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Designing and Supporting Collaborative Modelling Activities in the Classroom

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"Collaborative mind tools" – a synthesis of two paradigms

Over the last ten years, we have observed an increasing interest of the "computers in education" and other related research communities in supporting not only individual learners but also learning groups. The most prominent scenarios in this line of research and development have certainly been centred around virtual learning groups using computerised communication and cooperation facilities. From a technology point of view, the focus of this work has been on synchronous and asynchronous information exchange, e.g. on conferencing techniques and sharing of resources and materials as well as on digital archives. Accordingly, communication facilities and techniques for information exchange have been in the foreground whereas the internal structure of the computerised representations has been of secondary relevance.

On the other hand, originally motivated by the limitations of conventional individualised computer tutors, there was another tendency to have more interactivity in learning environments using rich and powerful "computational objects to think with". This lead to the development of interactive cognitive tools or "mind tools", which were essentially based on the direct manipulation of visual objects by the user-learner but also based on the computational processing of related symbolic objects and representations. Typical examples are visual languages for argumentation and discussion as well as visual tools for simulation and scientific modelling. In the co-construction of scientific models, learners can engage in cognitive and social processes that promote collaborative knowledge building. Rouwette, Vennix and Thijsson [1] argue that a collaborative approach to model and policy design is effective to foster learning and understanding. Accordingly, we see a new challenge in providing modelling tools in a collaborative, distributed computing framework. This is typically achieved through shared workspace environments which allow a group of learners to synchronously co-construct and elaborate external representations. Concerning the domain content of these representations, two poles can be found: on the one hand, System Dynamics models or Petri Nets provide a complete semantic definition of all objects and thus allow for running the models as simulations. In contrast, less specific systems like Belvedere [2] do not interpret the semantic content of the objects but the rhetorical or argumentative types and relations between objects (e.g. "hypothesis", "conclusion"). The system is aware of the developed argumentation structure and points out missing relations via a support agent.

Recently, Milrad, Spector and Davidsen [3] have suggested an approach called "Model Facilitated Learning" (MFL) in combination with instructional design principles. Key aspects of this design framework include the use of modelling tools, construction kits and System Dynamics simulations to provide multiple representations to help students in developing an understanding of problems in situations that comprise many interrelated components which are subject to change over time and often involve ill-defined aspects. MFL distinguishes learning by modelling from learning with models and suggests when and why each approach is most likely to be appropriate. In addition, MFL emphasis the notion of socially situated learning experiences threads throughout elaborated learning sequences. Here, the notion of social situatedness extends to the idea of collaborative modelling.

In this paper we present an integration approach of both views 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 specialised devices such as big interactive screens (whiteboards) or pen-based tablet computers has been used in practical scenarios. A new quality of educational computing technology was created 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 conflicts with grown pedagogical traditions and teaching-learning settings.

The Cool Modes environment

Cool Modes ("COllaborative Open Learning, MOdelling and DEsigning System") is a platform and tool environment to facilitate co-constructive activities. It offers a shared workspace environment allowing the co-learners to synchronously and jointly elaborate external graph representations based on visual languages [4]. The main difference between Cool Modes and other comparable tools like Sepia [5] or Belvedere [2] is the approach of adding semantic structures to flexibly and externally define co-operative visual languages without a priori assuming a given specific domain semantics for the overall system. This makes it a system capable of integrating multi-purpose structuring tools, e.g. for discussion, with specialised domain-related functions in the way proposed by van Joolingen [6] in regard of integrating simulations with argumentation environments to support "collaborative discovery learning" in science education.

Visual Languages in Cool Modes

Generalising this aim from the viewpoint of visual languages leads to "partially formal" languages in which some objects have a specified domain-related functionality and semantics, enabling the system to provide e.g. special tools, means of analysis or domain-related support, mixed with other elements that represent generic aspects of the environment (e.g. discussion statements).

Dividing a visual language into content objects (nodes) and relation objects (edges or connections between content objects), the content objects typically contain textual information or images although many other media types are imaginable. The "meaning" or interpretation of the content of an object can generally only be derived by the system if a domain specific context is available, either predefined, as e.g. within a UML tool, or dynamically assigned by the user.

