KUNGL TEKNISKA HÖGSKOLAN
Royal Institute of Technology
Numerical Analysis and Computing Science

TRITA-NA-D9910 • CID-52, KTH, Stockholm, Sweden 1999

Conceptual Navigation and Multiple Scale Narration in a Knowledge Manifold

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Report number: TRITA-NA-D9910, CID-52
ISSN number: ISSN 1403-073X
Publication date: August 1999
E-mail of author: amb@nada.kth.se
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ABSTRACT: This paper discusses conceptual organization and exploration in the context of a *Knowledge Manifold*, which is a framework for individualized learning that was introduced in [(10)]. It also presents an overview of the *Garden of Knowledge* as an example of a KM and describes the basic design goals of the GoK project. Moreover, the paper introduces the idea of a *concept browser* and presents a set of design principles for such browsers based on a strict separation of *context* and *content*, contextual descriptions in terms of *concept maps* expressed in UML, and viewing of the content components through various *aspect filters*. Finally, this paper introduces the concept of *multiple scale narration,* and illustrates this idea by an example that shows the browsing of an archive of components at multiple scales of resolution based on the dimensions of *clarification* and *depth*.

KEYWORDS: Garden of knowledge, knowledge manifold, conceptual modeling, UML, knowledge component, concept browser, conceptual neighbourhood, conceptual topology, context map, aspect filtration, multiple scale narration.

1 Acknowledgements

The work presented here has been performed in collaboration with a number of different people at CID and elsewhere. Although I cannot mention all of them, I gratefully acknowledge the contributions of Donald Broady, Hans Melkersson, Mikael Nilsson, Matthias Palmér, Sören Lenman and Bo Westerlund all of whom work with interactive learning environments and digital worlds at CID. I am also indebted to Daniel Fagerström at the CVAP-group and Lars Svensson at the dept. of Mathematics for many stimulating discussions. Last - but not least - this work has been financially supported by the Foundation for Knowledge and Competence Development (KK-stiftelsen), which is most gratefully acknowledged.

2 Introduction

Due to the rapidly increasing use of information and communication technology, the amount and variety of information that we have to deal with in our everyday lives has become much greater than only a few years ago. This process has led to new ways of structuring information, that aim to clarify both the context and the content of different concepts.

One obvious trend in the evolution of information handling is that the traditional, hierarchically structured systems of classification (e.g. dictionaries and filing cabinets) have been expanded -

with digital support - to include links of various types - as e.g. the directory trees with soft links where we store the electronic mail messages or the personal files on our computers. Of course, the most complex information structure that we are dealing with today is the Internet, where the (hyper-text) links have been taken to their extreme - creating a “linked anarchy” where anyone can connect anything with anything else. It is a well known fact that - unless these anarchical powers are balanced by careful design - they easily lead to link-structures - and therefore web-sites - that are difficult to navigate and conceptualize as a whole, which in turn makes it hard for the human recipient to organize and integrate the separate pieces (= components) of information that is presented into a coherent pattern of knowledge.

3 Conceptual modeling - describing the conceptual context

3.1 Background

Wittgenstein has demonstrated [(21)] that we cannot speak about things in their essence. Therefore we attach names to things in order not to have to talk about whatever lies behind these verbal labels. Instead, we talk about the only things that we can talk about, namely the relations between things. This fundamental fact forms the basis of the entire scientific project, so clearly stated by one of its most eminent proponents - Henri Poincaré: “The aim of science is not things themselves - as the dogmatists in their simplicity imagine - but the relations between things. Outside those relations there is no reality knowable” [(15), p. xxiv].

Hence, according to Poincaré, the conceptual relationships are fundamental to any linguistically based world model, because they represent the only things that we can talk about.

3.2 Short dictionary of terms

The following terms are fundamental for the discussion of this paper and will appear in several places below. Most of them are introduced in [(10)] and they are redefined here for the sake of clarity.

Thing = group of phenomena.

Concept = representation of some thing.

