaphors are used for emotional and motivation related effects in human-machine interaction. Duttke has highlighted the importance of attitudes and moods of the users influenced by the appearance of the metaphors chosen.
"If a metaphor links to a mental model of a new situation which refers to a well known [situation] the insecurity about the new situation is reduced." (cp. Duttke, 1994, p. 83).

A metaphor, be it a textbased or visualized one has to be well designed in terms of a clear and unmistakeable appearance. However, we think the software selected in the project met this selection ciriteria to a wide extent.

[29] Project courses in Schleswig-Holstein aim to support team based work and collaboration in a joint project. Such courses are compulsory elective subjects which count to the Abitur (upper secondary leaving certificate).
[30] German term: Ikonische Programmierung
[31] Environents are installations which are strongly related to the room, that is the room itself is addressed here.
[32] Cp. the works with tangible interfaces of Ishii, Patten and Griffith at MIT
[33] Cp. Dutke, 1994

Fig. 1 Example of a programming line represented by on the desktop (Icon based programming)

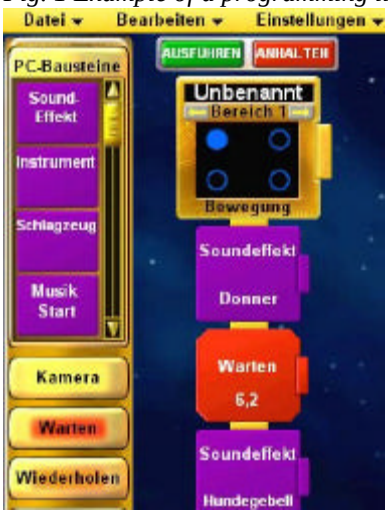


Fig. 2 Example of a programming line represented by on the desktop used at primary school

By creating program features using icons connected by virtual strings**,** the programm row is represented. The "If-then-relation" the software is operating on, is visualized by wired icons on the desktop[34]

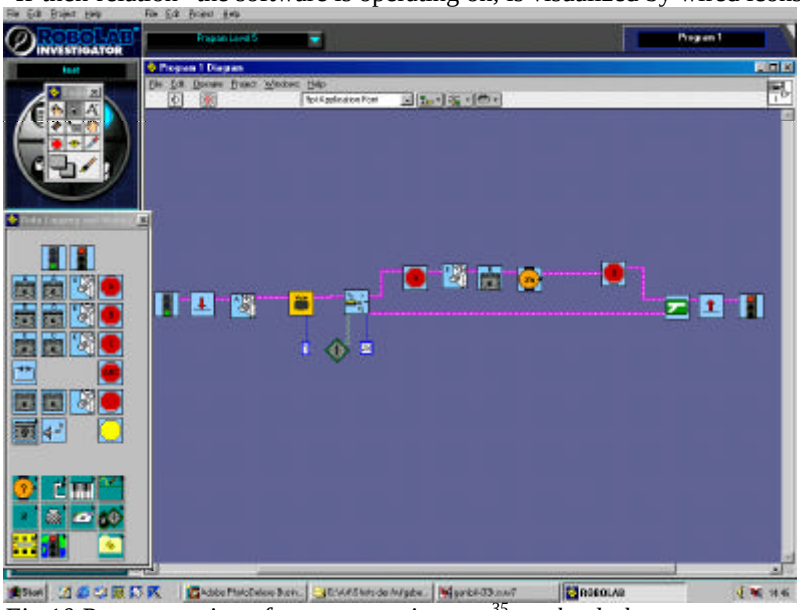


Fig.10 Representation of a programming row[35] on the desktop

Phases of working and learning

All pupils were working collaboratively in the different phases of their projects, such as

- Experimenting with hard- and software
- Confrontation studio and presentation room as an inpulse to develop a conception
- Development of a conception within the team
- Co-ordination of all teams and conception in the studio
- Building the setting
- Simulating the project
- Presentation

A wide range of activities and communication has been undertaken by the pupils.

Linking art education at school to teacher training at university level

The scenarios tested have been linked to teacher training at university level, that is students preparing, attending and reflecting (post-processing) the sessions at school. Thereby they have been able to realise their compulsory stages to be carried out during their studies. All groups involevd have been benefitting from this arrangement:

[34] "German term Ikonische Programmierung"

[35] Programmierzeile

The students were able to bring in their own ideas, to give presentations at school, to talk to the pupils and comment on their work. Thereby teachers have been releaved of work. The pupils were benefiting from it as they received a more intensive support concerning their art projects.
The teachers involed have had the opportunity to attend the seminars at the university which made possible to link two social groups, which are the students and the pupils who are located away from the university.
Special teacher training has been offerd to those teachers involevd in the projects. Software has been presented, tested and linked to individual szenarios in art education, depanding on the particular context of the school and courses selected.

