Research and Practice in Technology Enhanced Learning
Vol. 2, No. 2 (2007) 105–129

EMPOWERING TEACHERS TO EVOLVE MEDIA ENRICHED CLASSROOM SCENARIOS

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Enriching existing classroom procedures and established pedagogic methods with computers is in no case a question of the number of computers available. In this paper, we present an approach of augmenting traditional structures of teaching at German schools by using innovative technology and collaborative software tools designed for the specific demands of teachers and learners for a certain topic. Starting with an overview of our experiences with the implementation of a computer-integrated classroom in the NIMIS project, we will continue with examples from our project SEED. There, computers were introduced to the classroom without redefining well suited pedagogic methods or changing the learning content at the beginning. Using the computer as a *trojan mouse* to enter the classroom, we simultaneously tried to empower the teacher to be able to implement change and innovation by using new technology in schools. Together with a community of secondary school teachers we have elaborated on classroom experiments which provide added value for both teachers and learners. For the development process, we brought together teachers, researchers and developers. Thus, we guaranteed that the "product" will cover the expertise of all three groups in a complementary way. We call this process *complementary action design*.

Keywords: Participatory design; teacher-driven innovation; interactive classroom scenarios; collaborative modeling tools.

1. Introduction

As the second PISA study (OECD, 2004) has shown, the majority of pupils at the age of 15 never experienced computers in schools as *expedient tools* for everyday life or learning purposes. The scientists who delivered the PISA study conclude that

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the reason for this lack, amongst others, is the insufficient usage of computers in schools and deficient equipment. Soloway *et al.* (2001) argue that a successful usage of computers in schools require that every pupil has at least access to his/her own hand-held computer. A large number of computer devices and an easy access are prerequisites for success.

During the last decade, several official programmes were conducted in most industrial countries to equip schools, make computers accessible to every pupil and achieve Internet-connection for schools (e.g. in Japan, cf. Hagiwara, 1999). Nevertheless, providing the technological environment does not guarantee that it is put to good use and enhances instruction in schools. This argument is also reinforced by the claims of Fischer (1998). In contrast Fuchs and Woessmann (2005) affirm that they have discovered that computers in the classroom have no discernible positive effect on children's educational performance while computers at home could actually be detrimental. "Taking account of the availability of other resources in school, the mere availability of computers does not translate into higher student performance [...]".

There is even a risk that established educational goals of school instruction are obscured behind a veil of technological features, devices, and problems: e.g. a teacher trying to fix networking problems in the computer room of the school instead of conducting the planned internet research with his class. The role assigned to a teacher in a computer supported learning scenario affects considerably successful usage of computers in classrooms (Rubin & Bruce, 1985).

Despite that, added value gained by the use of information technology is, for example, the unrestrained availability of notes taken during class, which can be stored persistently, whereas notes on the chalk board are usually lost after the lesson is finished (Hoppe, Luther, Mühlenbrock, Otten, & Tewissen, 1999). A more profound enhancement can be achieved by providing computer-based simulation and modeling tools, which can be used creatively and interactively as an addition to conventional instruction, in which real experiments (e.g. in physics or chemistry) are either too dangerous, expensive, or just not practical.

Our tools Cool Modes and FreeStyler, which are used in our projects are platforms to facilitate co-constructive activities. They offer shared workspace environments allowing co-learners to synchronously and jointly elaborate external graph representations based on visual languages (Pinkwart, Hoppe, & Gassner, 2001). The semantics of a visual language is carried by its domain specific objects and relationships. Compared to similar tools like Sepia (N. Streitz *et al.*, 1992) or Belvedere (Suthers, Weiner, Connelly, & Paolucci, 1995) the main difference is the idea of adding semantic structures to flexibly and externally define co-operative visual languages without assuming a given specific domain semantics for the overall system. Furthermore, the possibility of building models to simulate processes by "running" these models in a simulation mode provides a better understanding of dependencies, influences and behaviors in a complex model.

In this paper, we will introduce our approach of *complementary action design* (*CoAD*) as a focal point and describe the strategies we developed to bring CoAD into practice. We will substantiate the predication that change and innovation in schools shall be borne by the teachers themselves and cannot be decreed from outside. Therefore, we will explain why it makes sense to follow the *Trojan mouse* approach (Soloway, 1996). This means to bring technology into school practice without re-defining well suited pedagogic methods from outside, but empowering the teachers to initiate changes on their own. Thus, we will show that in existing school practice supporting existing learning structures with technology and developing innovative learning scenarios is not a polar opposite.

2. Complementary Action Design

We elaborated and established mechanisms to use the experiences of our teacher community and integrate their and our findings in our designs. Feedback concerning the usability of the tools which are developed is permanently given by the teachers. Concrete scenarios are designed for the use of the collaboration tools Cool Modes (Pinkwart, Hoppe, Bollen, & Fuhlrott, 2002) and FreeStyler (Hoppe & Gassner, 2002) in secondary schools. The teachers are supported technically and conceptually to implement the scenarios in their daily school life. In this way, an empirical base for usability evaluation of the system was created. This approach shares a lot of properties with the *co-design* approach (Penuel, Roschelle, & Shechtman, 2007) that similarly involves teachers, researchers, and developers in classroom innovations: first, it begins by taking stock of current practice and classroom context, second it requires built-in flexibility with respect to the curricular target, i.e. researcher's conceptions of currciculum and research question are not forced onto the teachers.

In the NIMIS project (cf. Sec. 3) the complementary expertise, i.e. the expertise of teachers, developers and researchers, formed the basis to design and explore visual languages as software tools to be used in computer enriched classroom scenarios. Against the background of the NIMIS experience we believed that only close cooperation between developers, researchers and teachers could lead to successful results. Based on this, we opted — in contrast to the co-design process, where the Principal investigator is ultimately responsible for decisions with teachers involved but non-equal partners in the design process which is "not a fully democratic process" (Penue *et al.*, 2007) — for a different perspective:

Our way of action research put the teacher in the crucial role: he put forward the ideas, "instructed" the developer and planned the actions in school, supported by the researcher during the design process and especially in evaluation questions. To differentiate this focus that makes use of the complementary expertises of the partners in the co-development, we call our approach *Complementary Action Design* (CoAD).