To implement our central idea – extension of co-operative visual language environments towards a flexible integration with domain content for reasons of intelligently supporting workflow management and reflection – we have identified the following challenges in terms of representation, information and interpretation:

- How can varying but domain dependent content be *represented* flexibly?
- How can a system *interpret* externally defined context information following a "plug in" approach?
- Which *levels of interpretation* are imaginable?
- Which user interfaces are appropriate to support the users' handling the *information*?
- How should an application be structured into components to reach these aims?

These questions can be broken down into two categories - the first one dealing with the meta level of the overall system structure, the second one with the micro level around the topic "representation of domain semantics in visual languages".

The main function of the system component structure is to facilitate the handling of varying visual languages. The environment is able to manage several workspaces represented in different windows. This offers the possibility to have private and shared sessions simultaneously or to clearly separate independent collaborative tasks. Each workspace can contain a number of transparent layers which can have "solid" objects like e.g. handwriting strokes or images. Similar to the workspaces, layers can be private or shared. A typical use case for this is a private handwriting layer used for personal annotations.

Example: the "probabilities" microworld

For the stochastic experiments, we implemented a new Cool Modes palette which supports the modelling of basic and extended experiments. The stochastic palette in Cool Modes allows to prepare, comment and save a model / worksheet. This means that in a way "microworlds" can be produced to be explored and enhanced by the pupils during the school lesson or at home.

A favourite choice are lotto problems. Beginning with simple problems like choosing „4 out of 6", the basic terms and models are initially developed and afterwards adopted and used in complex situations as, e.g., the setting of the German lotto "6 out of 49". The topics are dedicated to pupils at the age of 15-16 years in their 9th or 10th grade. The course and the underlying material has been planned for use in a class of 9th graders attending the Elsa-Brändström-Gymnasium, Oberhausen.

Another experiment, e.g. is the "birthday problem" (Fig. 1). An urn is filled with the 365 dates of a year. The prepared urn is offered to the pupils. One by one, the elements are drawn and put back. The sequence of the dates is not of any importance. Pupils have to perform 10 experiments and they have to determine how often the event "two or more times same birthday" occurs if you have 24 pupils in a class.

The experimental work can be arranged in small groups working in one environment or in synchronous shared environments. For the sharing of results, it is possible to exchange settings and data between the groups and help to demonstrate how a group has achieved their outcomes or conclusions, e.g. using a public workspace.

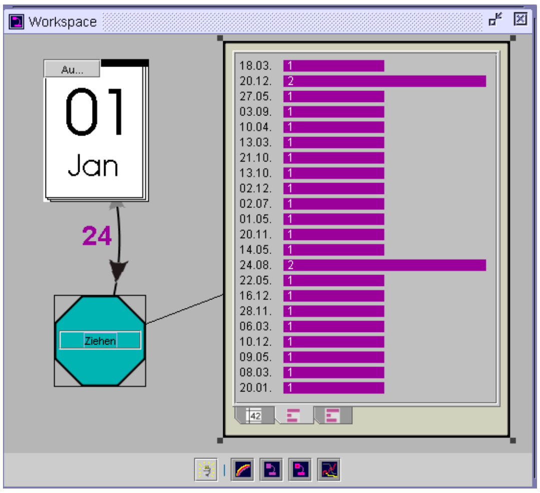

Fig. 1 "Birthday" experiment

Because of the experimental character of the lessons, the role of the teacher differs considerably from ordinary lessons. He or she has to prepare the initial problem descriptions and the specific settings in the visually orientated microworld of stochastics. Also, the teacher has to help the pupils to draw conclusions from their observations by stimulating and guiding the structuring of their ideas. These tasks are facilitated by the external visual representation in the software environment using annotation elements and free hand input.

From a more general perspective, in our stochastic environment for Cool Modes, we focus on the transformation of a concrete problem into an adequate model. The software gives the pupils opportunities to explore or create and carry out (virtual) experiments, help them to note down and organise their results, discuss and reflect their experiences to build up and formulate mathematical rules. The pedagogical innovation includes the possibility of facilitating a rich repertoire of learning styles and increasing engagement, motivation, and self-determination on the part of the students.

