Dimitracopoulou, A., Fessakis, G., Melendez R, Gallego B. [2003). collaborative learning environment and Modelling Activities in primary and secondary education: The ModellingSpace Project In A. M. Vilas, J.A. M. Gonzalez, J. M. Gonzalez (Eds) Advances in Technology-Based Education: Toward a Knowledge-Based Society. II International conference on multimedia ICT's in Education, Badajoz, Spain, Dec 3-6 2003, Edition: Junta de Extremadura, Consejeria de Education, Volumes: I-III, Collection. Vol. 2, pp.: 1276-1280.

COLLABORATIVE LEARNING ENVIRONMENT AND MODELLING ACTIVITIES IN PRIMARY AND SECONDARY EDUCATION: THE MODELLINGSPACE PROJECT

A. DIMITRACOPOULOU[1], G. FESSAKIS[1], B. GALLEGO[2] & R.MELÉNDEZ[2]

Learning Technology and Educational Engineering Laboratory,Department of Education, University of the Aegean,

(1) 1, Av. Democratias, GR85100 Rhodes, GREECE.
E-mail: {adimitr, gfesakis}@rhodes.aegean.gr

(2) SchlumbergerSema, Albarracín 25, 28037 Madrid, SPAIN.
E-mail: {ruth.melendez, belen.gallego}@madrid.slb.sema.com

Faster networking technologies are allowing us to build wider and more effective communities for collaborative learning. Technology-based modelling environments have enhanced the pedagogical possibilities for learning activities. However, most of the available modelling systems usually support very specific types of modelling, and the vast majority are not appropriate for young children. MODELLINGSPACE is a project funded by the IST program of the European Commission that explores the pedagogical possibilities of modelling activities in actual schools. This paper presents some MODELLINGSPACE tools and functions, typical use-scenarios of modelling and collaborative modelling within the classroom; addressed to students 11-16 years old, as well as an outline of the main current research results.

1 Introduction

During the last years, modelling activities have become an important aspect of the curricula in European secondary education. Technology based modelling environments have enhanced the available possibilities for learning activities in schools, while networking technologies have allowed us to associate promising capabilities for collaborative learning in a wider learning community.

The possibilities offered by technology have led to the development of a number of systems that concern different kinds of modelling. Some of them are dynamic modelling systems involving mainly quantitative reasoning, such as STELLA [12] and MODELLUS [7];[13], which is appropriate for mathematical modelling in physics and other disciplines. There are four systems that support semi-quantitative reasoning: the prototypes IQON [3] and WlinkIt [9] permitting the modelling of everyday situations, the system MODEL-IT [11] dealing with ecosystems, as well as the SimQuest system and its successor Co-Lab [10]. Additionally, the modelling systems AXON [2] and INSPIRATION [5] permit the creation of concept maps, while the system WORLDMAKER [8] is a spatial distribution prototype that permits the creation of qualitative models. Only MODELLUS, STELLA, AXON and INSPIRATION can be considered nowadays as complete systems. Some of them are not appropriate for young children (e.g. STELLA & AXON). Most of these systems usually support only one type of modelling (dynamic, space distribution, logic, or qualitative), some of them focus on special domains and only one of them supports collaborative modeling (Co-Lab, which is get to be fully developed).

A new collaborative learning environment has been developed during the last few years, called MODELLINGSPACE, that is based on issues from the cognitive psychology field, sciences and mathematics education as well as recent achievements in human computer interaction. In parallel, the environment is grounded in research (in laboratory and in real school settings) that validate or improve the design choices. This paper presents an overview of MODELLINGSPACE tools and functions, elements of its architecture, and general scenarios of modelling use in classrooms. Finally, it presents an outline of main current research results.

2 What is MODELLINGSPACE and which are its specificities?

MODELLINGSPACE constitutes a complete open learning environment, for students 11-17 years old. It supports students as well as teachers during learning/teaching activities and permits them to model situations studied as part of the national curricula in Mathematics, Physics, Chemistry, Biology, Environmental Education, etc. as well as other interdisciplinary situations [4]; [6].

It enables students to create and work on different categories of models (semantic such as concept maps and logic formalisms, semiquantitative and quantitative models). In order to support them, it offers rich visualisations, real-world simulations, multiple forms of representations, metacognitive tools, collaboration-support tools, activities' meta-analysis tools, etc. The learning environment allows students not only to express, build and test their own models, but also to create models through collaboration with other students and teachers via the Internet.

The specificity of MODELLINGSPACE rises on the fact that incorporates multiple modelling modes and a wide range of entities and variables (from the most concrete to the most abstract ones), has specific tools to support not only students but also teachers during learning activities in both standalone or networking collaborative mode. Moreover, it supports various representational forms, and allows the expression through the greatest visualisation, combining the modelling tools with real world simulations (not only abstract ones).