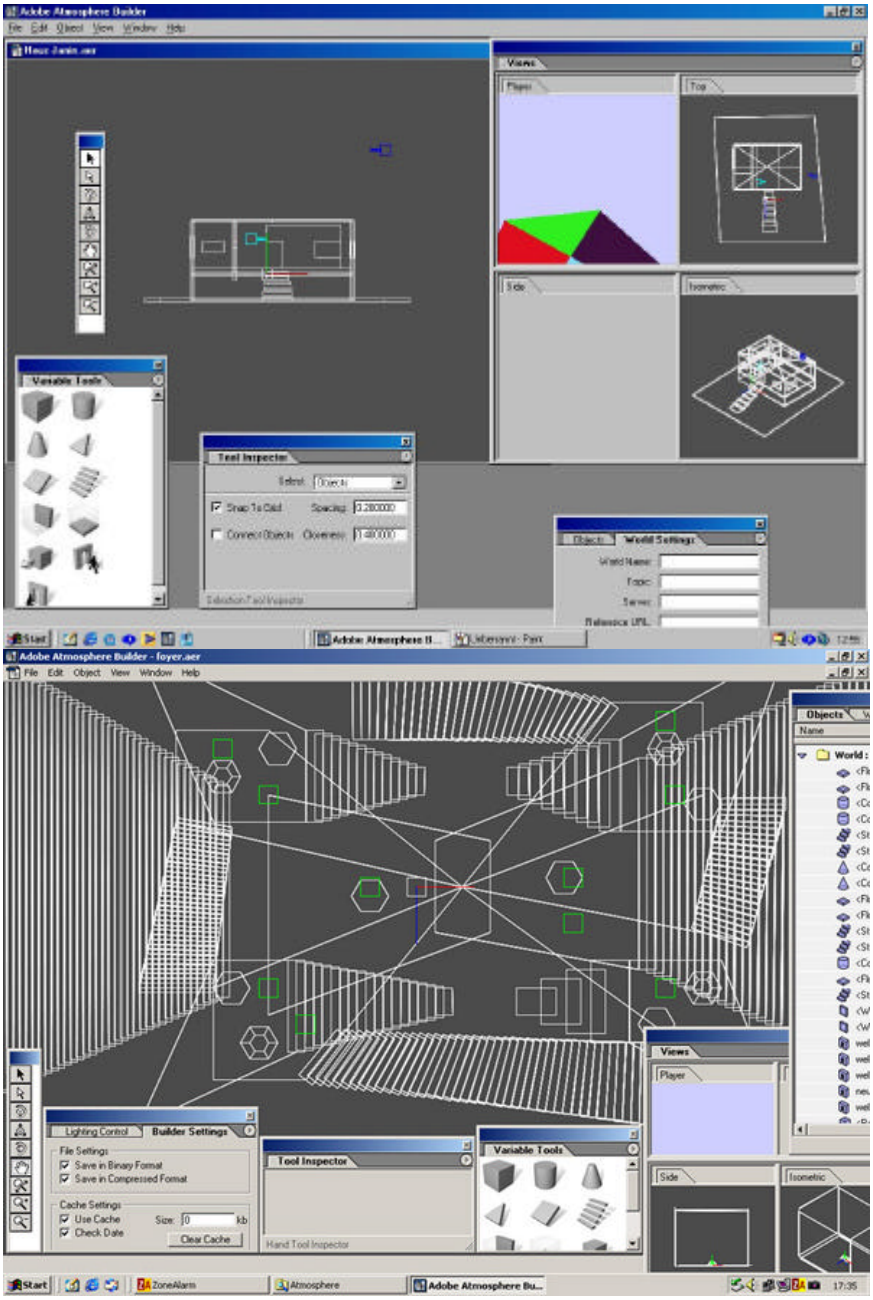
Scenario 3:
Creating and networking dispersed 3-D-Internet worlds with an interface to reality