Mental concept = inner representation of some thing.

Medial concept = communicable representation of some thing.

[We cannot talk about things, but we can talk about the concepts that things evoke within ourselves. This is why we label things - in order to represent them symbolically in such a way that their relationships become ‘speakable’ in the sense of Wittgenstein or Poincaré discussed above.]

Communication = the process of constructing medial concepts of things and exchanging them with others.

Talk *about* a concept = explain it.

Talk *with* a concept = use it to explain other concepts.

Independent concept: Concept *A* is independent of concept *B* if *A* can be defined without making use of *B*.

Basic concept = concept that cannot be completely talked about in terms of independently defined concepts.

[Examples: The concepts of point, line, plane, ... in geometry. No geometric theory will ever tell you what a ‘point’ is - in independent terms. Surely it will say things like “a point is the intersection of (= determined by) two lines, but then it will be forced to admit that a ‘line’ is the connection of (= determined by) two points. Neither will a physical theory ever tell you what ‘force’ is, but it will tell you what a lot of other things are - in terms of forces.]

Context = relations between concepts.

Paradigm = relations between basic concepts.

Context *diagram* = map of relations between concepts = concept map.

Static context diagram = map of types and their associations = *class* diagram.

Dynamic context diagram = map of activities and their sequencing = *activity* diagram.