Figure 1 shows the correlations in a complementary action design process. The dark gray triangle in the middle symbolizes the initializing kernel where conceptual

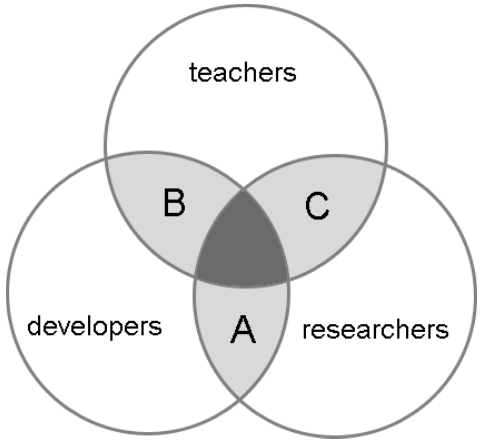


Fig. 1. Complementary action design.

design as well as regular controlling of results is done by all the partners involved in the design process. Besides these all-embracing situations, the three bilateral cooperations between stakeholders — represented in the sectors A, B, and C in the diagram — also contribute to the CoAD:

- Since developer and researcher are usually located nearby, e.g. in University, (A) is often the most intensive connection during the development. This is especially pronounced if computer science research is involved in the project and developer and researcher frequently are the same persons in a project. If the research is mainly of educational or psychological nature, the cooperation between the two groups tends to participatory approaches (Greenbaum & Kyng, 1991), i.e. involving the researcher into the software development directly in a collaborative and incrementally refining process.
- To ensure that teachers' needs are met, regularly feedback meetings between teacher and developer are equally essential. Sector (B) represents these aspects of participatory design, that let the teacher participate directly in the design, e.g. the visual layout of the user interfaces, and the development, e.g. needs and requirements directly tied to the school practice and infrastructure (such as firewalls, licenses needed etc.). The frequent meetings needed for an incremental development with quick turn-around cycles have to be coordinated with teacher's time constraints, work schedules, and the school calendar. During our CoAD phases with teachers we found out that for funded research projects of this type the partial hiring of a teacher on the project for this kind of cooperation can boost the intensity in this sector. It provides the timeframe for regular and frequent meetings between the teacher and the developer.
- The third bilateral cooperation between teacher and researcher in sector (C) is particularly targeted to evaluation purposes. The complementary expertise of

teacher and researcher is needed both for the identification of research questions in *in vivo* conditions and to analyze the results jointly. A close cooperation is highly desirable here, because in the — compared to lab experiments — less controlled settings of a classroom, the evaluation is frequently conducted by using mixed-method designs and triangulations (Denzin, 1980) where the combination of results supports each other. While the methodological expertise of the researcher is invaluable for the general procedure of the analyzis, the insights of the teacher into the context, practices, and class, facilitate especially the qualitative parts of such a multi-method evaluation. Recent examples of such research designs in the field of Computer Supported Collaborative Learning have been published in Monés *et al.* (2006); Harrer, Zeini and Pinkwart (2006).

During the SEED project we used complementary action design with a specific core of teachers who committed themselves to the process with regular meetings and use of the prototypes. Via this design process we developed the visual languages for probability exploration and genetics (cf. Sec. 7 for details). Other teachers in the wider context of the project (e.g. colleagues of the core teachers or participants in our teacher workshops) noticed the process and realized that teachers can benefit from this approach by getting what they asked resp. designed for, i.e. the results meet their personal needs for a creative, open environment. This stimulated other teachers to come up with concepts, e.g. for a visual language for chemistry, for modeling circuits in physics and teaching road traffic situations and rules. Although these proposals could not be realized completely during the SEED project, we observed that teachers are still highly motivated to integrate the concept of hardware and software usage we introduced into their lessons.

3. Background and Previous Work

The experiences from the project *Networked Interactive Media in Schools* (NIMIS, 1998–2000) which formed the starting point of our work can be best described along the "design philosophy". The NIMIS project was based on an *ubiquitous computing* approach (Weiser, 1993) with interactive devices embedded in a spatial and physical context, very much in the sense of *roomware* (Elrod *et al.*, 1992; N. A. Streitz, Geissler, & Holmer, 1998). According to the notion of the *invisible computer* (Norman, 1998), the computer does — also metaphorically — no longer form the center of interest in the environment. The adaptation of these general principles of embedded interactive computing technologies has led to the concept of a *computer–integrated classroom* (CiC), as formulated originally by Hoppe, Baloian, and Zhao (1993). In a CiC, various computational representations as well as networking, interaction and presentation facilities support face-to-face learning by adding values such as smooth and easy flow of information between places and between different (re-)presentations. Also, the CiC provides "group awareness" with respect to the different roles and interactions within the learning group and with the teacher.

From NIMIS, we learned that successful development and use of learning scenarios implies close cooperation with teachers on the one hand but also immediate feedback from users and learners on the other hand. In NIMIS, we realized these two paradigms by using the programming technique of rapid prototyping (Isensee & Rudd, 1996). That means, we have developed software components in short cycles where teachers and pupils had the opportunity to test it and give their feedback for the next version. As a final output we had the NIMIS software as a well elaborated product (Lingnau, Hoppe & Mannhaupt, 2003) which is the result of close cooperation between teachers/educational users, researchers and developers. It is still used in a productive way, seven years after the project ended.

4. The Seed Approach

The SEED project (SEED, 2001–2004) differs very much from NIMIS, concerning initial settings and objectives. In NIMIS, one classroom was set-up with a fixed installation of hardware integrated into school furniture to be used by small groups of children to be taught in a specific domain. SEED aimed at setting learning scenarios in various classrooms for different subjects taught to normal groups of pupils of all ages: Since a math-course of 9th graders about stochastics differs very much from the requirements of a German language course of 12th graders about the characters of a drama, a much more flexible solution had to be found. Furthermore, SEED aimed to change mindsets of teachers and educational decision makers (diSessa, 2000). This could not be realized by setting up only one showcase classroom as an experimental long term research setting but must be deeply embedded in already existing classroom and teaching scenarios to enrich learning by seamless integration of interactive media.

Within the European SEED project, new forms of using digital media in classrooms were tested with groups of associated teachers in different countries (Hoppe, Kynigos, & Magli, 2002). This endeavor was based on the premises that we did not want to introduce new computer orientated content but work with the given curriculum. We want to maintain, maybe enrich, each teachers grown teaching style and "personal curriculum". Together with every teacher, we want to establish richer and more integrated forms of using interactive digital media in the classroom.

