FINAL REPORT. APE TRACK A, STUDY 1

Carl-Gustav Jansson and Ambjörn Naeve

Administrative overview

Experiment 2 of the initial set of SWELL experiments was named ´Content archives, student portfolios & 3D environments (APE). APE has been coordinated by Upsala Learning Lab.The work described here concerns track A:Content and Context of Mathematics in Engineering Education. That track comprises two studies:

> Study 1: Modelling of conceptual development in mathematics on the Information Technology Program at KTH.
>
> Study 2: Portfolio based reflection on the curriculum of the Media Technology Program at KTH with focus on mathematics.

The initial plan was to coordinate these two studies. This plan was not fulfilled and the studies has been carried out separately. This report does only cover study 1.

Principal Investigators:

Ambjörn Naeve, KTH (CID)

Carl Gustaf Jansson, KTH (DSV)

Other staff

Klas Karlgren, KTH	Olle Sundblad, KTH
Matthias Palmér, KTH	Mikael Nilsson, KTH
Daniel Pettersson, KTH, MSc student	Johan Olsson, KTH, MSc student
Sofia Olsson, KTH (KTH Online)	Kristina Edström, KTH (KTH Online)

International collaborative partners

Brad Osgood, Mathematics Dept. and Stanford Learning Lab, Stanford University.

David Hestenes, Physics, Arizona State University.

Project aim and goals

Important research questions in study 1 are the following. What conceptual structures in first year academic mathematics courses do the students regard as most important, and how do these structures evolve over the first academic year? How do these structures correlate with the students' perception of the most important mathematical concepts in high-school mathematics courses? On a more abstract level, study 1 focuses on the students abilities to document and reflect over their learning process, including courses and the connections between them. Will knowledge capture, organization, re-use, self-coaching and collaboration will enhance the learning experience.

"One does not understand mathematics, one gets used to it", von Neumann claimed. Students at the IT- University in Stockholm seem to have difficulties with both getting used to and with understanding certain math concepts introduced in the math courses of their engineering study programme. They also have trouble seeing the relevance of the math concepts to other subjects in their study programme. Students could, e.g., have trouble understanding concepts such as Taylor-development, multivariable functions and multivariable equations and also to see when there are, and are not, solutions to math problems. As a first step toward alleviating students' learning problems a study investigating the learning and understanding of math concepts was carried out among the students.

There is extensive research in related areas on design tasks and learning. E.g., "constructionism" – a theory of learning and a strategy for education - suggests a strong connection between design and learning (Kafai & Resnick, 1996). Related to designing conceptual models are the learning-by-design (LBD) approaches using design challenges as a pedagogical method: "Construction and trial of real devices would give students the opportunity … to test their conceptions and discover the bugs and holes in their knowledge." (Kolodner, Crismond, Gray, Holbrook, & Puntambekar, 1998). Others have studies the advantages of using specific diagrams to support conceptual learning (Oshima, Yuasa, & Oshimo, 1998).

Introducing conceptual modeling techniques and modeling tasks would be beneficial in three different ways, namely:

- that conceptual modeling would support the learning of mathematical concepts. Engaging students in modeling tasks hopefully supports learners' conceptual development by making important concept more explicit and by turning learners' attention to related concepts that they may have neglected otherwise.
- that conceptual modeling would support and encourage reflection on their learning in general, i.e., that conceptual modeling may be an efficient technique to encourage meta-cognition. Hopefully students would reflect more on the concepts and the terminology, how they are related, and maybe also about which concepts they had not yet mastered as well as why some of theses concepts were causing learning problems.
- Understanding why they have problems is the first step towards overcoming learning problems that conceptual modeling would support "transfer" of math concepts to other (computer science) subjects. Hopefully students would be supported and encouraged to reflect on how the math concepts could be relevant to other subjects.

Evaluation plan overview

Focus and general objectives	Activity	Supportive technology	Data collection	Data analysis/method	Timing
STUDY 1 Promote meta-cognition in mathematics, including own understanding, difficulty and applicability. Promote transfer.	Concept modeling exercises and knowledge management	Conzilla UML Web-support (study material and interactive exercises)	4 * 150 concept maps Observations (field notes, participant observation) Questionnaires	Content analysis Correlation analysis on individual concept submaps, students and alternative observations	Fall 2000 - Spring 2001

Goal accomplishment

After the 24 months of the study, we consider our goals to be reached. In fact, due to the tools' development (Conzilla), the archiving efforts, the conncection to the CyberMath system and the construction of the virtual mathematics exploratorium, we even consider us to have reached beyond our initial goal expectations. These results form an important part of the base for the planned continuation of our project. In fact, they have been crucial in creating a formal continuation of the project as the submodule "Personalised Mathematical Courselets" within the PADLR-project (Personalized Access to Distributed Learning Resources). Further publications based on the analysis of the empirical data will also add to the result.

Activities during January-June 2000

An overview of activities in this period is given in the following table.

Activity	Outcome/Results	Realized/Timing
Integration of the project activities within the framework of the IT program, year 1.	A positive and stable context for carrying out the study.	Spring
Seminars and conceptual modeling exercises for faculty involved in IT-program	Making the involved teachers more familiar with conceptual modeling Widening the range of the conceptual modeling exercises to include other subjects than mathematics on the IT-program. in a longer perspective.	Spring
Design of study-material for IT students	A paper on conceptual modeling of mathematical knowledge	Summer
Preparation of tasks	Short papers specifying the students tasks	Summer
Development of a lecture series	A specification to be integrated with the descriptions of the IT program curriculum	Summer
Design of evaluations for the study	Scheme of evaluations	Summer
Software development	Usability tests by the end of the summer	Summer
	Start of two masters theses	Spring
Design of interactive web-support	Conceptual modeling activities and links to suitable interactive exercises (e.g. UML Tutorial).	Summer
Dissemination and outgoing activities such as: meetings, workshops, conferences, talks, presentations etc. (see section 6 for further details)	Contacts and future collaboration opportunities	January-June

Integration of project activities within the framework of the IT program, year 1. Carl Gustaf Jansson has in dialog with the involved faculty and Ambjörn Naeve planned the study within the context of the IT program. The students will get a task split up into two parts (solutions to be submitted at the end of each term), a series of lectures integrated with the regular courses, studymaterial on modelling in general and modelling of mathematical concepts, intercative studymaterial and computerbased tools for modelling. Formally the students will get 1 credit for this course out of the 5 credits for the course Introduction to IT.

Design of a lecture series. Ambjörn Naeve, Carl Gustaf Jansson and Klas Karlgren has planned a lecture series to be integrated in the different courses of the IT program. The lectures will mostly be given by Ambjörn Naeve, but in some cases by the regular teachers.

Preparation of tasks. Carl Gustaf Jansson, Klas Karlgren and Ambjörn Naeve have designed and compiled a conceptual modeling task to be presented to IT students in the autumn and which will be the basis for their work within this study during 2000, 2001. The task should be solved in two steps (term 1 and term 2) The tasks are of three kinds, producing maps of high level conceptual maps, detailed maps on particular concepts and maps on the structure of proofs. The conceptual maps are assumed to be annotated in such a way that the students selfreflection concerning understanding, perceived difficulty and applicability is reflected. A preparatory exercise has also been produced, with the aim of training the students on modeling of the high school mathematics that is part of the curriculum during the introductory weeks.

Seminars and conceptual modeling exercises for faculty involved in IT-program. Ambjörn Naeve has on several occasions, illustrated the basic techniques of conceptual modeling in UML for the teachers involved in the IT-program at Kista, and shown examples of how this technique will be used in the mathematics courses. This has formed a good base for the current studies and created interest in widening the range of the conceptual modeling exercises to include all the different subjects on the IT-program.