Virtuality as representation of reality – challenges, opportunities and constrains
Media art is currently being increased and enriched of a new genre, which is, for commercial reasons, currently not established as such: Computer games. However, it is a big issue of interest for the youngsters.
Amongst other reasons, virtuality has been criticised for being seperated to a wide extent from the users' real environment. Another point of critique is a lack of speech when it comes to navigating in a virtual world. Like most first generation technologies, it was not convincing as such. Time delay in terms of navigation, uncomfortable data gloves as well as long rendering times to generate of such worlds by a system and the bad resolution of images made it quite unattractive. However, computer games have become more and more realistic over time.[36] The development software for such worlds has become affordable for school kids. From an art education point of view, a variety of challenges and opportunities is opening up using such tools in creative and collaborative education processes. The characteristics of experiences made in reality differ from virtuality for several reasons: The limits and borders of the physical world with its gravity are abrogated in virtuality. Identity which is represented by an avatar could be anonymous or changed. The new identity can be developed self-actingly by means of a representation in virtual spaces, e.g. by creating dynamic avatars[37]. Following from technology new opportunities open up and lead to **contents** for education processes, such as the multidimensional topic of the *identity*. Further one of the main artictic means of expression and basic element for the human being –the physical space – is mediated to the school scenario. Virtual spaces developed offer the link to reality as well as to themes like architecture and the like. Perspective drawings may be transferred into virtual worlds, that is, it may be navigated online. The latter can be percieved as added value delivered by the computer. Re-thinking VR on the bases of the design principles of traditional media is one of the main opportunities we see for media education purposes.

Aims and objectives
The tools needed for creating virtual worlds are available for download in the Net. Most pupils are fascinated by computer games and accordingly they are quite familiar using those tools. One main aspect for us to choose such a programme was the interface which allows the students to import objects of their real environment- or other found material of digital nature available. Another reason for seleting the software was its support of collaboration via network facilities. Another didactical reason for selection for us was linked to its inner added value as an artistic medium, that is the lack of traces and borders we - as human beings - know from the experiences made in real world, such as the rules of gravitation, borders, limits and the like. New opportunities are offered in virtual spaces: Apart from changing and developing identities by creating virtual bodies represented as dynamic avatars on the screen, the system allows the users to investigate the world different from reality: Changing perspectives, walking through walls, flying over the world – those are new challenges for the pupils.
The software selected
The programme selected[38] is supporting the following services of a three-dimensional CAD- software architecture: The development of technical drawings on the *construction level* of the programme (including diverse views on the object to facilitate imagination such as side view, isometry as well as the top and the player level). On the browser level the software is supporting the appearance of the constructed world in three dimensional optic. Further it allows for navigating through the generated virtual world. Also the software has an interface which allows for importing photos as well as differing file formats to implement textures and objects of reality into the virtual world.
After finishing the construction of a world, it can be networked to other worlds via the Internet. Links to enter the different worlds of other users might be investigated online. To meet each other in cyberspace apart from text based chat options, a selfmade avatar that is representing the virtual identity of a user can be selcted.

[36] cp. Kurzweil, 2000
[37] by using java applets
[38] Adobe Atmosphere Beta Version

According to the characteristics of the avatar, e.g. size and nature, the perspective is determined. (E.g Chosing an avatar of the size of a mouse, the user would look from the perspective of a mouse) Therfore The latter looks to us as an important issue to use the programme in the framework of education purposes.