Our perspective for using computers in instruction at schools in the SEED project is to move the computer out of the focus of attention and — similar to NIMIS — to enrich instruction with computers where appropriate. We do not want technology to redefine pedagogy but to preserve the possibility for the teacher to use their style of instruction, with all their individual capabilities and characteristics, while also offering additional functionalities with interactive media. Thus the teachers themselves could redefine their pedagogy utilizing the potential of technology support.

To give teachers the opportunity to exchange their experiences, discuss ideas and even to stay in contact with the researchers and developers during and after designing a concrete scenario we set up an Internet portal for the local teacher community. New software versions can be found there, different discussion forums can be joined and also own results can be uploaded to share with other teachers. Because community building was one of the main goals of SEED, an international Internet portal was launched in conjunction with an international teacher workshop, in order to accompany the last third of the project's lifetime.

5. Digital Mimicry

The leading questions for our approach are: How can added value be gained by usage of computers and interactive media compared to conventional instruction? How can technology be as unobtrusive as possible for all participants (pupils, teachers and schools)? Our answer to the latter question are devices that preserve the usual style of instruction without causing a disruptive change of media when using interactive technology. This is for example the use of interactive electronic whiteboards which provide all the possibilities conventional chalk boards do, or the use of pen-based tablets instead of the usual exercise-books.

Hoppe (2002) calls this type of technology usage *digital mimicry*, because the digital technology mimics behavior and usage patterns of non-digital devices. Besides the use of interactive pen-based input devices, such as boards or tablets, digital mimicry has been used in educational games and simulations (Kusunoki, Sugimoto, & Hashizume, 1999; Eden, 2002). The advantage of this approach is that the barriers of introducing technology into educational environments, such as school, are much lower when the typical way of using tools is maintained and thus, the learning and teaching style is not compromised. This can be seen in the natural adoption or combination of physical and digital tools, such as in Fig. 2, where a teacher used a physical ruler to draw a line on a digital whiteboard; similar phenomena have been observed with school kids using their rulers on a Tablet-PC's surface to underline their writing or drawing line graphics (Hoppe, 2007).

Obviously the first question concerning the added value of interactive media and technology can be addressed by the high potential of digital media for storage, re-use and sharing of results: the finished products of school projects can be published on the web or a school intranet. There is also the possibility to enhance static diagrams and models with operational semantics and thus make the models executable, enabling interactive simulation and exploration. We will go into detail on this in the passage about practical school experiments.

6. Collaborative Mindtools and Modeling

To achieve more interactivity in learning environments, interactive cognitive tools were created and used to express oneself intellectually and artistically. Jonassen, Peck, and Wilson (1999) refer to such software–systems, providing interactive

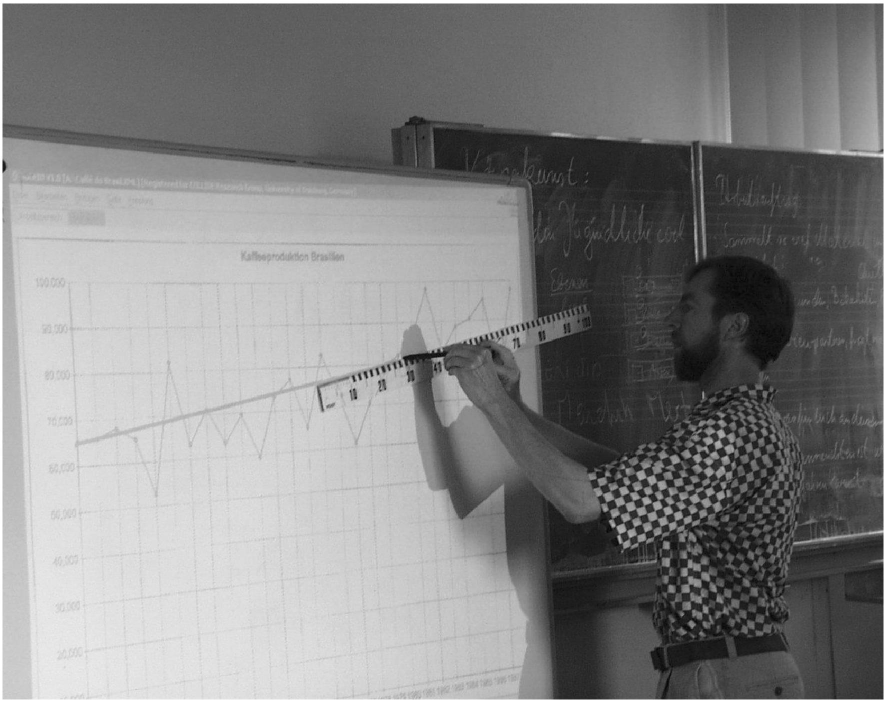


Fig. 2. Digital mimicry mixed with physical devices.

learning environments with *computational objects to think with* as *mindtools*. This complies with Dewey's notion of expressive media (Dewey, 1934): the student manipulates visual objects whose representations can be computationally processed — a typical example for these "visual languages" (Hoppe, Gassner, Mühlenbrock, & Tewissen, 2000) are languages for argumentation and discussion (Suthers *et al.*, 1995), where different contributions, such as question, proposal, counterproposal have distinct visual representations and the structure of resulting argumentations can be interpreted. Another example are visual tools for simulation and scientific modeling (de Jong & van Joolingen, 1998).

In our research, we follow an integration approach by providing *computational objects to think with* in a collaborative, distributed computing framework. This technology is not only of interest for virtual learning applications but also for face-to-face classrooms with networked computing facilities. Ubiquitous computing technology with specialized devices such as large interactive screens (whiteboards) or pen-based tablet computers has been used in practical scenarios. A new quality of educational computing technology was achieved which is on the one hand integrative in that it unifies media and representation formats on a digital platform, but on the other hand, neither dominates or determines the educational environment nor does it conflict with grown pedagogical traditions and teaching-learning settings.