3.3 Representing conceptual relationships in UML

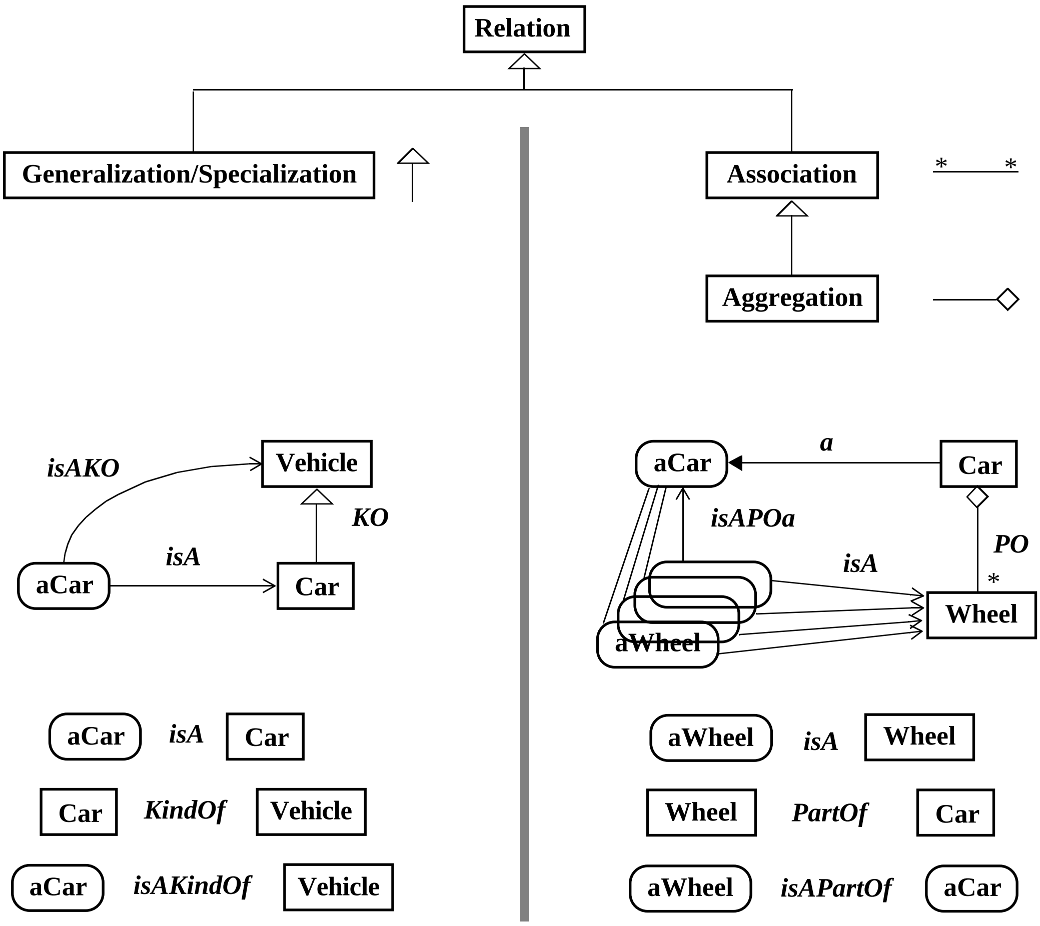

Fig. 1.The UML notation with the addition of *isA*, *isAKO* and *isAPOa*.

During the last few years there has emerged a language for conceptual modeling called UML (Unified Modeling Language) which is rapidly gaining the position of standard within this field [www.omg.org]. It has originated within the object-oriented programming community, but today it is used not only to create computer programs but for the purpose of modeling conceptual relationships in general.

Such relationships are of three basic kinds - called respectively *generalization*, *classification* and *association*. Moreover, there is a special form of association which is called *aggregation*.

These relationships are illustrated in Figure (1). A generalization expresses an *abstraction* of a concept - e.g. the concept of *Vehicle* is an abstraction of the concept of *Car*, and *Car* is in turn a *specialization* (= *KindOf*) *Vehicle*. A classification expresses a *type/instance* relationship between two concepts - e.g. *Car* is the type of the instance *aCar*, and *aCar* is an *instance* of type *Car*.

An *association* models the structure of the *connections* (= *links*) between two or more *instances* of the corresponding *types*. As an example, an association between the types *Car* and *Person* expresses the connection that the instance *aCar* (of type *Car*) is driven by the instance *aPerson* (of type *Person*).

Finally an *aggregation* (= *whole/part* relationship) models a tighter form of association, which implies some kind of *responsibility* of the aggregate (= whole) for its corresponding parts - e.g. *aWheel* is a part of *aCar*, and *aCar* is the *container* of its wheels. For a thorough discussion of the foundations of conceptual modeling, the reader is referred to [(12)].

3.4 Three hierarchical dimensions of constraint

Associations between different concepts form a general graph structure with no restrictions at all. This means that the corresponding links can form circular chains (= cycles), i.e. we can encounter a situation where concept *A* is linked to concept *B*, which is linked to concept *C*, which is in turn linked to *A*. Such a situation could be referred to as "relational anarchy", and it is in general more difficult than non-cyclical relationships to handle in an automatized way. It is therefore important to note that the three other types of relationships mentioned in the previous paragraph are all hierarchical, in the sense that they cannot form such cycles. Instead each one forms what is known as a DAG (Directed Acyclic Graph). For instance, aCar is a kind of Vehicle, and aSportsCar is a kind of Car, but aVehicle cannot be a kind of SportsCar. In the same way, aWheel is a part of aCar, and aHubcap is a part of aWheel, but aCar cannot be a part of aHubcap.

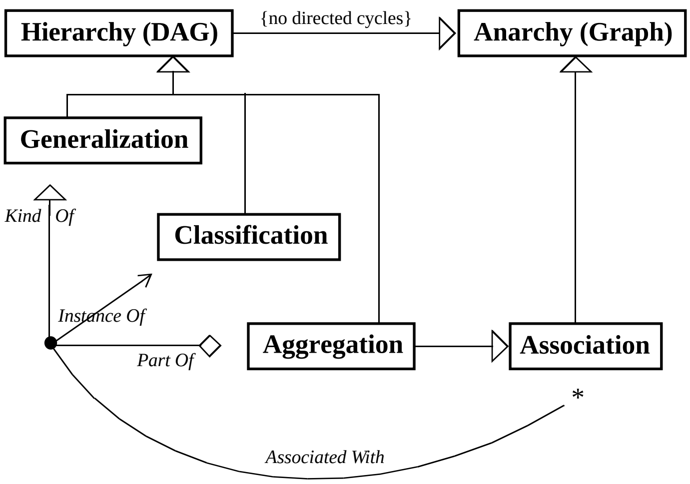

Fig. 2. Four basic types of conceptual relationships - three of which form hierarchies.