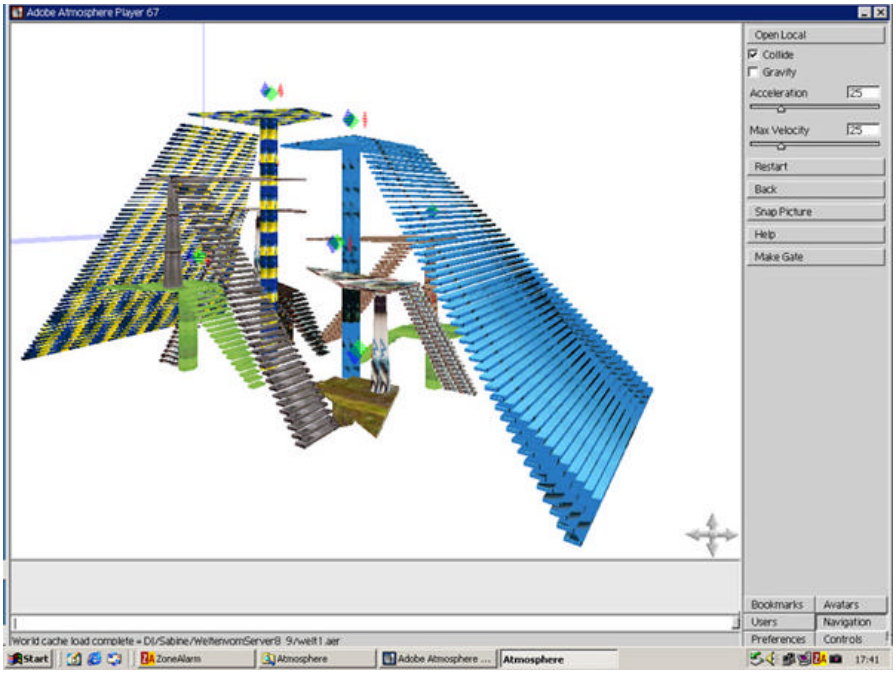


Fig. 11 Interface of development- software incuding. the levels of the construction,side, top view as well as the player level which allows for navigating the created world through the Internet via the entrance portal

Learning and work processes

A class of twenty-seven pupils in their second year of an accademic secondary school[39] have developed three-dimensional worlds networkable via the Internet. Two teachers of arts and computer science have been involved as well as students of art education studies at the university. Therefore a group of students as well as the pupils have worked collaboratively on a common project - developing a virtual world. The pupils were ask to create a world according to the theme: The future world in the year 3000. Amongst observing the lessons at school it was the task of the students to link the different projects by developing an overall *foyer* (Entrance portal) linking the worlds of the pupils and allowing the users to explore each of the worlds. For online meetings an avatar, that is a virtual representation of ones' identity, can be chosen or created by oneself. The hightlight of the course is an online meeting within the worlds via the Internet. It will contribute to the evaluation of the project as the pupils have to explain their works to the others online.

The learning process of the pupils and students is parted in different phases, such as constructing the architecture of the world as well as deciding on internal appearance and design elements to give it an individual particular look. Photos and textures are to be selected, processed and imported into the world. Entrance portals are set up, online meetings are to be planned and moderated. An identity is created or selected from a given collection of dynamic objects.