Simulation and modeling tools are called *collaborative mind tools* when used by a group of participants, in that case pupils or teachers, together in a co-constructive way with shared goals. Within collaborative mind tools the above described two lines are combined into a single environment, where *computational objects to think with* are created and manipulated in a collaborative, distributed settings supported by a technological infrastructure. In the following chapter, we describe how these tools can be used in school scenarios.

7. Examples from Classroom Practice

To convince and involve teachers to use new media technology we initially defined several scenarios on different topics (Lingnau, Kuhn *et al.*, 2003; Lingnau, Harrer, & Yiannoutsou, 2003), that show the feasibility and richness of interactive, collaborative scenarios. In this section, we give some examples how teachers made use of the potential of our tools acting as partners in the CoAD process (see Figure 1), taking up existing tools and bringing forth new ideas for additional scenarios and tools.

7.1. *Modeling with system dynamics*

7.1.1. *Introduction*

In order to introduce teachers to the principles of Cool Modes we started with presenting an existing visual language for system dynamics (Forrester, 1985). Thereby, initiate a discussion about the needs and requirements of visual languages for teaching subjects in our local teacher community, not only in natural science, and inspire teachers to become active parts in the CoAD process.

One teacher came up with the idea to introduce system dynamics into biology and chemistry lessons to allow pupils to simulate complex quantitative relations, e.g. epidemic growth, relations between cattle breeding and usage of resources in tropical forests or the cool down of a cup of coffee.

7.1.2. *Language description*

System dynamics implemented as a visual language for Cool Modes has been in use for several activities with students in university previously (Pinkwart *et al.*, 2002). It provides basic support for modeling and simulating system dynamic models. By using different types of relations, the flow of information and the current flow of quantities between the objects (*stock*, *rate* and *constant*) can be distinguished (see Figure 3). A user interface for the simulation is integrated, containing buttons to control the simulation of the model. During the use at university, the tool was refined iteratively based on the users' feedback with respect to usability of the tool.

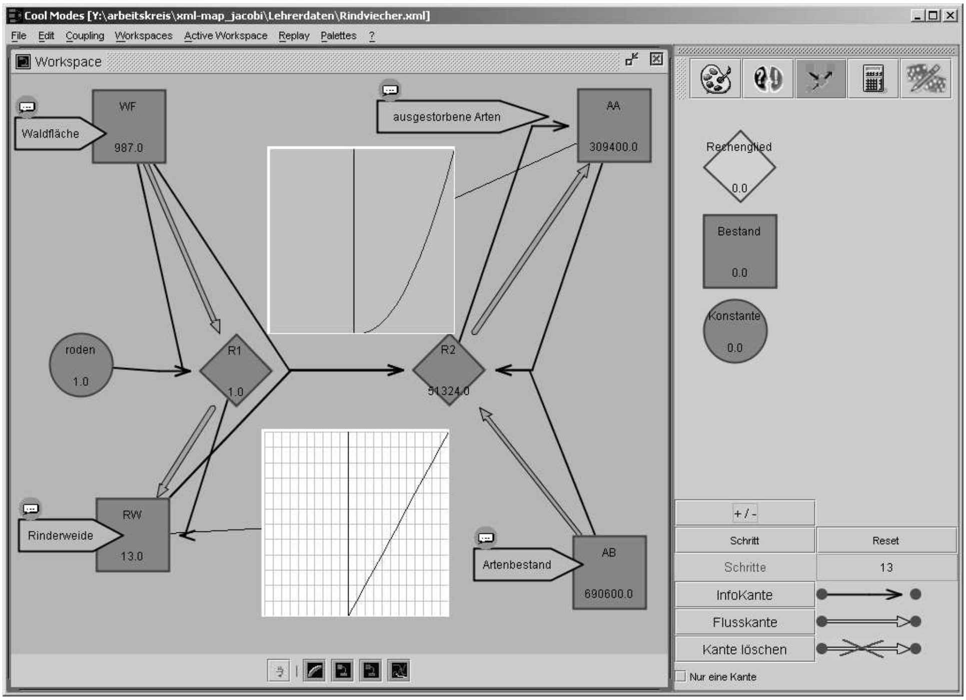


Fig. 3. Pupils result of modeling dependencies between resources needed for cattle breeding in tropical forests.

7.1.3. *Setting and results*

The system dynamics language has been used in SEED facilitating a lesson series on the topic "sustainable usage of resources". This topic is designated for secondary school students at the age of 18 in their 12th grade in biology courses. Although pupils needed further instruction for difficult models, they were able to construct simple models on their own from the very beginning (see Figure 3). To create a model concerning the need of resources for cattle breeding in tropical forests the pupils started with finding elements and their dependencies by investigating different approaches. After this phase different models were presented to the whole group. The pupils finally constructed a model in a collaborative session which lead to a model that contained four main elements (forest area, pasture land, population, diversity of flora and fauna) and their dependencies.

Students of biology in secondary schools are usually not very interested in learning *abstract* models. Being asked about the benefit of using an open modeling environment the students answered that they found constructing models collaboratively more motivating than simply reading about a model in a book or listening to the teacher explaining it.

7.2. *Modeling of elementary probability in mathematics*

7.2.1. *Introduction*

Learning probability is a relatively modern aspect of school education in Germany, France and other countries. Fischbein points out that "practical experience with probabilities provides an ideal way of familiarizing children with the fundamental concepts of science, such as prediction, experiment and verification" (Fischbein 1975). Teachers often use hands-on experiments to help the students understand basic concepts. Exploratory learning is practiced in throwing dice or coins and examining the outcomes of such experiments. Pupils are often motivated to find out more about "chance", especially concerning gambles. Normally the experimental work is limited to introductory lessons, followed by a lot of theoretical and often disillusioning, de-motivating work. For example, for investigating the law of great number it is necessary to let pupils throw the dice a thousand times and more and cumulate the results to watch the stabilization of the relative frequencies. This requires great patience and preciseness for repetitive, inefficient work by the students and control skills by the teacher.

Combining the advantages of students' hands–on–experiments with computational capabilities expands the mentioned limits and opens up new ways of teaching and learning. This approach shows parallels to the French statistics curriculum which is "grounded on the idea of observing the fluctuation of samples by simulating the repetition of a random experiment and observing the stabilization of the frequency distribution of the possible outcomes, the notion of probability being introduced later as a *theoretical frequency*" (Parzysz, 2003). In simulating and analyzing experiments pupils build up probabilistic concepts based on own, empirically grounded experiences. Even complex problems, based on urn experiments and automatic analyzis, can be modeled, simulated and examined using the visual language, for example, the birthday paradox or Bernoulli processes.