Design of study-material. Ambjörn Naeve has written a study-material that presents conceptual modeling at a suitable level for this experiment. No material meeting the pedagogical requirements did exist. Apart from being a basis for this study, the produced material will have a much wider applicability.

Design of Interactive web-support. Ambjörn Naeve has together with Sofia Olsson and Kristina Edström at KTH Online developed a web-support for the conceptual modeling activities. This web support includes a UML tutorial (Interactive UML) produced by the Open Training company, some web-based animations produced within the Conzilla tool and some additional interactive exercises.

Software development involves improvements and extensions of the Conzilla tool. This work has proceeded according to plan. Mikael Nilsson has documented the code structure. Matthias Palmer has worked on aspect filtering. Richard Wessblad from DataDoktorn has worked with the the help-service system. Ambjörn Naeve have started up two master thesis projects for two KTH-students, Daniel Pettersson and Johan Olsson. These projects both represent extensions of Conzilla that will make the program more useful as an overall tool for knowledge management.

Design of an evaluation scheme for the study. Klas Karlgren has in discussion with Carl Gustaf Jansson, Ambjörn Naeve and the SWELL assessment team developed an evaluation scheme including content and correlation analysis based on results from student task, observations and input from questionnaires. An iterative revision of the evaluation scheme has been carried out as scheduled during the first half of 2000.

Activities during July-December 2000

During the fall of 2000 the 150 students of the IT program have been carrying out a conceptual modelling exercise as part of the "Intro to IT" course. The exercise is concerned with creating conceptual models based on the mathematics they have experienced in the IT-program curriculum. More specifically, three different concept maps are to be constructed: The first one should describe the overall relationships between the most important mathematical concepts that the students encounter in the mathematics courses, as well as the relationships between these concepts and their applications in other courses. The second concept map should focus on the function concept and describe the relations between the different types of functions that the students encounter in the mathematics courses, and the third concept map should describe the logical relationships between the different theorems that are presented in these courses. The conceptual maps are assumed to reflect students' understanding, perceived difficulty and applicability.

The modelling activity was initiated by a lecture on conceptual modelling in UML given by Ambjörn Naeve on September 4. As a support structure for the modelling exercise, the students have had continuous access to the modelling web site and the interactive UML course described above. The exercise stretches over the entire first year, and involves handing in two sets of these maps - one set by the end of the fall term, and a second set by the end of the spring term. The students have been allowed to work in groups of up to 4 persons.

Some minor deviations from the original plan have occurred. The modelling activities_ have been "added on" rather than integrated with the mathematics courses as originally planned. The initial plan was to collect four different versions of the concept maps. However, because of the work load involved (and the credits given) we have reduced the number of versions to two. Moreover, during the modelling process, the students requested to be allowed to work in groups of up to 4 persons. We considered this to be reasonable, especially since conceptual modelling benefits strongly from communication with others.

Implementation of interactive content and appropriate tools - Mathematical Resource Components:

1. **Constructing the components:** Using programs like Mathematica, Projective Drawing Board and the Graphing Calculator, we have constructed a number of mathematical resource components that illustrate mathematical concepts and relationships. Some of these components have been transformed into interactive web-graphics and some have also been translated into CyberMath (the shared3D interactive learning environment for mathematics that has been created as a part of the APE-track-C project).

2. **Archiving the components:** There are different ways to archive mathematical components of different kinds - including the ones described above. A newly developed test-archive which can be updated dynamically and where the components are viewable under the common browsers is available at http://www.nada.kth.se/cgi-bin/osu/dirlister2?math.

3. **Interacting with the components**: Exploring how to interact with the components, focusing on the ones constructed by using the Graphing Calculator, a program that is available today for the visual display of mathematical formulas. We have acquired 250 user licenses for the Graphing Calculator at KTH (to cover the teachers and students of the IT- and Media Technology program). The Graphing Calculator offers truly novel ways to interact with the components of a mathematics archive, where frozen animations can be downloaded and easily manipulated by users. This constitutes a very exiting graphical way of conducting mathematical discussions between the teachers and the students as well as between the students themselves. We have started to introduce this technique to some of the mathematics teachers at KTH, and we are planning to introduce it for the students of the IT-program in the spring of this year.

Activities during January-June 2001

During spring of 2001 the 150 students of the IT program continued carrying out the conceptual modeling exercise described above as part of the "Intro to IT" course. The exercise is concerned with creating conceptual models based on the mathematics they have experienced in the IT-program curriculum. More specifically, three different concept maps have been constructed: The first one describes the overall relationships between the most important mathematical concepts that the students encounter in the mathematics courses, as well as the relationships between these concepts and their applications in other courses. The second concept map focuses on the function concept and describes the relations between the different types of functions that the students encounter in the mathematics courses, and the third concept map describes the logical relationships between the different theorems that are presented in these courses. As a support structure for the modelling exercise, the students have had continuos access to the modelling web site and the interactive UML course described above. The exercise has stretched over the entire first year, and has involved handing in two sets of these maps - one set by the end of the fall term, and a second set by the end of the spring term. The students was allowed to work in groups of up to 4 persons.

Student tasks from the fall term have been collected and systematised. A systematic way to encode the structure of the large variety of types of concept maps has been developed, which will be presented in an upcoming report. This encoding will make it possible to investigate a variety of correlations between different types of conceptual representations. The maps from the fall term exercise have all been encoded in this way.

Student tasks from the spring term was collected. The work to encode of these maps in our systematic notation is started.

The implementation of interactive content and appropriate tools has continued along the lines specified above. These archives and tools will be introduced to the students on the IT-program in the fall as a part of the continuation of the APE-project within the PADLR-project.

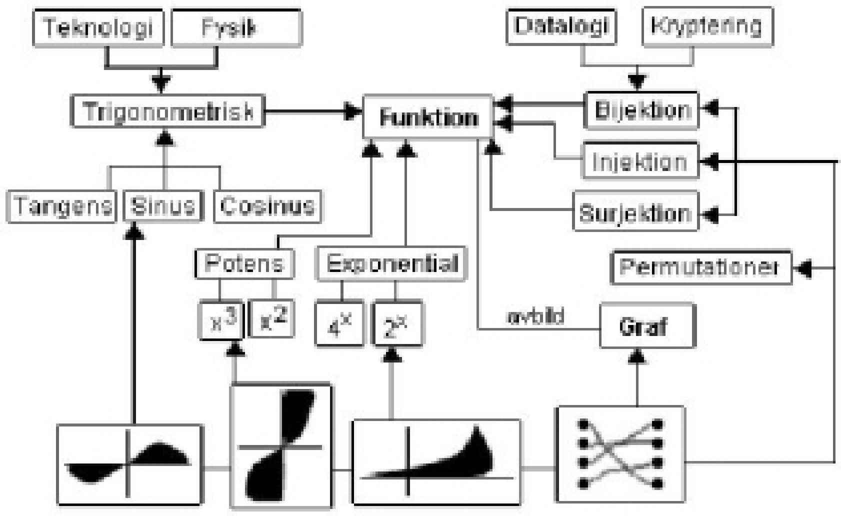


Fig. 1: A UML diagram describing the function concept drawn by a student of the IT-programme (fall 2000).

Educational evaluation/assessment results

A series of meetings with Monica Langerth of the Learning Lab assessment team was conducted. Through these meetings we did establish a strategy of applying the theory anchored evaluation model developed by Monica Langerth and Helge Strömdahl. The analytic evaluation of the students submitted conceptual graphs, will be completed with a series of deep interviews with selected students at the IT-program.