[39] 8 graders

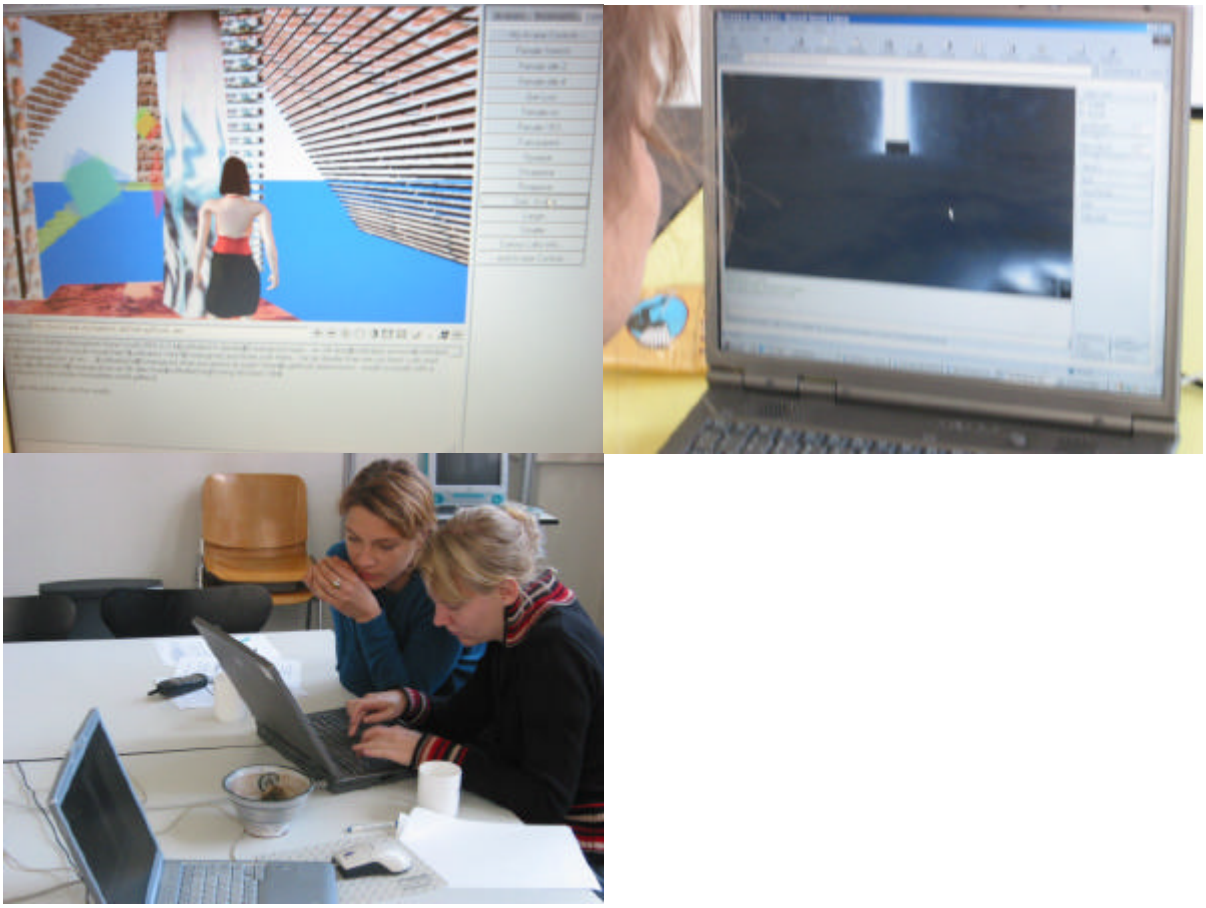


fig. 12 Students navigating the self-created Internet-world using a virtual identy (Avatar)

1. Evaluating creative work processes in art and computer education

If we want to evaluate creative processes in education, we have to look at the term of creativity firstly. The creativity we want to promote is not only defined in the very narrow sense of supporting art related activities. What we mean is a broader concept of creativity in terms of thinking and acting in the world as a holistic human being experimenting diverse media and tools.

Accordingly the methodological approach is based on the methods of qualitative social sciences. Different methods of data collection have been combined according to the needs of creative work processes in art education. The research approach is based on a formative evaluation which is shaping the process during the class/course and from session to session.

Firstly a typology of research ares to be investigated linked to the project's aims has been developed. The main research areas were as follows:

Evaluation criteria:

- Support of a broader concept of creativity[40]
- Embedding the computer in multidimensional[41] work processes in art education
- Mediating informatic thinking models/mental models as being the core of the machine
    - Making transparent how hard- and software function together
- Exploring the added value of the computer as an independant artistic medium
- Supporting an awareness about the computer as a shapable medium by the user
- Mediating the complexity of creative work processes- from the conception to reflection, realisation and presentation of one owns work with digital and non-digital media

Methodolocical approach

The research methodology includes a series of qualitative semi-structured interviews including the representatives of the social actors involved such as pupils, teachers, students, as well as external experts and non-experts[42]. The following techniques to get indepth information required have been used:

- Walk around/ observation at the schools and studio
- Attending and observing the lessions in the classroom and in the studio[43]
- Video-documentation during the course
- Qualitative survey
- Semi-structured qualitative interviews
- Walk and talk strategy with pupils
- Semi- structured interviews/ (Qualitative oriented staff surveys in case interviews are not possible)

A combination of diverse techniques such as focus group interviews, video clips of the education sequence and the like turned out to be most fruitful. The interviewees at primary school also were confrontated with the hard- and software during the interviews.

Computational literacy

To us the long term support of *computational literacy* is required in the context of computers and communication technologies in education processes. DiSessa has introduced the term of *Computational Literacy*[44] (cp. DiSessa, 2000) differenciating from *computer literacy* as a term introduced in the framework of increasing digitalisation and data processing of the last ten years. However, in Germany the term "Medienkompetenz" is indicated by the ministries of education as being a goal to aspire to. It could be translated by the terms of "media skills", "computer skills" or "computer literacy". Like in other countries it has developed from a more technial approach to information and communication technologies. Anyway, most approaches are based on skill development linked to the handling and applying of software programmes rather than including the *shaping principle*, that is, the idea of participative shaping of the computer by the user (e.g. by self-acting programming). However, one of the ArtDeCom's main aims is to develop models to establish a broader concept of computer and media skills including the human being as a *wholistic creature* addressing the diverse senses of perception. The latter is of particular importance in the context of the human-machine-

[40] That is the initiation of new hybrid artifacts, asthetic objects
[41] multisensual
[42] such as spectators of presentations
[43] German term „teilnehmende Beobachtung"
[44] in his book "Changing minds – Computers, Learning and Literacy", MIT, 2000

interaction. DiSessa has described in detail that the general term of *computer literac*y is characterised as being too narrow.