7.2.2. *Language description*

The development of the visual language for stochastic experimenting is a showcase example for the *complementary action design* process. While the System Dynamics example showed mainly the successful takeup of an existing visual language/tool by a teacher, this case is an example for the design and development of a completely new visual language based on the teacher's needs to conduct interactive teaching: Initiated by a comprehensive secondary school teacher, a simulation environment for elementary experiments was developed to provide curricular activities of 9th graders. This co-development took place between the teacher, a student programmer and a computer scientist (in the role of researcher and consultant for development). Pupils should model, control and analyze experiments in which throwing of dice and coins, drawing of numbered or colored balls are simulated. During the design process the visual language was adapted and extended in several development cycles to simplify the usage and to explore a variety of perspectives and principles of stochastics.

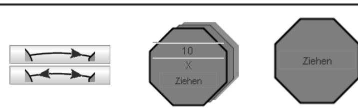
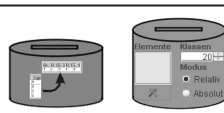
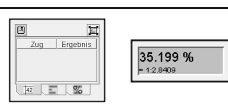
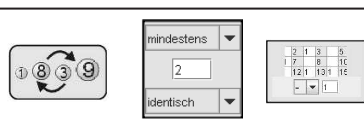
The underlying mathematical theory is the *probabilistic urn model*. It allows to calculate the probability taking into account the drawing mode (with or without replacement) and considering or neglecting the order of the elements in a drawing. Due to this model different types of random generators are representing the urns e.g. a dice, a calendar, numbered or colored balls (see Table 1). Control elements allow to execute an experiment once or several times. The different drawing modes are represented by special edges connecting urns and control element. At the beginning of the participatory design process the sorting of a draw was realized as part of a visualization element. Later, we decided to add a filter element which can be interposed to sort out the events of interest.

The visual language contains other elements to build up a microworld for exploring probabilistic problems through experimenting like control elements to repeat an experiment, data collectors to store the results, filters for automatic analyzis, e.g. in lotto experiments. Further elements support collaborative activities. Special emphasis is laid on the visualization of the outcomes. They are visualized in the form of a table, as bar charts for absolute or relative frequency or as a numerical result. Nearly all types of problems in stochastics based on urn models can be modeled and explored in an empirical way. For a subset, it is even possible to compute the probability.

7.2.3. *Setting and results*

The first example of the practical use of the tool shows, how learning probability and modeling, both important aspects of math education, work hand in hand playing

Table 1. Parts of the visual language for stochastics.

Random generators		urns
Multiple drawing with/without put back		drawing edges, drawing nodes
Collecting and sharing of results		collector, converter
Display of frequencies and probabilities		drawing table, calculation node
Extraction of positive events		sorter, equalization filter, lottery coupon

an essential role to initiate learning processes. In a sequence of lessons with a class of 9th graders, the birthday paradox, an ideal problem to leave the traditional ways of math instruction and to initiate inquiry learning, has been investigated. For the lessons an existing computer room in the school has been used but enhanced with pen-based input devices replacing the normal computer mouse. Thus pupils were enabled to do hand-written annotations during the modeling process in Cool Modes and naturally act with the pen while building the model in the workspace. The pupils worked in small groups of 2–4 joining one computer being allowed to discuss with other groups.

Beginning with easy models such as *throwing* one or two dice or drawing colored balls the pupils got familiar with the software and refreshed their basic knowledge. The birthday paradox "How high is the probability that in a group of n people at least two have a common birthday?" was introduced through a betting contest following the crucial steps "test own beliefs against the beliefs of others, [...] against own beliefs about other related things, [...] against empirical evidence" (Konold, 1991; Nilsson, 2003) to increase the pupil's motivation. For them it is not evident how to calculate the probability directly using the complementary event *no common birthday*. It was intended that they use the modeling environment to prepare a theoretical, algebraic solution.

In a first step, the pupils used Cool Modes to elaborate an adequate model. Using the calendar urn, a representation of 365 days, a basic model was immediately found where one date after the other could be drawn 24 times to simulate a given group size of 24 people. Right at the beginning of the modeling process even the replacement of the drawn date was obvious for some pupils. The model was supplemented by a bar diagram to visualize multiple birthdays (see Figure 4).

Pupils had to perform at least 10 experiments to determine how often the event "at least one common birthday" occurs dealing with a group with 24 members. The experimental work was arranged in small groups working either in private or synchronized, shared workspaces. To share the findings between the groups the pupils used a common Cool Modes object. At the end, the results have been entered group wise into a synchronized table and the overall relative frequency could be calculated.

In a second scenario the pupils had to modify the model to explore how much members a group should have to get a chance of 50% for *at least one common birthday*. Now the pupils not only had to analyze and count positive outcomes but also decrease or increase the group size. This time the pupils reported their findings permanently into a synchronized, shared table in the workspace. Thus, each group could make use of all reported findings and alter its procedure accordingly.

In a comprising lesson the empirical results were compared with the theoretical probability which was computed using the complementary event *no common birthday*. During the whole course the teacher made constantly use of an interactive board to structure and document the learning outcomes and results. These documents were archived and sent to the pupils via email. These scenarios have been regularly conducted by the teachers of the SEED teacher community, even after the