3 MODELLINGSPACE tools and functionalities

MODELLINGSPACE is designed according to well-defined principles grounded on issues of science and mathematics education, and cognitive psychology [4]. Concerning the modelling process, the most important designed tools and underlying functionalities are the following ones:

i) The ***Study Themes Creation Tool*** contains a number of situations that are proposed for modelling, while it allows for the creation of new problems by teachers and students.

ii) The ***Models Design-Testing*** area invites students to design, test and validate models. It consists of the area where the models can be designed. It contains the design tools, the representation tools and the control tools (necessary to run the model). In order to design a model, students have to determine the model' s entities (concrete objects or abstract concepts), their properties and the relations between them. The effect of the values appears directly in a visual mode. For instance, in the semi-quantitative reasoning mode, the fact that the value of the volume (property) of the water in a barrel (entity) is high or low can be seen from the water level at a barrel's icon. The students can choose and determine the desirable relation between two properties of two entities, among the available relations of the four categories:

- *Qualitative semantic relations*: they are used to produce concept maps, which are particularly useful to present and study the relations between concepts coming from various subject matters (environmental education, physics, history, etc).
- *Semi-quantitative relations*: these relations are in terms of variation of properties' values and direction of this variation. In the current version, the student can use simple relations that correspond to simple algebraic relations, which are common in mathematics and physics as well. Each relation is represented by a symbol. For instance, the relations of analogy or inverse analogy are expressed through the reasoning "If the first entity increases, the second one might increase, decrease, or remain unchanged".
- *Quantitative simple algebraic relations*: these relations are defined by arithmetic operators (+, -, *, /,=). In a direct manner, a dialogue box permits to relate some of the entities' properties – previously defined in a model- with arithmetic operations in order to determine a quantitative algebraic relation. Additionally, students dispose two other means to explore relations between properties of entities or abstract concepts:
- *Graph based indication of co-variation:* students have the possibility to draw (through the mouse) a graph showing the co-variation between two properties, and when running it, they can see the simulation of the phenomenon. It is very useful (a) for complex models that cannot be expressed by a known mathematical relation, (b) to enhance the flexibility of students thinking on representations.
- *Table of values based indication of co-variation:* Students can insert the values of two variables that disposes (for instance from an experiment), so as to simulate the phenomenon, and then to try to explore the appropriate underlying model. This characteristic enables the user to represent data from external real experiments, and compare them with the data coming from the model, -a possible necessary step in the phase of model's validation.

Dimitracopoulou, A., Fessakis, G., Melendez R, Gallego B. [2003). collaborative learning environment and Modelling Activities in primary and secondary education: The ModellingSpace Project In A. M. Vilas, J.A. M. Gonzalez, J. M. Gonzalez (Eds) Advances in Technology-Based Education: Toward a Knowledge-Based Society. II International conference on multimedia ICT's in Education, Badajoz, Spain, Dec 3-6 2003, Edition: Junta de Extremadura, Consejeria de Education, Volumes: I-III, Collection. Vol. 2, pp.: 1276-1280.

(iii) Representation Tools (tables of data, graphs, and bar charts): Students can activate them before or after model running. The system can also count the variation of a variable between two successive instances.

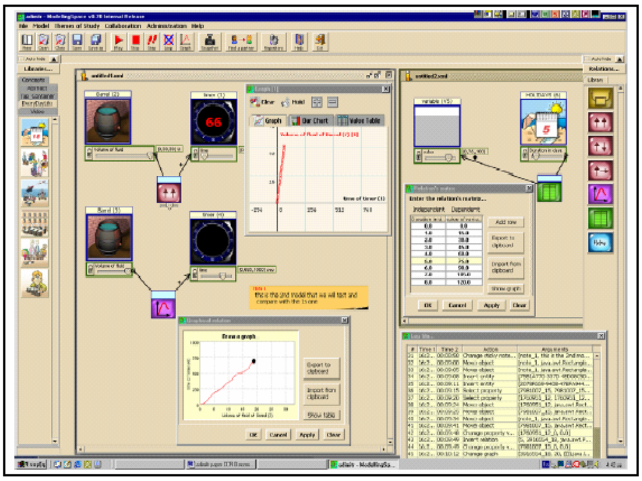

Figure 1. Tools on the model-design area of MODELLINGSPACE

(iv) Annotation tools: There are three kinds of annotation tools: a) *the sticky notes*: that can be posted in the models-design area. They consist of flexible resizable notes linked to specific positions of the space, to specific objects or to other notes. (b) *the "structured worksheets"* that stimulates students to take notes during the modelling process. It gives to students the possibility to recall these notes later, working on the model, in order to think about the evolution of their ideas. (c) *The Report*: aimed to promote reflexive modelling activity, inviting students to prepare a whole report synthesizing the previous activity. Into the report students insert 'icons' from intermediary or final models as well as data (images of graphs, of data or of simulations) that support the validation or the reject of a given model.
(v) Management tools for teachers: There are two different functionalities' categories that permit teachers correspondingly to add/delete registered students, and to allow him/her to create and insert new entities. The existing entities editor allows the creation of new entities of various kinds, extending the range of the already available phenomena or situations to model.