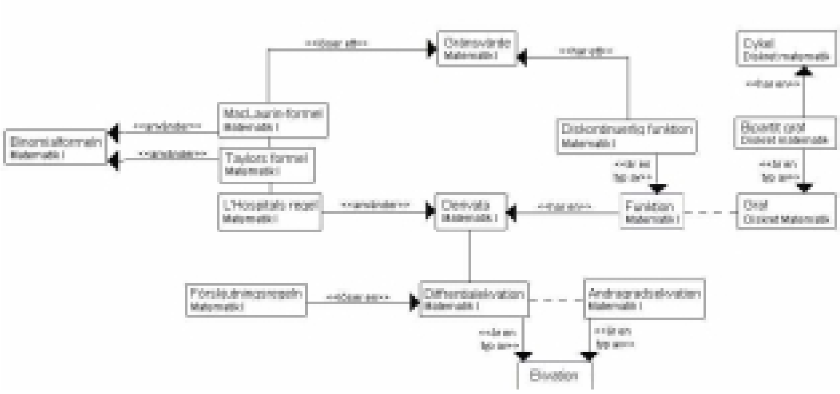
Activities during July-December 2001

During the fall of 2001 the main effort in the APE-track A project has been concerned with the following three main activities:

1. Analysing the context-maps that were collected in the mathematics modelling experiment. This work is described briefly above. A more detailed account is available in the form of a scientific publication.
2. Construction of mathematical components (joint work with APE-track C). A fuller account of this work is included as an Appendix.
3. Developing the Conzilla concept browser in a way that makes it more suitable for use within the PADLR-project – both the module 3.1 (Edutella) and the module 5.3 (Personalized Mathematical Courselets).

Analysis of conceptual graphs submitted by first year MSc students at KTH

This study is the first step towards developing and offering students support in their learning. Therefore, the goal was to investigate the learning and understanding of math concepts. 150 engineering students participated in the extensive study involving modeling tasks stretching over the entire first year of the study programme. In the fall, the students initially performed a diagnosis task investigating which concepts they viewed as the most central concepts in mathematics. During the first semester they were asked to construct graphical conceptual models describing and relating all mathematical concepts they were confronted in the study programme. Their views on the math concepts could be expressed in different ways. A Unified Modeling Language (UML) notation was preferred, but if students experienced it as too restrictive other notations were allowed, e.g., "mind maps". These models were handed in around Christmas, in December. During the spring semester students continued modeling how they viewed the math concepts as well as all new math concepts introduced in the following courses. New models were once again collected in the end of the spring semester. A typical model could look like the one below.



The students' answers to the diagnosis tasks and the two modeling tasks differ the most. The study showed that students picked up and noted a number of new concepts from the math courses which they included in their models. If the spring models are compared to the fall models a number of differences can also be observed: New concepts are added. Specifically concepts related to courses the students had attended during the spring semester. The models also become more homogeneous. Perhaps because the students discuss the models with each other, and perhaps because the students become more familiar with UML.

The table below shows the most central math concepts according to the students, at three different occasions during their study programme; when initially enrolling in the study programme, after one study semester, and after an entire study year. The lists are based on the number of diagnoses and models in which each concept occurs.

Concepts after one semester	Concepts after one year
Funktion	Vektor
Derivata	Matriser
Gränsvärde	Gränsvärde
Polynom	Determinant
Komplext tal	Derivata
Differentialekvation	Partiell/partialderivata
Felrättande koder	Funktion
Homogena (ekvationer)	Jacobimatris
Inhomogena ((diff-)ekv)	Skalärprodukt
Bipartit (graf)	Polynom

In the last model students typically add new concepts from newly attended math courses (e.g., *kedjeregeln, flervariabel, integral, extremproblem…*) to the earlier model. Often students also developed and elaborated on a concept that had previously been included in a model.

Rather often, however, students construct an entirely new model which do not include any parts of their previous models even though much work was put into these. In many cases students seemed to presuppose the parts not mentioned. Perhaps the parts were left out to save the effort of relating these to new concepts in their new models. Another plausible interpretation is that the connection between courses is not clear enough and concern uses of the certain concepts (e.g., function) which do not overlap thereby making it difficult for students to relate the different uses of the concept in their conceptual models. These connections between courses should perhaps be made clearer and more explicit for the students. Further analysis of the extensive data resulting from this study is on-going with a special focus on the relationships between the different concepts and how these developed.

A more extensive description of the study can be found in the article ´Conceptual Modeling as a Metacognitive Tool for Learning Math Concepts´, Karlgren, Naeve and Jansson, to be submitted to *e-Learn 2002* (*the World Conference on E-Learning in Corporate, Government, Healthcare, & Higher Education)*, October 15 - 19, 2002, Montreal, Canada).

Creation of mathematical content

In parallel with the work of APE-track C, a large number of mathematical structures have been visualized using special tools such as Mathematica and the Graphing Calulator. These components include material from the basic courses in Linear Algebra, Differential and Integral Calculus of one and several variables, Differential equations, Fourier Analysis and Differential Geometry. They are presently being integrated in the Conzilla-based mathematics exploratorium described below.

During the duration of the APE-project, we have been using Conzilla to build a virtual mathematics exploratorium, which makes it possible to navigate a mathematical knowledge manifold and explore its content in various ways. This exploratorium is available on the net by downloading the Conzilla program [**http://conzilla.sourceforge.net**]. During the fall of

2001, we have recorded an entire lecture series on the history of ideas in mathematics, which will be available as streaming video content components in the exploratorium. In the near future, this exploratorium will be offered to students as a way to support the traditional mathematics education and (hopefully) serve as a way to stimulate interest and motivate further studies within the field of mathematics.

Extensions of the Conzilla program

Some of the major issues deemed to be strategically important have been to refactor the code of Conzilla so that it can be used both as a standalone application and together with ontology construction tools such as e.g. Protegé [**http://protege.stanford.edu**]. On the basis of the refactored code, we have developed an applet version of Conzilla - which means that context-maps can be navigated in an ordinary web browser - as well as RDF backend [**www.w3.org/RDF**], which will serve as a basis for the ongoing adaptation of Conzilla to the information standards of the emerging next generation of the Internet, the so called Semantic Web [**www.SemanticWeb.org**], [Berners-Lee et.al., 2001], [Nilsson, Palmér, Naeve, 2002]. The RDF backend will also enable the use of Conzilla as a presentational tool and a graphical query interface on top of the Edutella infrastructure mentioned above [Nejdl et.al., 2002].

Closely related to the refactoring work has been the necessary modularization of Conzilla. In this phase Conzilla has been divided and separated so that parts can be exchanged and excluded if needed. For instance the frame based appearance has been changed into a dynamic solution with ViewManagers that now includes the old frame-view, internal-frame-view, tabbed-view and single pane-view, which greatly facilitates the simultaneous presentation of different context-maps as well as the semantic connections between them. This has been used for developing the basic Protegé-Conzilla connection. The menu system has been reworked in order to support modular design allowing modules and plug-ins to add menus everywhere.

A better configuration system for modules as well as cleaner interfaces between them have been developed. Hence the former modular system has been turned into a full fledged plugin-system greatly easing the pain later when designing specific functionality.

The Graphical User Interface, has been greatly improved reflecting the changes above. As an example, it is now possible to use curved lines (cubic B-splines) in connecting the concepts, which greatly improves the possibility to design intelligible context-maps.

Conzilla has been made into a tab-plug-in under Protegé. This has included a wrapper to their knowledge base API (based on their OKBC standard). Some simple layout code has been written for further adaptation to GraphViz. Several issues remain to be resolved: roundtrip, project management in Protegé should be matched to some similar solution in Conzilla, namespaces in Protegé need further investigation, etc.