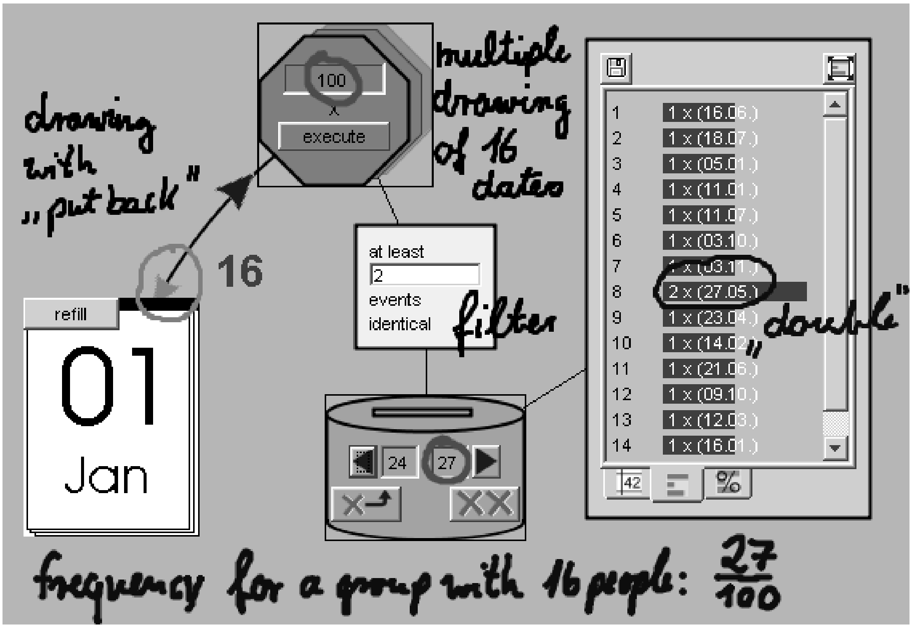


Fig. 4. Shared model for the *birthday experiment*.

end of the project lifetime; this shows that teachers who took up and brought in their own ideas into such a tool appreciate these and make use of it in a sustainable manner.

7.3. *Exploratory learning in genetics*

7.3.1. *Introduction*

After observing the successful development and usage process of the visual language for probability, a biology teacher of the local teacher group came up with the idea of a visual language for modeling and exploring genetics, a typical domain in teaching biology. This teacher also had used the system dynamics tool before and thus had an impression about possible scenarios and the feasibility of designing new visual languages for Cool Modes. He created graphical sketches and a storyboard and discussed this design with a developer and a researcher, using meetings for discussion about development cycles. In Germany genetics starts to be part of the curriculum in grade 9. Questions concerning the heredity of blood types, Rhesus factors and of "defects" like the Red-Green Color Blindness are examined, allowing to differentiate between dominant-recessive, intermediary and sex-linked traits and their effects on the phenotypes of the "offsprings". In grade 12, the topic of genetics is brought up again. Besides molecular genetics concentrating on chemical aspects of inheritance like DNA and its components other topics are taken into account:

More complicated heredities based on several traits (Mendelian Genetics) and the linkage of genes on the chromosomes (Morgan Genetics) and their effects on the traits of the offspring generations. Later on evolution related questions are important concerning population genetics. Factors of "personal fitness" are analyzed to find out in which way they have an impact on the composition of the offspring generation.

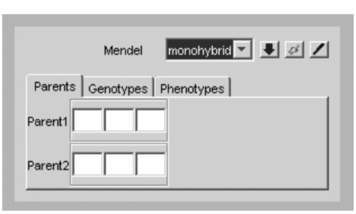
7.3.2. *Language description*

To facilitate exploratory learning the teacher of the SEED-community designed a modeling language for Mendelian, Morgan and population genetics (Falconer & Mackay, 1996). The modeling of heredities through Punnett squares (see Figure 5) is provided in various ways, the offspring generations are created automatically, their genotypes and phenotypes are visualized, improper assumptions can be corrected without effort. Furthermore, the modeling process aides the students to structure and visualize the relations between parents and offspring generations. All aspects are essential to offer or even open students an exploratory approach. Starting from the phenomenon they can make assumptions concerning the traits, their number and the "power" of the alleles. With an adequate effort they can model the suitable (dominant-recessive, intermediary or sex-linked) crosses, analyze the illustrated offspring generations, and validate their results. This procedure is based on the idea of inquiry learning: near to scientific research work, i.e. making assumptions, collecting,

The variable leaf beetle (Chrysomela varians) can only be observed on the St. John's wort (Hypericum perforatum). Its name causes on the fact that he appears in three different colours. Some of the metallic shining beetles are green, others are blue and some are red.

The visible colour is not created by pigments but in a physical way by reflection of the light in the structure of the exoskeleton. This way of reflection of light is similar to the one we observe when there is some oil, e.g. in a puddle.

By cross breeding red and green beetles, 50% of the offsprings were red and 50% were green. By cross breeding green and blue beetles, 50% of the offsprings were green and 50% were blue.



Exercise:

a. Analyse the heredity! Explain the result!

b. Elaborate a Punnett square (cross breeding table) for the two above mentioned cross breedings.

Fig. 5. Students' hands-on material in genetics.

structuring and analyzing data, validate assumptions. So it is manageable by the students to cope with more authentic and complex problems. For example the complexity of the Punnett squares, reduplicate with male and female in every generation, expands exponential with the increasing number of the traits: in a monohybrid cross four combinations of the genotype exist, a dihybrid cross possesses up to 16 different combinations for the genotype of the offsprings and a trihybrid 64 combinations. A genetic analyzes concerning a described or observed phenomenon, which may have to be carried out through a number of offspring generations is impossible because of the limits of school practice.

7.3.3. *Setting and results*

The tool was used in grade 12 at the end of a course section to foster pupils' existing knowledge and to evaluate the design decisions of the tool. Concepts under investigation were two monohybrid and one trihybrid heredity with up to three offspring generations. As an introductory example the leaf beetle (Chrysomela varians) was chosen, an example of a simple trait with an astonishing phenotype: it showed not the expected intermediary or dominant-recessive, but a fifty-fifty allocation in the following generation. This leads to a situation that the problem solving takes place right at the beginning of the modeling process to find an explanation for the beetles surprising color, similarly to the initial surprise connected to the phenomenon of the birthday problem. The material given to the students can be seen in Figure 5.

In an elementary problem for classes in the secondary there are different cultures of pea plants, which will produce green and yellow seeds in their pods if pollinated with their own pollen. If these homozygous plants are cross bred all offsprings will be green peas. If they are seeded and reproduced among each other, a counting of the seeds from 1000 of these plants showed 753 green and 247 yellow peas. The solution showed similar ratios than that in the given numbers of the problem description, and thus the hypothesis about the heredity was supported for the students.