In order to allow and support effective communication, cooperation or collaboration, via local network or via Internet, two categories of tools and services are implemented:
(vi) Synchronous collaboration tools and functionalities, that are needed for the synchronous collaborative problem solving on modeling (usually by a small group of students):

- Two *dialogue modes* are available during synchronous collaborative activity, through: free chat dialogue, and structured one (via a specific structured chat interface)
- *Awareness of others activity* support: providing information related to other collaborators actions (e.g. that the partner is in process to write a message), and/or indicating the ownership of each contribution.
- Coordination of the shared workspace actions: Users can select to work under a specific synchronous collaboration protocol, coordinating their actions via a 'Action-key exchange' metaphor.

(vii) Community level services, that are needed to support the exchanges and the actions of a wide community of learners around common activities. We can distinguish: a) the website general level information and tools, b) the groups management tool, c) the session management tool, d) the repository of various materials (primary entities, models, problems, reports on modelling process, etc.)
(viii) Students' activity meta-analysis tool*:* that presents a Visual Historic of modeling process (a kind of playback of the modeling process). It provides a memory aid, promoting the development of metacognition.
(ix) Teachers' supervision and meta-analysis support: Three different tools support teaching process:

- *Supervision:* the corresponding tool is a viewer that allow teacher to supervise students screens when they work in a local framework, supporting also a simultaneous view of students' finals productions.
- *Modelling Process Historic:* Presents the process of individual or collaborative solution
- *Meta-analysis tools:* Presents and supports advanced analysis of students actions based on functional roles of students actions and utterances, which constitute indicators on the quality of modeling and collaboration [4].

4 Architecture elements

MODELLINGSPACE architecture [1] is based on a thick client component which contains a number of interoperable tools, as well as a server node supporting services such as management of the repositories, management of individual users and collaboration groups, assuring in parallel peer-to-peer collaboration.

Synchronous collaboration is based on a peer-to-peer communication protocol although there is a server, which supports this collaboration, as well as offers some functionalities as the management of users, schools, repositories and collaboration groups. Two different kinds of collaboration groups can be created: temporary groups and permanent ones. A temporary group is automatically created every time that a user searches another on-line student to start an on-line collaboration, whereas permanent groups are created by a teacher or an administrator for a medium term purpose and support both on-line and off-line collaboration. A teacher can create groups of different numbers of students with the purpose to work on a more complex problem. Students belonging to the same group will have access to the material created by members of this group. All the created learning materials are kept in one of the repositories at the server: the group repository that is automatically created when the group is created. Therefore there is not only one big repository where all material is kept, but on the other hand, material is organised in different kinds of repositories:

a) Personal repositories: when a new user is created in the system, a personal repository is also created for her personal use.
b) Group repositories: Only members of the group have access to the material stored in this kind of repositories. When a new group is created, a group repository is also created.
c) The Public Repository: This is the main repository of the server. All users have access to the material stored here, but only teachers are allowed to upload new material.

The server supports also peer to peer communication when users who possess different entities are collaborating on the construction of a model and one of them uses an entity that the second user does not have, and which is very big. When this happens, a process is activated in the server to update the library of the second user. It is first searched at the repositories in the server to which the user has access, and if it is found, it is added to the personal repository of the user, and it appears in the model of the second user. If the entity is not found at any of these repositories, the entity is sent directly from the user who introduced it in the model through the server. All this is made transparently to the users without needing any action from them.

5 MODELLINGSPACE typical use-scenarios within actual schools

The MODELLINGSPACE environment, taking into account the users to which it is addressed, can be used in *a school context in the following general cases:*

i. In a typical class setting, exploiting or not local network facilities. Students will work by collaborating face to face (in small groups of 2 or 3 students) on a simple or more complex problem to model
ii. In class but with global network within the whole school. Exchange ideas on problems, exchange ideas on solutions and reports, find peers for a specific problem, or classes that work on the same or similar kind of problems, etc.
iii. In class with collaboration through networks in a national, or European level: it does not concern exchanges but collaborations with a specific aim to investigate one or more specific study themes.
iv. From users homes (students' or teachers'), as supplementary of the work started in school class: we consider that in the few next years it should be possible for students to work via network from their home, in order to continue a study theme started at school. Additionally, they could have the time and

the opportunity to research the material and the experiences of other students or group in other classes, other schools or other countries.