A similar environment has been described by Pratt [7], yet with a different focus: He has constructed a setting "in which young children articulated their meanings for chance through their attempts to mend possibly broken computer-based stochastic gadgets". Here, the computer acts "as a window on the children's internal resources for stochastic sense making". With "internal resources" he designates all forms of intuitional and formal thinking. An important question of his approach is what maximal level of performance a child's internal resources can reach with the support of computer tools, namely the possibly broken computer-based stochastic gadgets.

Perspectives for practical use

We have formed a small community of associated teachers to propagate practical use of Cool Modes and interactive presentation technologies [8] in schools. The group comprises several secondary school teachers who are interested in using modern technologies in their schools. This community primarily has the following agenda:

- A permanent feedback of teachers concerning the usability of the tools developed in Duisburg with regard to an adaptation to user needs.
- The development of concrete scenarios with regard to the use of the Cool Modes system in secondary schools.
- Teachers give lessons that are supported by the Cool Modes system. In this way an empirical base for usability evaluation of the system can be created.

Cool Modes as a tool to facilitate co-constructive activities currently includes the following palettes that can be utilised in school: a stochastic palette, a system dynamics palette, a turtle palette for learning Java and a Petri net palette that can be used in secondary school or in academic teaching in computer science. In the meetings of the teacher community, the stochastic experiment palette and the system dynamics palette have been used until now. In the discussions, the following notes were given by the teachers:

- The application of Cool Modes is suited for a structured presentation of results. An important advantage in comparison with a conventional chalkboard is the reusability of results. Furthermore, every pupil can work with his own copy and complete it as desired.
- Modelling is an important topic in natural sciences and in computer science. Conventional modelling tools do not have the possibility of a synchronous information exchange between learners and teacher. The system dynamics palette that can be used for modelling includes the possibility of a synchronous information

exchange and the integration of hand written notes. This is an advantage compared to conventional modelling tools.

A secondary school teacher is currently using this palette in connection with the topic „sustainable usage of resources“. This topic is designated for secondary school students in biology courses (12^{th} degree, 18 years old). From teachers point of view, the use of the Cool Modes system has the advantage that pupils can construct the mathematical model themselves (or in cooperation with the teacher) which leads to a better understanding of the topic. In Fig. 2 the model of a fish population is shown. This model was built up in the lessons. In Fig. 3 you see pupils constructing a system dynamics model in groups.