7.4. *Drama analyzis in literature*

7.4.1. *Introduction*

In the last example we did not develop a new visual language in a CoAD process, but enabled a teacher to make use of an earlier developed environment in a new way. To provide lessons about a German drama (Dürrenmatt, 1957) a secondary school teacher elaborated a scenario using the FreeStyler application and its concept mapping and collaboration facilities. The topic is dedicated to pupils at the age of 16 in the 10th grade. The idea behind this computer–enhanced learning scenario was to provide the pupils with tools for structured presentation and to support collaborative work not only by discussing but also by giving immediate access to other pupils' work. Also reusability of the products instead of writing at a normal chalkboard was an important cause for the teacher to use a computerized environment.

7.4.2. *Language description*

FreeStyler (Hoppe & Gassner, 2002) technically bases on the same platform and libraries as Cool Modes. It provides a modified user interface to support an organizational learning approach which puts the emphasis on creative meetings and its outcomes and the incremental building of a group memory. It serves primarily as an interface between face-to-face discussions and the documentation process, but it can be used during multiple working phases as preparation, creative meetings, presentation, post processing or wrapping up information. This is enabled by a cooperative visual language which offers a set of content objects to structure information. A content object combines a symbolic view with predefined interactions. It can be characterized as a template for a special type of information as ideas, concepts, decisions, addresses or internal and external links. Whereas several content objects rather define the category of information, others, i.e. the links, provide additional structural information and interaction features. Users can mix these content objects with handwritten input flexibly. Methods, such as concept mapping, mind mapping or MetaPlan are easy to perform with the FreeStyler. The external representations both enrich and influence the communication. Figure 6 shows an example for a FreeStyler mind-map created while evaluating ideas generated in a brainstorming session with handwritten annotations to select part of the ideas.

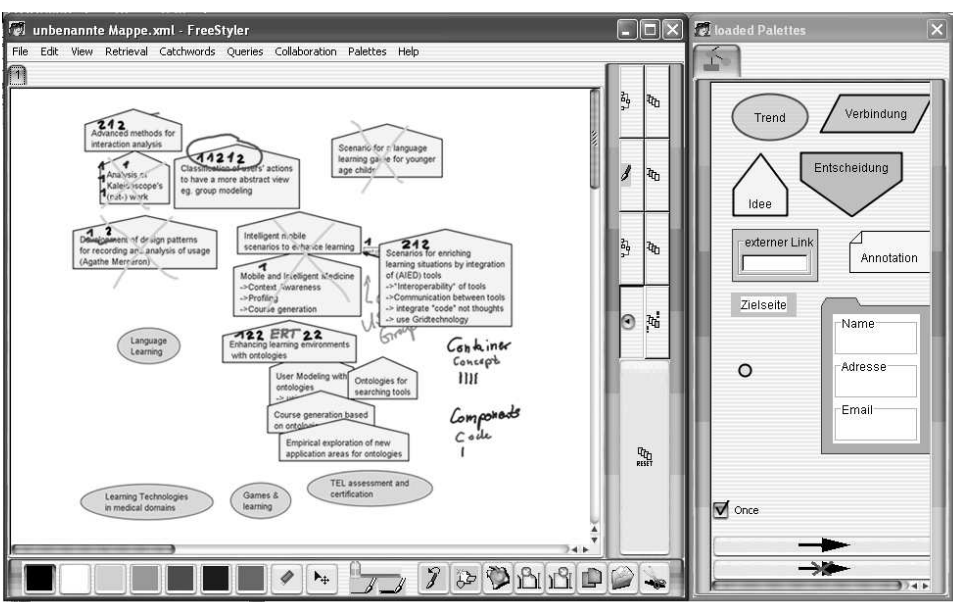


Fig. 6. Example for a FreeStyler mind-map.

FreeStyler files are page-based *portfolios*. Internal links help to structure the representation. User definable external hyperlinks can be used to point to and to access related files. To arrange the objects and to integrate handwriting comfortably, layers are available that can be faded out independently. With respect to the documentation the system offers retrieval and indexing functions. Keywords can be assigned to maps, too, for further organization and structuring. In order to exchange the maps an integrated mail function can either send snapshots of the pages or the full information represented in a XML file as attachments.

7.4.3. *Setting and results*

Using the schools' own computer room, which is usually only used by science classes, this was an interesting new experience for the German teacher and the pupils. After the drama had been introduced in former lessons, the teacher planned a whole day lesson for the computer supported scenario. In the first hour the pupils learned to handle FreeStyler and solved a short task for practice. In the following two hours the pupils had to work on a task concerning the drama. Therefore the class was split into four main groups of six pupils. The task was to devise a strategy both for an accusation and a defence plea at an imagined court trial for the four main characters in the drama. Each main group was divided again to deal with one of the characters' accusation and defence. For every micro-task a separate cooperative workspace was opened in FreeStyler. Every group worked in their own workspace but had also the possibility to connect with the other workspaces to track the work of the other groups but without making changes in the others' workspaces. This collaborative elaboration influenced the argumentation because *defence* and *accusation* teams knew each others' arguments immediately as well as the arguments the other teams found for the characters they were working on. In the end, each group created a mindmap with the arguments and the context like laws etc. to simulate a court hearing. Figure 7 shows the whole FreeStyler map with all the different solutions for accusing and defending the different characters in the drama, each represented by a tab in the upper area. The selected tab gives an example of the accusation strategy for the character *teacher* in the drama.

The complete computer enhanced scenario also supported the German language teacher in the supervision: Starting her own FreeStyler instance she was able to connect with each of the pupils' workspaces as a supervisor and track the work of the different groups not only for information but also to decide whether a group needs help or not and how the different arguments were elaborated.