Presentations and Publications

Presentations

Visit to Stanford and Arizona State University (March 9-29, 2000)
Participation in SIGGRAPH 2000 (July 2000)
Presentation for the KK-foundation and the Swedish School Board (Skolverket) at Levintelligence (Feb 1, 2000)
Presentation for Teachers at KTH at Dept of Didactics at KTH (April 4, 2000).
Presentation for Mathematics teachers from Kista (secondary school level) at CID (April 12, 2000).
Presentation at the inauguration of Uppsala Learning lab (May 25, 2000).
Presentation for 150 science and technology teachers at KTH (May, 2000).
Presentation for Human Machine Interaction graduate students at KTH (May 26, 2000).
Presentations at two planning workshops for the IT program (Kämpasten March 7-8 and Hässelby May 9 – 10, 2000)
Presentation at the SweLL Evaluation meeting (May 9 and 10, 2000)

The Conzilla program was presented in Washington DC on October 28 at the CILT-2000 learning conference (www.cilt.org/cilt2000) arranged by the Center for Innovative Learning Technologies. A report from this conference - in power point format - can be found on http://www.learninglab.kth.se/library/presentations.

KTH Learning Lab, seminar 10/1 - 2001
Uppsala Learning Lab, seminar 21/3 - 2001
International Conference on open learning and Distance Education (ICDE) Düsseldorf, 3/4 - 2001.
Högskolan i Gövik, Norway, tele-presence mediated presentation, 3/5 – 2001.
Luleå Technical University, seminar on mathematical didactics, 7/5 – 2001.
Mitthögskolan Östersund, e-Learning conference, 16/5-2001.
WGLN workshop on performance learning, KTH, 18/6 - 2001
SIGGRAPH-2001, Los Angeles, USA, Aug12-17, 2001.
8:th Conference on Advanced Computer Systems (ACS-2001), Mielno, Poland, Oct17-19, 2001.
2:nd european web-based e-learning conference (WBLE), Lund, 24-26/10 - 2001.
Invited talks by Ambjörn Naeve at Umeå universitet, Sept 21, 2001, Ingenjörsskolan KTH-Haninge (KTH), Oct 23, 2001, Högskolan i Kalmar, Oct 30, 2001 and at Riksutställningar, Dec 7, 2001.
Swedish Educational Television (UR) visits CID , Dec 13, 2001
Swedish National Board of Education (Skolverket) visits CID, Dec 14, 2001
National Centre for Flexible Learning (CFL) visits CID, Dec 14, 2001
The CyberMath system was presented to 200 high school students during the Kowalewski mathematics days held at KTH on Nov, 9-10.

Publications

Karlgren, K., Naeve, A. and Jansson, C-G , *Conceptual Modeling as a Metacognitive Tool for Learning Math Concepts* , to be submitted to *e-Learn 2002* (*the World Conference on E-Learning in Corporate, Government, Healthcare, & Higher Education)*, October 15 - 19, 2002, Montreal, Canada.

Naeve, A. (2001a) *Begreppsmodellering och matematik*, CID-109, TRITA-NA-D0103, Department of Numerical Analysis and Computer Science, KTH, Stockholm, 2001, http://kmr.nada.kth.se/papers/MathematicsEducation/cid_109.pdf.

Naeve, A. (2001d) *The Concept Browser - a New Form of Knowledge Management Tool*, Proceedings of the 2nd European Web-Based Learning Environment Conference (WBLE 2001), Lund, Sweden, Oct. 24-26, 2001, http://kmr.nada.kth.se/papers/ConceptualBrowsing/ConceptBrowser.pdf.

Nilsson, M. & Palmér, M. (1999) *Conzilla - Towards a Concept Browser*, CID-53, TRITA-NA-D9911, KTH, 1999, http://kmr.nada.kth.se/papers/ConceptualBrowsing/cid_53.pdf.

Nilsson, M. (2000), *The Conzilla Design - The Definitive Reference*, CID/NADA/KTH, 2000, http://kmr.nada.kth.se/papers/ConceptualBrowsing/conzilla-design.pdf.

Palmér, M., Naeve, A., Nilsson, M. (2001) *E-learning in the Semantic Age*, Proc. of the 2nd European Web-based Learning Environments Conference (WBLE 2001), Lund, Sweden, Oct. 24-26, 2001, http://kmr.nada.kth.se/papers/SemanticWeb/e-Learning-in-The-SA.pdf.

APPENDIX

Development of Mathematical Content and the Conzilla tool

Ambjörn Naeve

CID, KTH

Background

Traditional educational architectures are teacher-centric and founded in curricular-based knowledge pushing. As described in [Naeve, 1997] [Naeve, 1999b] and [Naeve 2001c], the Knowledge Management Research group at CID [http://kmr.nada.kth.se] has developed a learner-centric educational architecture called a *knowledge manifold*, which supports knowledge-pulling based on interest. A knowledge manifold can be described as a kind of patchwork, consisting of a number of linked *knowledge patches*, each maintained by a *knowledge gardener*. A knowledge patch is constructed from *context maps*, whose concepts are filled with *content components*, which are designed with the overall aim to separate content from context by making use of *multiple narration* techniques.

The knowledge manifold architecture is based on the following fundamental principles:

- Nobody can teach you anything. A good teacher can inspire you to learn.
- Your learning motivation is based on the experience of subject excitement and faith in your learning capacity from live teachers.
- Your learning is enhanced by taking control of your own learning process.
- No 'problematic' questions can be answered in an automated way. In fact, it is precisely when your questions break the pre-programmed structure that the deeper part of your learning process begins.
- Respect for ignorance, which is of fundamental importance in a non-elitist knowledge society, can only be upheld when the ignorant person is uneducated[1].

In order to support the knowledge manifold architecture, the KMR-group is developing a set of tools. This set includes a *concept-browser,* which is a new kind of knowledge management tool designed in accordance with a set of principles that are laid down and discussed in detail in [Naeve, 1999b] and [Naeve, 2001d]. These principles include a strict separation of *context* and *content*, contextual descriptions in terms of a collection of semantically visual context maps, which can be navigated by moving through *contextual neighborhoods*, presentation of the content components through context-dependent *aspect-filters*, and *contextualization* of content components that are themselves context maps.

During the last 3 years the KMR-group at CID has developed a first prototype of concept browser called *Conzilla* [Nilsson & Palmér, 1999], [Nilsson, 2000]. It has the potential of being useful within the fields of *e-learning*, *e-commerce* and *e-administration*, and the KMR-group is presently participating in national- and international collaborations within all these fields. For more details on these projects, see http://kmr.nada.kth.se. Within the newly started WGLN-supported PADLR-project, Conzilla will be used both as an interface to the Edutella system constructed within PADLR-module 3.1 and as a tool for the creation of personalized mathematical courselets (PADLR-module 5.3).

[1] The term "educated" is being used here in the formal sense, meaning "graduated from an educational system".

Extensions of the Conzilla program during July-Dec 2001

Some of the major issues deemed to be strategically important have been to refactor the code of Conzilla so that it can be used both as a standalone application and together with ontology construction tools such as e.g. Protegé [http://protege.stanford.edu]. On the basis of the refactored code, we have developed an applet version of Conzilla - which means that context-maps can be navigated in an ordinary web browser - as well as RDF backend [www.w3.org/RDF], which will serve as a basis for the ongoing adaptation of Conzilla to the information standards of the emerging next generation of the Internet, the so called Semantic Web [www.SemanticWeb.org], [Berners-Lee et.al., 2001], [Nilsson, Palmér, Naeve, 2002]. The RDF backend will also enable the use of Conzilla as a presentational tool and a graphical query interface on top of the Edutella infrastructure mentioned above [Nejdl et.al., 2002].