> "It means something like being able to turn a computer on, insert a CD, and have enough keyboarding and mouse skills to make a few interesting things happen in a few standard applications. Computational literacy is different. In the scale of achivement involved in computer literacy is microscopic compared to what I am talking about. Is it as if being able to decode, haltingly , a few "typical" words could count as textual literacy […] by computational literacy I do not mean a familarity with a machine that computes." (DiSessa, 2000, p.4 ff)

The desciption given above is corresponding to the term of "Internetführerschein" German schools have introduced in the late nineties[45]. It is a test designeded to assess the pupils technical and mechanical computer skills related to the competent use of the Internet, driven in the 90ies by the then initiatives "Schulen-ans-Netz" which mainly were concerned to implement machines and Internet access to German schools. However, it is a definition of literacy which is strongly technically determined, comparable to knowing some words or sentences of a language would count as *texual literacy*. We believe in the necessity of a *broader concept* of *computational literacy* which would be characterised as being infrastructural and constantly accompagning students through their schooling carreers[46].

To us, the use of computers in education has strongly to be linked to the idea of getting the pupils involved in the process of *shaping the algorithmic machine,* for example by selfdependent and self-acting programming. We believe that the computer has to get embedded into new forms of project oriented learning rather than simply being a tool for data processing and applying software. There are more challenges to be realised by means of a computer than applying software packages according to a given instruction.

The added value of the computer as a shapable medium

The computer as an algorithmic machine is a special case of medium linking all the different sorts of media such as image, sound, video, and the like. It can be perceived as an overarching umbrella linking all sorts of media and therefore providing a variety of artistic expression. We see the computer as an algorithmic machine to be shaped by the users rather than as being a closed system. The idea of shaping the machine is based on the concept of mediating informatic thinking on which the machine operates. We percieve the computer as an independent artistic medium adding particular value in terms of increasing the opportunities and variety of artistic expression rather than being a simple tool. We believe scenarios of learning must be developed bearing in mind the particular functions and services it offers adding its specific value in terms of artistic or creative expression. (E.g. a drawing of a perspective that is fixed on a two-dimensional piece of paper might be investigated in a three-dimensinal world by generating the corresponding virtual space *inside* of the computer.)

2. Lessions learned – first findings

Some key issues of first findings

During the realisation of the diverse model scenarios, a lot of common issues of findings occurred. One of those we came up with is the high level of **computer skills** in terms of technical software handling. Pupils have a different apporach to developing software skills. Different from most of the teachers they would not use tutotrials but like to investigate the limits of soft- and hardware by try-and-error. They are interested in finding out what's behind the screen. In this context we also found the primary school children being highly skilled, especially in terms of experimenting with hard- and software.

On the age level of 8-10 grades we found, that some of the pupils are quite familiar with VR and online games, so that they took over the role of advisors in the context of problem solving and realising ideas in terms of technical support. Concerning the role of the teachers we came up with a big need for **re-thinking digital media and re-link them to the "older" media**, such as the principles of art and design. We found the **change of role between teachers and pupils** as both being students in a way. The teacher is asked to initiate creative processes and facilitate project work by bringing his own experiences and knowledge concerning arts and design, rather than teaching computer and software skills. He is getting in the back in the way he might lecture less, but is of big importance in terms mediating artistic and scientific methodologies.

To **bridge the gap** between pupils high technical computer skills and the lack of technical computer skills of a wide number of the teachers, the latter need to be supported by **individual models of teacher training** which would be related to the particular requirements as well as in the framework of **decentralised training models** which also may be offered via the Internet.

[45] The term might be translated with "Internet-driving licence" to assess technical skills using the Internet.

[46] Cp. DiSessa (2000). He also puts the term of "material intelligence" as a substitution for literacy.

The **meaning of multidimensional storytelling by developiing artefacts** turned out to be of big interest. Pupils like to explore the computer and its new opportunities of storytelling. We found storytelling is a means to get pupils **involved** into the collaborative learning process.
Pupils are stimulated by means of combining computers and creative activities in education which is a new perspective on technology.