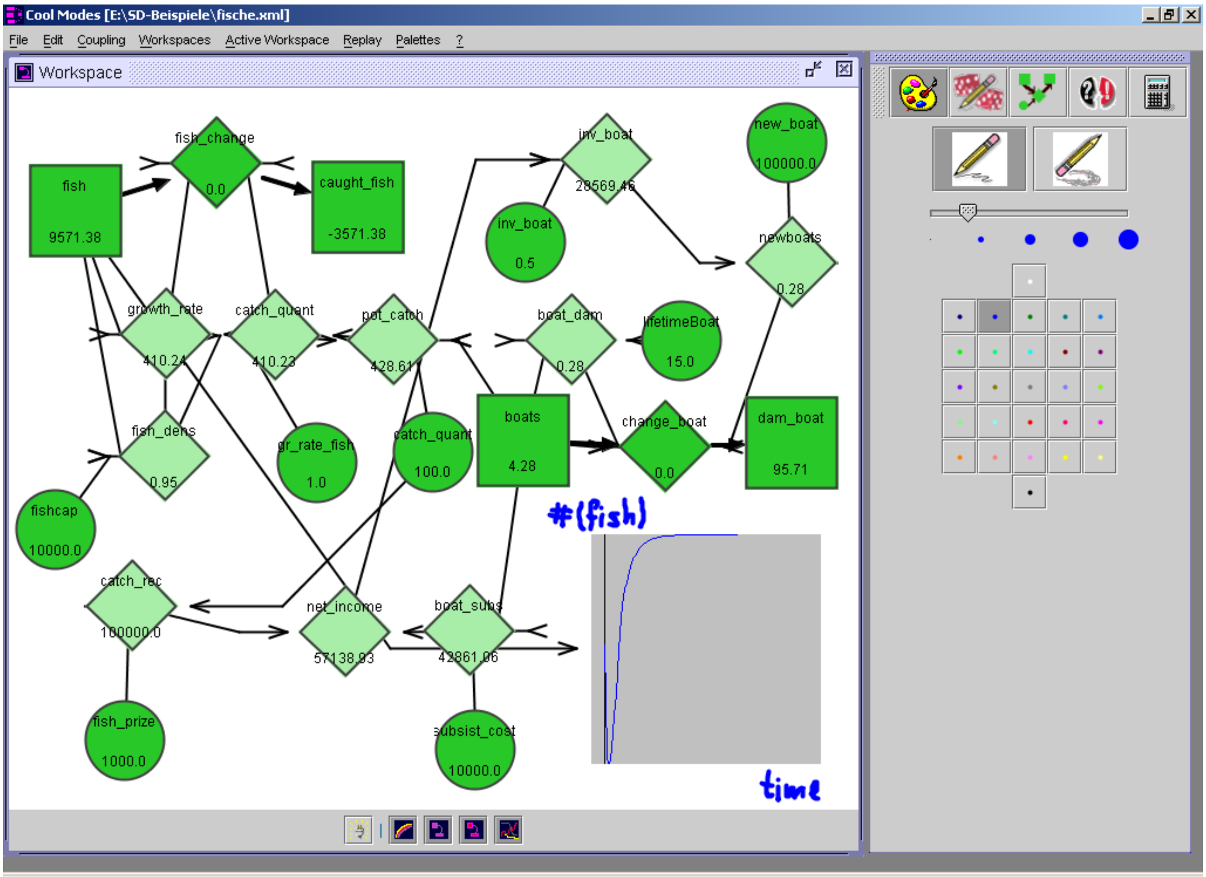

Fig. 2 Change of a fish population in conjunction with fishing rate, number of fishing boats and so on

A member of the Collide group is supporting the teacher during the lessons. This support comprises e.g. an introduction in Cool Modes and System Dynamics and a technical support.

The teacher appreciates this kind of support because it would be difficult to manage the transport and the setup of the technical equipment on his own. Concerning the appropriation of our tools by the teachers this is an important point. If there are extravagant expenses every time teachers want to use modern technologies in their schools then this will not be very motivating for them. Here for the future if will be important that schools are well equipped with necessary hardware which is easy to handle.

Fig. 3 Pupils constructing a system dynamics model

An alternative to a special computer room is the use of Cool Modes together with a notebook and a data projector in a normal classroom scenario. Pupils can alternate in creating system dynamic models and the results can be visualised for all participants in a suitable manner.

The *chemical equilibrium* is another example that can be represented by the system dynamics palette of the Cool Modes system. This topic is dedicated to pupils at the age of 17-18 years in their 11th or 12th grade. This example bases on a chemical equation of the form A→B and its reverse reaction B→A. Both processes can be expected to occur and result in an equilibrium mixture containing finite amounts of all the components of the reaction system. Teachers emphasise that the system dynamics model illustrates the following aspects that are not easy to understand without the use of a simulation: In equilibrium, the rate of reaction A→B equals the rate of the reverse reaction B→A and the concentration of reagents A and B remains constant.

Outlook

In the future other scenarios using Cool Modes are planned. So it would be motivating for pupils to learn chemical nomenclature using a Cool Modes palette. This palette could consist of several triangles containing totals formulas of chemical substances or the names of these formulas. Putting together these triangles one to another in the right manner will result to a big triangle containing small triangles in which the total formula of each side adjoins to the right formula of another triangles side. Constructing of these triangles should be realised as co-constructive activities. Of course there will be the possibility to construct other figures than triangles.

From the teacher point of view, it will be a problem to convince schools to integrate a hardware equipment needed for the ideal work with the Cool Modes System. But the system can already be used with a basic equipment (pen based input, WACOM tablet) in an effective manner.

We believe that a smooth introduction of this new technology creates new chances for pedagogical innovation and increases engagement and motivation on the part of students.

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