Closely related to the refactoring work has been the necessary modularization of Conzilla. In this phase Conzilla has been divided and separated so that parts can be exchanged and excluded if needed. For instance the frame based apperance has been changed into a dynamic solution with ViewManagers that now includes the old frame-view, internal-frame-view, tabbed-view and single pane-view, which greatly facilitates the simultaneous presentation of different context-maps as well as the semantic connections between them. This has been used for developing the basic Protegé-Conzilla connection. The menu system has been reworked in order to support modular design allowing modules and plugins to add menus everywhere.

A better configuration system for modules as well as cleaner interfaces between them have been developed. Hence the former modular system has been turned into a full fledged plugin-system greatly easing the pain later when designing specific functionality.

The Graphical User Interface, has been greatly improved reflecting the changes above. As an example, it is now possible to use curved lines (cubic B-splines) in connecting the concepts, which greatly improves the possibility to design intelligible context-maps.

Conzilla has been made into a tab-plugin under Protegé. This has included a wrapper to their knowledge base API (based on their OKBC standard). Some simple layout code has been written for further adaptation to GraphViz. Several issues remain to be resolved: roundtrip, project managment in Protegé should be matched to some similiar solution in Conzilla, namespaces in Protegé need further investigation, etc.

Creation of mathematical content

In parallel with the work of APE-track C, a large number of mathematical structures have been visualized using special tools such as Mathematica and the Graphing Calulator. These components include material from the basic courses in Linear Algebra, Differential and Integral Calculus of one and several variables, Differential equations, Fourier Analysis and Differential Geometry. They are presently being integrated in the Conzilla-based mathematics exploratorium described below.

During the fall of 2001, Conzilla has also been connected to the CyberMath system developed with partial support from WGLN in the project APE-track C. This connection is reported in the APE-track C scientific progress report for July-Dec 2001.

The virtual mathematics exploratorium

During the duration of the APE-project, we have been using Conzilla to build a virtual mathematics exploratorium, which makes it possible to navigate a mathematical knowledge manifold and explore its content in various ways. This exploratorium is available on the net by downloading the Conzilla program [http://conzilla.sourceforge.net]. During the fall of 2001, we have recorded an entire lecture series on the history of ideas in mathematics, which will be available as streaming video content components in the exploratorium. In the near future, this exploratorium will be offered to students as a way to support the traditional mathematics education and (hopefully) serve as a way to stimulate interest and motivate further studies within the field of mathematics.

What follows below is a series of snapshots of a "walk-through" of part of the exploratorium. Although the pictures are chosen to try to convey an impression of what it is like to navigate a knowledge manifold with Conzilla, they cannot convey the dynamic aspects of such an experience. Downloading the program and trying it out for yourself is the only way to do that.

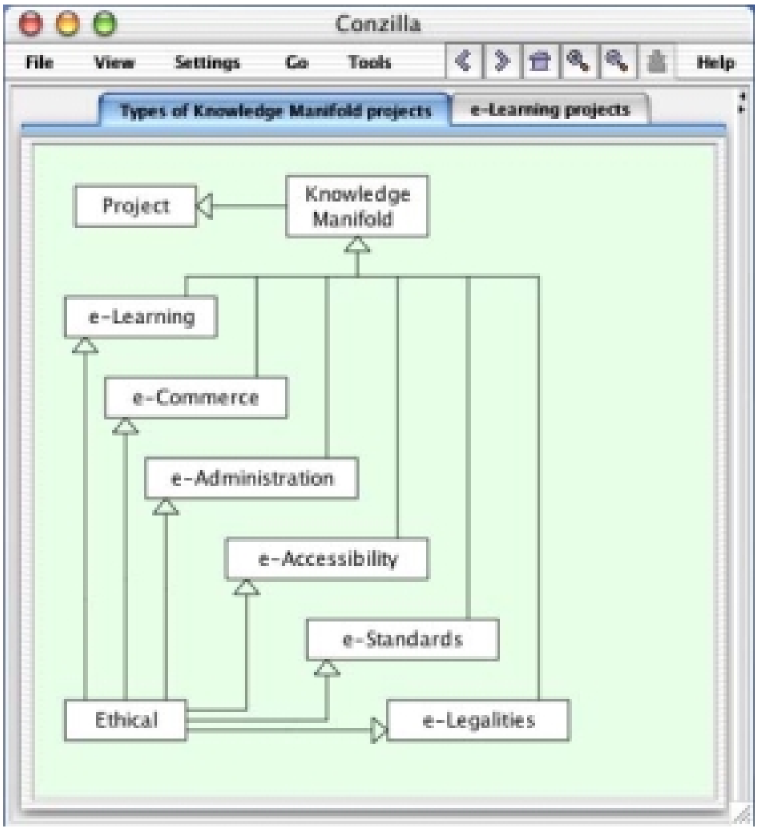


Figure 1. This is a context-map showing the different types of knowledge manifolds that are presently being developed by the KMR-group at CID. The language used for the context-map is a dialect of UML [http://www.uml.org] called ULM (Unified Language Modeling), which is designed to visually depict how we talk about things. ULM is described in [Naeve, 1999b] and [Naeve, 2001d].

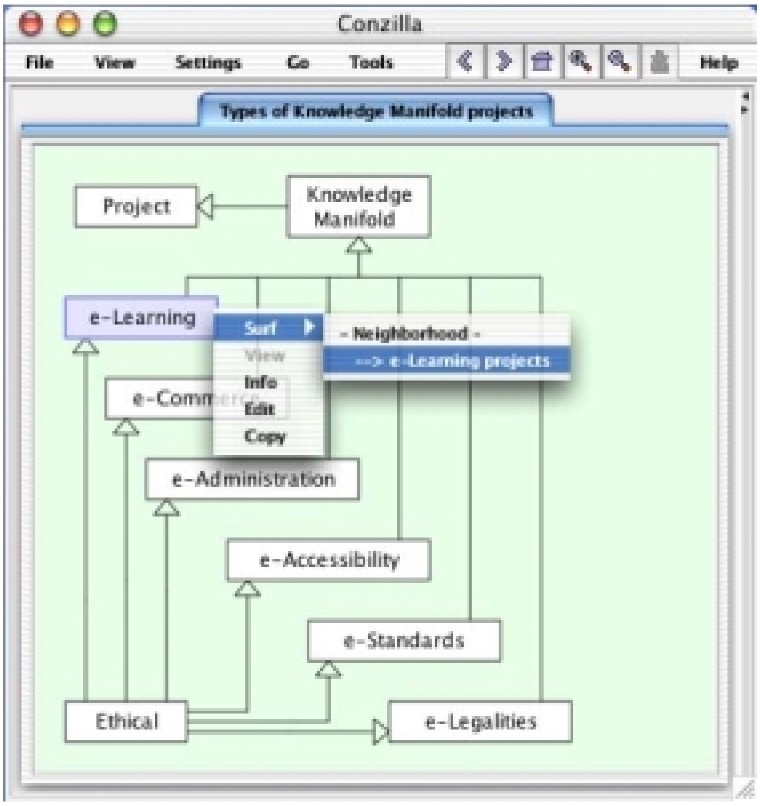


Figure 2. Right-clicking the concept e-Learning brings up the main navigation menu. Choosing **Surf** brings up a sub-menu showing the contextual neighborhood of the e-Learning concept, which is all the different context-maps where the concept e-Learning appears. In this case there is only one more context-map, namely the one titled e-Learning projects. Choosing this entry from the **Neighborhood** menu brings up the corresponding context-map, shown in Figure 3.