In the second part of academic secondary schooling we found, pupils are quite interested in **experimenting** with the hard-and software packages,. At the same time they are much more driven by the pressure of grades in the framework of the leaving certificate Abitur. They want to be sure to not risk the Abitur as leaving certificate, so open tasks which allow to bring in ideas and to develop selfresponibly a collaborative project seems to be a threat to them.
The teachers are asked to to strengthen their own creative ideas, for example by explaining the meaning of collaboration and creativity for their vocational carreer, be it in arts and design or any other profession where creativity and team work are on the agenda.
The experiences made in the second stage of academic secondary school lead us to another issue of **structural change required** for new forms of learning in the school context, that is the time frame of rythms of 45-minutes.

Role of Technology
As we found good opportunities of leading to content by means of technical opportunities such as the issue of Identity in the context of developing virtual avatars and the like, technology also puts a lot of pressure towards the teachers who are struggeling with technological problems on a variety of levels. The ArtDeCom-project was supported by students who were in charge of technology. However, we found that problem solving is dominating the learning content to a wide extent. Technical problems are strongly time consuming and must be embedded into a broader conception of technical maintenance. Teachers can not be concerned with with problem solving in terms of technical issues concerning Hard- and software as well as the school network.

As the courses are currently being evaluated, further key issues derived from the evaluation have been identified and are briefly summerisd in the following list.

What they learned - Learning in creative work processes

- Learning about the **dimensions of project development**
    - From Visualization of mental models to the
    - Development of a visual model and its' realisation and the
    - Conception and its' asthetical appearance after realisation
    - Time frame of a project
- Experiencing a varietyof **phases of creative work processes** such as developing, destroying and creating new dimensions of a project. Processes of tranformation and their mening for the overall project.
- Learning about the meaning of presenting one's own work: A push towards valuing one's own work
- Linking of individual and team based decisions

Collaboration

- Learning that learning is a collaborative and social process in which communication processes and discussions are important.
- Co-ordinaion skills (bringing together the work of three work group)

- Get to know the meaning of sharing ideas and work tasks as a part of the creative learning process

- **Experimental use of computer** is supporting the motivation to investigate hard- and software

- **Interdisciplinary approach**
  - Pupils have learned about the methodological approaches of the other discipline
  - Pupils have developed ideas on how to intergrate the computer in the courses the long run.
  - Subject linking and subject crossing learning in cooperative projects require a link of processuality and infomatic thinking in real space, that is, sensual, haptical needs of the pupils and motor activities need to be considered and linked to informatic models of thinking.

- **Technical problems** are should not play the main role during, before and afer the lessons. Teachers are not in charge of solving technical problems linked to hard- and software and the local network. Technical problems need to be integrated in a broader conception of selfresponsibility of students, that is, to facilitate students' creativity in terms of problem solving which is a communicative process. It needs to be implemented in the schooling sequence.

Prerequisites and conditions required at school

- Computers need to be taken out off the computer classrooms in order to integrate into the learning enviroments of the studios. Mobile equipment is needed to support flexibility.
- Development of hybrid learning environments for experimental and collaborative use of media
- Time frame of lessons is highly problematic. To us, this seems to be one of the main issues hampering project-based learning proceses. Learning and thinking in time frames of 45 Minutes followed by a change of subject seems to be unreasonable in the context of interdisciplinary learning.
- Pupils need different time frame to experiment with the material given

Outlook on future research - Suggestions for structural change and responsive curriculum development for integrated arts and computer science

To overcome splitting of art education and scientific education the project aims to develop suggestions for the development for schools and on the university level. The necessity of deleoping a *framework paper* summerizing the *conditions* and *skills required* for the different educational levels and social actors[47]. It will contribute to an overall framework paper to be developed in co-operation with the KuBiM-program of the BLK.

[47] in general education

What are

- Conditions required at school, that is the learning and working environment as well as the time frame and organisation of lessons at school (studio-atmosphere, project oriented work,)
- Conditions required in terms of the organisation of art education (linking the multidimensional character of nondigital media to the challenges of digital media
- Basic informations on facilitating processes of understanding and reflection concerning the digital media. How can computational literacy be supported on the long run? The aspect of the “added value” of computers is to be analysed from different angles and made transparent.
- Skills and competencies required from teachers including teacher training as well as further training models
- Essential issues concerning future art education which are not linked to particular soft- or hardware

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