Students could analyse a study theme, and produce a model that could be considered as:

a). *A simple model*: For instance, they could study an object moving on a inclined plan, that will need one or two sessions for young students of 13 years old, using only semiquantitative relations. Additionally, it may concerns simple models that need two or more sessions, if they have to support the transition from semiquantitative models to quantitative ones (e.g. models of simple standard types of motion).

b). *A complex model*: A complex model that incorporates many variables (e.g. in environmental education: where a group of the class will model only a part of the problem while another group will model another part. At the end, they will collaborate in order to produce a common model.

c). *A complex model with different levels of sub-models*: For instance, problems in physics incorporating different "languages": (e.g. a sub-model in terms of energy and another in terms of cinematic equations).

6 Some Research Results and Discussion

Actual research has validated some of the main features of the environment. Specifically, research results in real school contexts show that: (a) students use the modeling entities and relations and evolve themselves gradually from intuitive reasoning modes to scientific qualitative and quantitative reasoning modes, (b) 11 and 15 years old students are really motivated and able to collaborate in a national or international level offering to their teachers rich diagnostic information, (c) teachers use the students' interactions meta-analysis tools in order to diagnose the students' individual or collaborative problem solving, allowing them to adjust their teaching strategies, and then supporting their students in a more appropriate way. Additional research is actually curry out focusing in the aspects of collaboration by young students of primary school, teachers strategies during collaboration and available tools exploitation, as well as young students' metacognition development.

7 Acknowledgements

The reported work has been performed in the frame of the IST, Education & Training, School of Tomorrow Project IST-2000-25385 "ModellingSpace".

References

1. Avouris N., Margaritis, M., Komis, V. Sáez, A. & Meléndez, R (2003). ModellingSpace: Interaction design and architecture of a collaborative modelling environment. In (Ed) C. Constantinou & Z. Zacharia "Computer Based Learning in Sciences, Sixth International Conference CBLIS, 5-10 July, 2003, Nicosia, Cyprus, pp.993-1004.
2. AXON: < http://web.singnet.com.sg/~axon2000/> Referenced 10 October 2003
3. Bliss J. (1994). From Mental Models to Modelling in H. Mellar, J. Bliss, R. Boohan, J. Ogborn, C. Tompsett (Eds).*Learning with Artificial Worlds: Computer Based Modelling in the Curriculum*, The Falmer Press, London
4. Dimitracopoulou A.& Komis V. (2003). Design Principles for an Open and Wide MODELLINGSPACE for Learning, Modelling & Collaboration in Sciences and Mathematics, In (Ed) C. Constantinou & Z. Zacharia, "*Computer Based Learning in Sciences*, 6th International Conference CBLIS, 5-10 July, 2003, Nicosia, Cyprus., pp 989-992
5. INSPIRATION: < http://www.inspiration.com> . Referenced 10 October 2003
6. MODELLINGSPACE: < http://www.modellingspace.net >. Referenced 10 October 2003
7. MODELLUS: < http://phoenix.sce.fct.unl.pt/modellus >. Referenced 10 October 2003
8. Ogborn J. (1997). "WordMaker": Design Principles for an Object Oriented Modelling System accessible to Young Pupils" In *7th European Conference for Research on Learning and Instruction, EARLI*, August 26-30, 1997, Athens, Greece.
9. Sampaio, F. Ferrentini and Ogborn, J. (1996). Linkit: A Modelling Tool without Mathematics. *The Thirteenth International Conference on Technology and Education. Proceedings* Volume 1. March 17 – 20, 1996. New Orleans, Louisiana.
10. SimQuest & CoLab: <http://colab.edte.utwente.nl >. Referenced 10 October 2003
11. Soloway E., Guzdial M., Hay K.E., (1994). Learner Centred Design: The challenge for HCI in the 21st Century, *Interactions*, Vol. 1. No 2, April, pp. 36-48.

Dimitracopoulou, A., Fessakis, G., Melendez R, Gallego B. [2003). collaborative learning environment and Modelling Activities in primary and secondary education: The ModellingSpace Project In A. M. Vilas, J.A. M. Gonzalez, J. M. Gonzalez (Eds) Advances in Technology-Based Education: Toward a Knowledge-Based Society. II International conference on multimedia ICT's in Education, Badajoz, Spain, Dec 3-6 2003, Edition: Junta de Extremadura, Consejeria de Education, Volumes: I-III, Collection. Vol. 2, pp.: 1276-1280.

12. STELLA: < http://www.hps-inc.com > Referenced 10 October 2003
13. Teodoro V.D. (1997). Modellus: Using a Computational Tool to Change the Teaching and Learning of Mathematics and Science, Paper presented at the UNESCO Colloquium "*New Technologies and the Role of the Teacher*" Open University, Milton Keynes, UK, 26-29 April 1997.