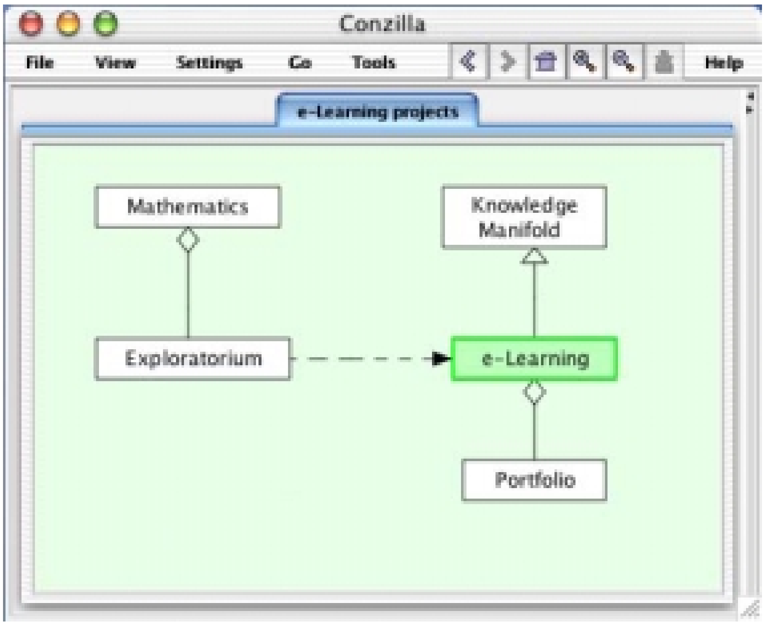


Figure 3. Since we have entered the e-Learning projects context-map through the e-Learning concept, this concept is shown highlighted (in green) when we enter this context-map. The highlighting remains until we click (anywhere) in the map. This is a feature of Conzilla that has been added during the fall of 2001. It is very useful in supporting the “cognitive connection” between the different context-maps.

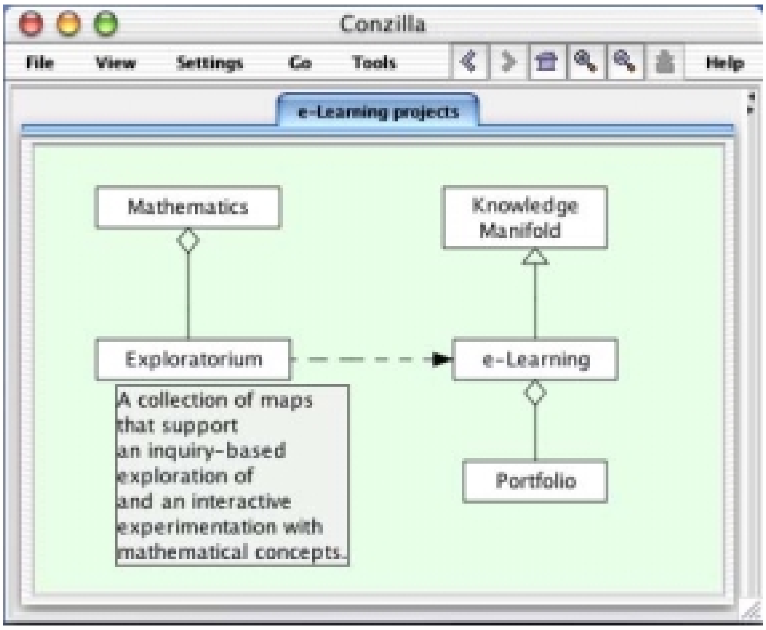


Figure 4. Pointing to the Exploratorium concept and hitting <space-bar> brings up information (meta-data) about this concept. Conzilla has a meta-data editor called *ImseVimse* [http://imsevimse.sourceforge.net] that supports full IMS [http://imsproject.org/metadata].

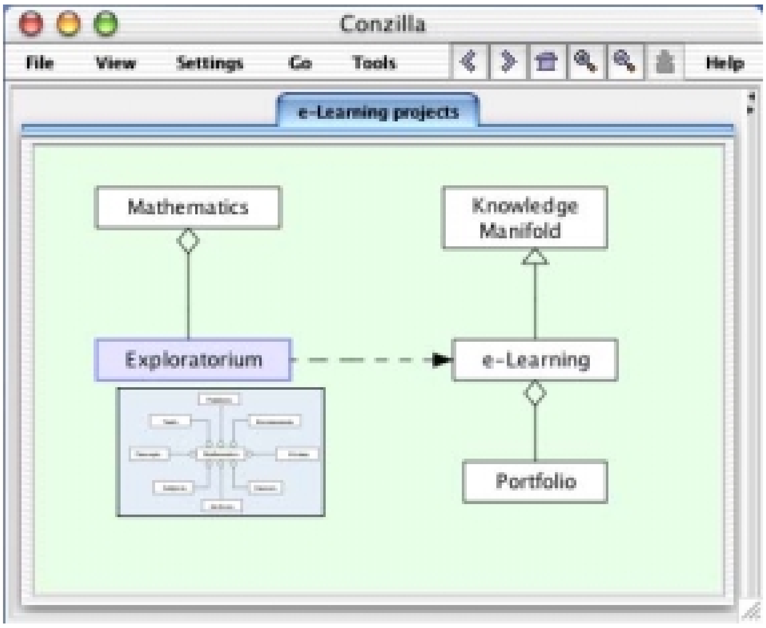


Figure 5. Hitting <escape> closes the meta-data window. Left-clicking the Exploratorium concept brings up an iconized version of the detailed map connected to this concept without changing the context. This is another feature that supports cognitive connection between the different contexts, since it allows a preview of another context without committing to it. Double-clicking the Exploratorium concept changes the context and brings up the context-map whose icon was displayed in the preview mode.

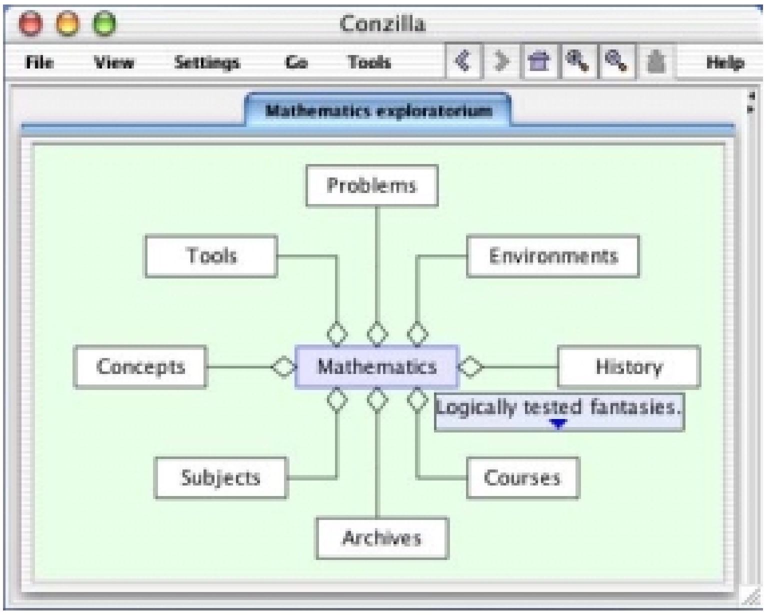


Figure 6. Pointing to the Mathematics concept and hitting <space-bar> brings up meta-data on mathematics. The arrow at the bottom of the meta-data window indicates that there is more information below