In the fourth hour the groups presented their carefully designed results to the whole class. Beginning with pleadings of accuser and advocate all arguments were presented. In the following, plenary discussion all pupils were able to participate and analyze the same material because of the structured representation which was available at both, the teacher workplace with a main projection screen, and

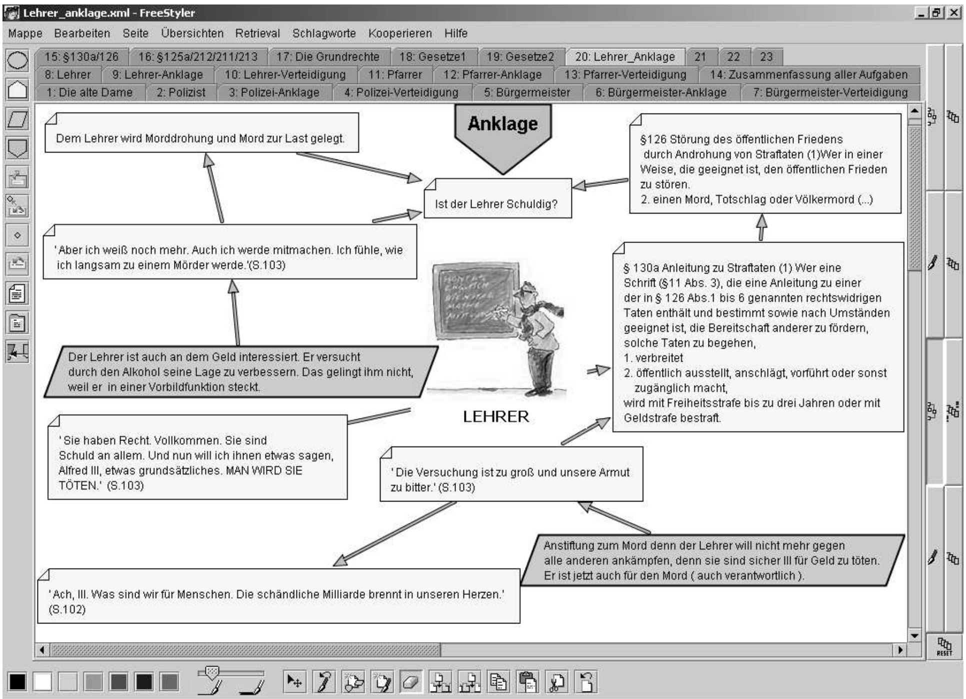


Fig. 7. Complete FreeStyler map with all accusation and defence strategies. The selected tab shows the elaborated argumentation for the accusation of the teacher.

each workplace. Figure 8 shows some snapshots from the classroom during the elaboration and presentation phases.

After the lesson was finished, the teacher collected the data using the storage functionality to a central server. This made it easy to distribute and to re-use all results during the following days and weeks. Pupils and teacher could easily work with the results not only viewing it again but also modifying it with the same tool they used to produce it. The teacher was able to evaluate the results at home and she could easily assemble the most important results in new workspaces to continue with in the next lesson. Compared to traditional lessons, pupils got easy access not only to the information and results in their exercise-books but could immediately make use of the whole range of results and information in the classroom. For documentation, purposes the teacher has also the option to send the results in JPEG format as e-mail attachments to the pupils.

8. Conclusions and Perspectives

8.1. *Convincing teachers*

Innovation in the field of computer usage in classrooms is neither a question of quantity of hardware (Fischer, 1998) nor a question of technical skills. From our

Fig. 8. Views from the classroom while pupils working on drama analysis with FreeStyler.

experiences in both projects, NIMIS and SEED, we learned that most of the teachers need to change their mindset to see a real benefit from using computers and software in their lessons before they will appreciate new technology. Consequently technology has to be a tool which supports the existing procedures and learning strategies in the classroom. So the design of hardware and software in the way of a digital mimicry aims to support and not disturb teachers and learners. This can be considered the "Trojan gift" (Soloway, 1996) contained in our proposed approach, that create first acceptance and takeup in the teachers.

But the availability of digital tools (hardware and software) without obstacles is only a prerequisite for a successful approach to enrich teaching and learning with media to achieve a higher performance and better results than in "normal" classrooms. Teachers are usually acting very conscious and sceptical if changes of their approved way of teaching are demanded from outside. Thus, we believe that the process of adapting new technology and changing mindsets has to be stimulated carefully and then implemented by the teachers themselves. Therefore we propose a two step strategy:

- In a first step, teachers have to be enabled to *mimic* their familiar teaching procedures using digital tools. Thereby innovation is brought to the classroom like a "trojan mouse" (Soloway, 1996) empowering the teacher to generate own ideas and elaborate needs for a further use of the new media.
- In the *complementary action design* process the teacher will keep the pedagogical responsibility and get the whole benefit of technological expertise from the developers and researchers of the joint project.

This leads to a process where teachers lead and control the changes that technology can bring to teaching and learning scenarios, thus increasing the chances of take-up and appropriation of interactive and collaborative technology.

8.2. *Spreading ideas*

From the teachers' point of view, it will be a problem to convince schools and responsible administration to establish an appropriate hardware infrastructure such as digital whiteboards needed for practical work with Cool Modes or FreeStyler. But the software can be used also with basic equipment, such as pen-based input device, in an effective manner, thus allowing to adapt interactive scenarios to the given context and situation of the specific school and teacher. We have demonstrated, for example with the drama analysis setting in the German language lesson, that even already existing standard computer rooms can be transformed into "interactive" media enriched learning settings by adding e.g. WACOM tablets to provide handwriting and thus replacing the normal computer mouse. In settings like this, one can say that a computer integrated classroom (Hoppe *et al.*, 1999; Hoppe *et al.*, 2000) could be easily set up "out–of–the–box".

Cool Modes and FreeStyler as learning platforms have been proven to facilitate co-constructive modeling activities including a wide range of visual languages that can be used in secondary school teaching (see Figure 9), e.g. for stochastics, system dynamics, genetics. Conventional modeling tools do not offer the possibility of a synchronous information exchange between learners and the teacher.

Another important advantage in comparison with the use of a conventional chalkboard is the reusability of results for homework, evaluation, and other post-processing. Furthermore, all pupils can work with their own copy and complete it as desired.

Altogether, we consider that making available collaborative and interactive tools to teachers accompanied by an innovation strategy outlined above can, overcome the obstacles both in the context of schools — with respect to infrastructure and practices) — and within the teachers themselves: empowering them to preserve grown

Fig. 9. Pupils constructing a model with FreeStyler.

practice as well as allowing interactive and collaborative scenarios with custom-tailored tools helps to create acceptance and adoption by the teachers. Our proposed and tested approach targets beyond mere "gift wrapping" (Fischer, 1998) but creates added value teachers appreciate in several aspects shown in our example cases.

Acknowledgments

Most of the work described in this paper has been funded by the European project SEED (SEED, 2001–2004). We would like to thank all the teachers involved in the project as well as the schools. Special thanks goes to the teachers and the headmaster of the Elsa–Brändström-Gymnasium, Oberhausen, Germany for the possibility of bringing our ideas and developments into school practice.

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