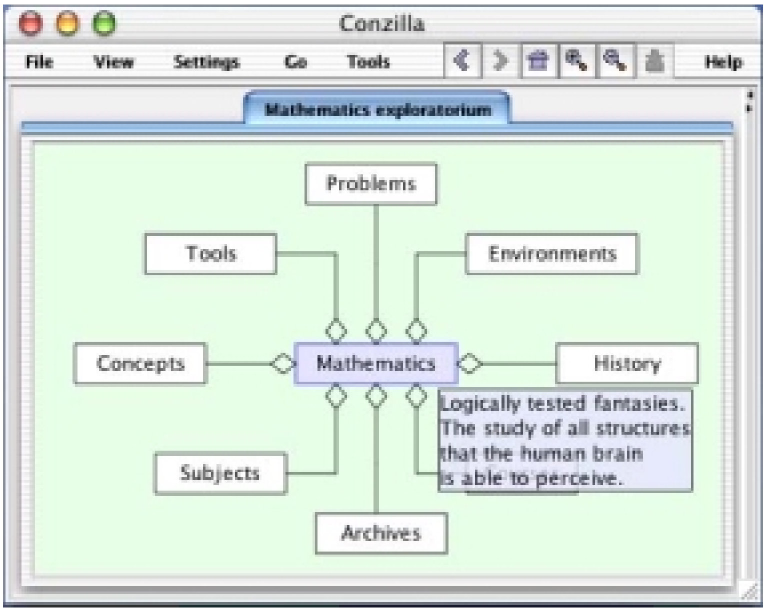


Figure 7. Hitting option-space-bar expands the meta-data window and shows the full information text. Hitting only space-bar (without the option) would have shown only the second part of the information text. In this way it is possible to browse through a lists of entries, leaving only the relevant parts on the screen.

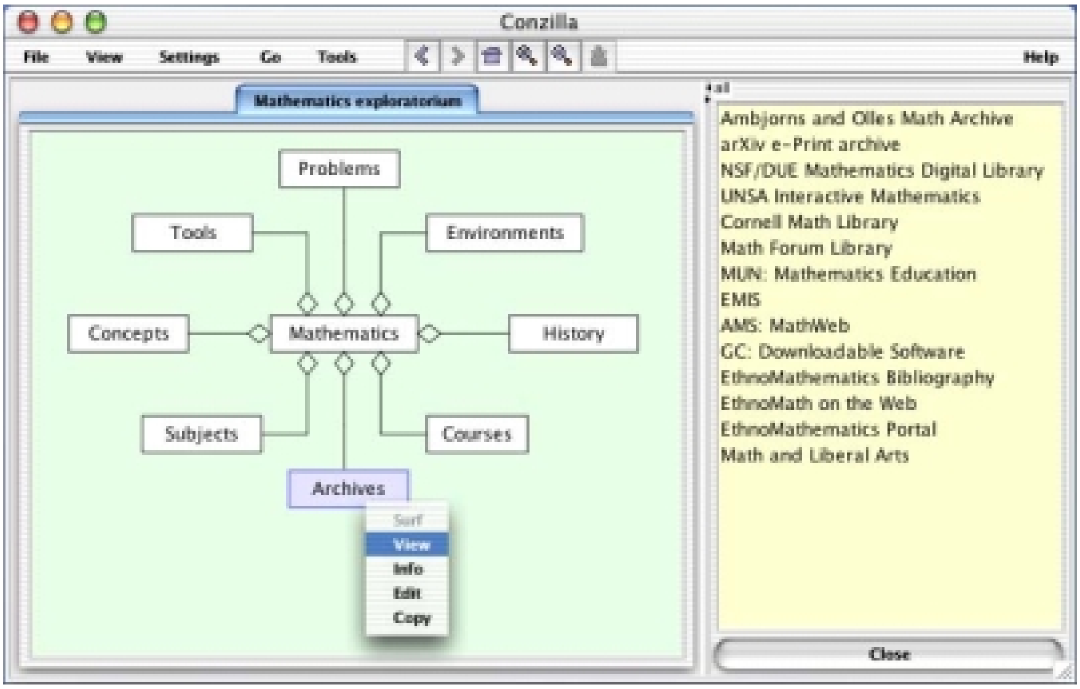


Figure 8. Right-clicking on Archives brings up the main navigation menu. Choosing **View** from this menu brings up the content window on the right. This window shows a list of content components. Double-clicking one of them will display its content in an ordinary web browser (such as Explorer or Netscape).

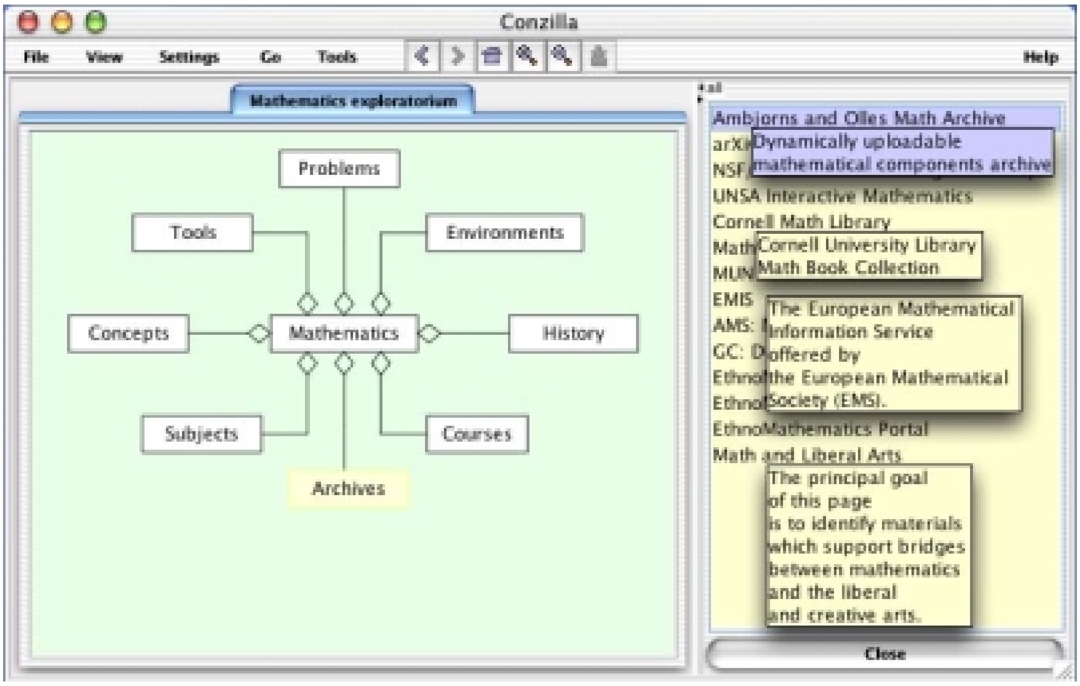


Figure 9. The content components also carry information (meta-data), which can be brought up by clicking their names and hitting <space-bar>. Notice that several pieces of such information can be visible in parallel. The figure shows meta-data about Ambjorns and Olles Math Archive, Cornell Math Library, EMIS and Math and Liberal Art. Notice also that the concept Archives, whose content components we are inspecting, is shown in the same color as the content window. This supports the cognitive connection between *context* and *content*.

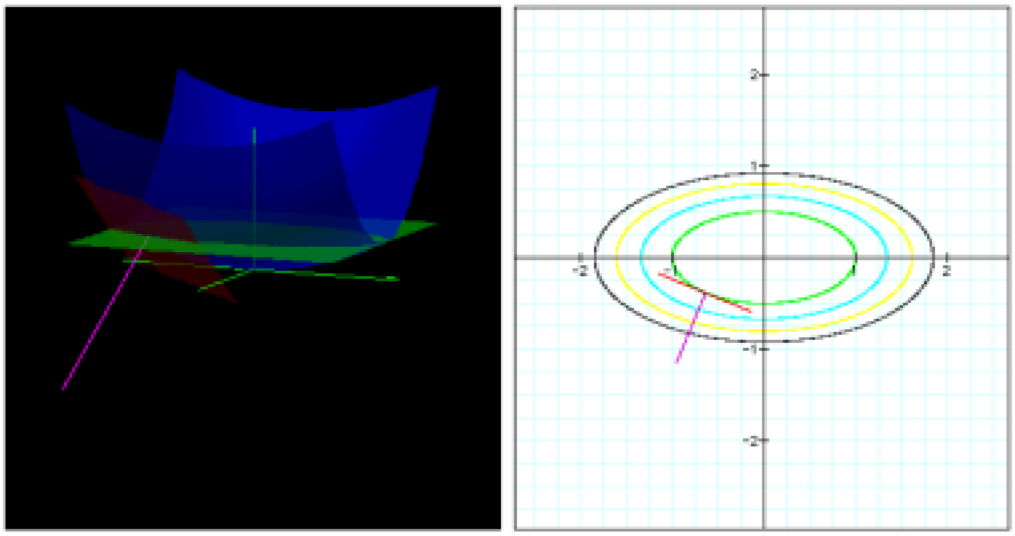


Figure 10. Clicking Ambjorns and Olles Math Archive, and navigating to Differential and Integral calculus / Several Variables / Gradients, displays an entry called FlyingCarpetSurfaceGradient.mov (not shown in the figure). Clicking it will display a Quicktime movie in the web browser of your choice. However, dragging the icon of the movie to the Graphing Calulator and dropping it there will invoke the mathematics behind the movie, making it amenable to parametric changes. The figure shows the graphing calculator window after dropping the movie in it.

References

Berners-Lee, T. & Hendler, J. & Lassila, O. (2001) *The Semantic Web*, Scientific American, May 2001, www.scientificamerican.com/2001/0501issue/0501berners-lee.html.

Knudsen, C., Naeve, A. (2001), *Presence Production in a Distributed Shared Virtual Environment for Exploring Mathematics*, Proceedings of the 8th International Conference on Advanced Computer Systems (ACS 2001), Szcecin, Poland.
http://kmr.nada.kth.se/papers/TelePresence/CJKPresenceProd.pdf.

Naeve, A. (1997) *The Garden of Knowledge as a Knowledge Manifold - a Conceptual Framework for Computer Supported Subjective Education*, CID-17, TRITA-NA-D9708, Department of Numerical Analysis and Computer Science, KTH, Stockholm, 1997,
http://kmr.nada.kth.se/papers/KnowledgeManifolds/cid_17.pdf.

Naeve, A. (1999a), *IT-baserade matematikverktyg på KTH*, CID-49, TRITA-NA-D0103, Department of Numerical Analysis and Computer Science, KTH, Stockholm, 1999,
http://kmr.nada.kth.se/papers/MathematicsEducation/cid_49.pdf.

Naeve, A. (1999b) *Conceptual Navigation and Multiple Scale Narration in a Knowledge Manifold,* CID-52, TRITA-NA-D9910, Department of Numerical Analysis and Computing Science, KTH, 1999,
http://kmr.nada.kth.se/papers/ConceptualBrowsing/cid_52.pdf.

Naeve, A. (1999c) *Det Virtuella Matematikexploratoriet-en översikt*, CID/NADA/KTH, 1999,
http://kmr.nada.kth.se/papers/MathematicsEducation/VirtualMathExploratorium/Exploratorium.pdf.

Naeve, A. (1999d) *Matemagiprojektet - en översikt*, CID/NADA/KTH, 1999,
http://kmr.nada.kth.se/papers/MathematicsEducation/Matemagi/Matemagi.pdf.

Naeve, A. (2001a) *Begreppsmodellering och matematik*, CID-109, TRITA-NA-D0103, Department of Numerical Analysis and Computer Science, KTH, Stockholm, 2001, http://kmr.nada.kth.se/papers/MathematicsEducation/cid_109.pdf.

Naeve, A. (2001b) *The Work of Ambjörn Naeve within the Field of Mathematics Educational Reform*, CID-110, TRITA-NA-D0104, KTH, Stockholm, 2001, http://kmr.nada.kth.se/papers/MathematicsEducation/mathematics_educational_reform.pdf.

Naeve, A. (2001c) *The Knowledge Manifold - an Educational Architecture that supports Inquiry-Based Customizable Forms of E-Learning*, Proc. of the 2nd European Web-Based Learning Environment Conference (WBLE 2001), Lund, Sweden, Oct. 24-26, 2001, http://kmr.nada.kth.se/papers/KnowledgeManifolds/KnowledgeManifold.pdf.

Naeve, A. (2001d) *The Concept Browser - a New Form of Knowledge Management Tool*, Proceedings of the 2nd European Web-Based Learning Environment Conference (WBLE 2001), Lund, Sweden, Oct. 24-26, 2001, http://kmr.nada.kth.se/papers/ConceptualBrowsing/ConceptBrowser.pdf.

Naeve, A., Nilsson, M., Palmér, M. (2001), *The Conceptual Web - our Research Vision*, Proc. of the First Semantic Web Working Symposium, Stanford University, July 30 – Aug 1, 2001, http://kmr.nada.kth.se/papers/SemanticWeb/pospaper.pdf.

Nejdl, W., Wolf, B., Qu, C., Decker, S., Sintek, M., Naeve, A., Nilsson, M., Palmér, M, Risch, T. (2002) *Edutella – a P2P Networking Infrastructure Based on RDF*, Accepted for presentation at the 11:th International World Wide Web Conference (WWW-2002) in Honolulu, Hawaii, May 7-11, 2002.

Nilsson, M. & Palmér, M. (1999) *Conzilla - Towards a Concept Browser*, CID-53, TRITA-NA-D9911, KTH, 1999, http://kmr.nada.kth.se/papers/ConceptualBrowsing/cid_53.pdf.

Nilsson, M. (2000), *The Conzilla Design - The Definitive Reference*, CID/NADA/KTH, 2000, http://kmr.nada.kth.se/papers/ConceptualBrowsing/conzilla-design.pdf.

Nilsson, M. (2001), *The Semantic Web: How RDF will change learning technology standards*, Feature article, Centre for Educational Technology Interoperability Standards (CETIS), 2001, http://kmr.nada.kth.se/papers/SemanticWeb/CETISSemWeb.pdf.

Nilsson, M. et al. (2001) *IMS meta-data 1.2 RDF binding*, Appendix to the IMS 1.2 metadata binding specification, IMS, 2001, http://www.imsglobal.org/rdf/index.html.

Nilsson, M., Palmér, M., Naeve, A. (2002) *Architectural Guidelines for Semantic Web Meta-data – Lessons from E-Learning,* Accepted for presentation at the 11:th International World Wide Web Conference (WWW-2002) in Honolulu, Hawaii, May 7-11, 2002.

Palmér, M., Naeve, A., Nilsson, M. (2001) *E-learning in the Semantic Age*, Proc. of the 2nd European Web-based Learning Environments Conference (WBLE 2001), Lund, Sweden, Oct. 24-26, 2001, http://kmr.nada.kth.se/papers/SemanticWeb/e-Learning-in-The-SA.pdf.

Wilson, S. (2001) *The Next Wave: CETIS interviews Mikael Nilsson about the Edutella project*, Feature article, Centre for Educational Technology Interoperability Standards (CETIS), Sept, 2001, http://kmr.nada.kth.se/papers/SemanticWeb/TheNextWave.pdf.