Hence, the conceptual neighbourhood of a certain concept can be said to contain three hierarchical kinds of dimensions - as depicted in Figure (3). Conceptual neighbourhoods are discussed further in chapter (7) in connection with conceptual topologies.

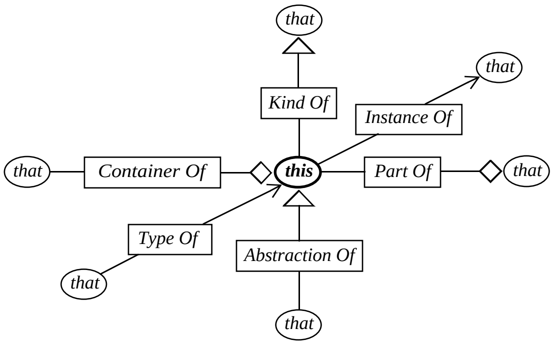

Fig. 3.The hierarchical directions from this to that.

The relationships in Figure (3) are verbalized by beginning with *this* and ending with *that* and always following *this* with the verb *is*: *This* is kind of *that*, *this* is instance of *that*, *this* is part of *that*, *this* is abstraction of *that*, *this* is type of *that*, and finally, *this* is container of *that*.

4 The Garden of Knowledge

4.1 CID

Established 5 years ago, the Centre for user-oriented Information technology Design (CID) is an interdisciplinary research group and academe-industry collaboration centre, which is located at the department of Numerical Analysis and Computing Science (NADA) at the Royal Institute of Technology (KTH). At CID there is a unique blend of knowledge from fields such as pedagogy, computer science, mathematics, art and design as well as cognitive and behavioural science. CID is engaged in a multitude of projects that aim to develop ICT-based tools of various kinds.

Today, the activities at CID are divided into three major areas of research and development called respectively Smart Things and Environments, Digital Worlds and Interactive Learning Environments. The initial project within the latter field was the Garden of Knowledge (GoK) project, which was initiated by Ambjörn Naeve in 1996.

4.2 The Initial Garden of Knowledge Project

The initial aim of the GoK project was to develop principles and prototypes that demonstrate how Information and Communication Technology could be used in order to support an interdisciplinary understanding of different concepts and phenomena by describing their mutual relationships as well as their evolution through different ages and cultures.

The first GoK prototype was developed in 1996-97 by a group of people that included Rikard Linde, Ambjörn Naeve, Kenneth Olausson, Katarina Skantz, Bo Westerlund, Fredrik Winberg and Kristina Åsvärn through a work-process that is described in [(10)]. The prototype made use of symmetry as a means to illuminate structural relationships between mathematics and music. It also introduced some interesting interface design ideas, and was nick-named the “rolling doughnut", because of its doubly wrap-around type of navigational connectivity. The rolling doughnut also provided a continous form of semantic zooming - without losing the overview of the conceptual configuration. The prototype was produced as a CD-rom, and is documented in Swedish in [(7)] and in English in [(10)].

4.3 Knowledge Components

Over the past three years, the GoK project has evolved into exploring principles for the design of interactive learning environments that provide ways to separate and modularize both teaching and learning. A fundamental idea in this context is the modularization of the conceptual content into what we call *knowledge components* [see (10)], as well as the description of such components in internationally standardized ways. The design of mechanisms for the cooperation of the components as well as the description of their content is carried out in accordance with the evolving international standards for net-based learning environments that is being developed and coordinated by the IMS project, which is briefly described in the next paragraph.

Knowledge components can take the form of digital files that can be downloaded to a knowledge patch from different digital archives, that have been assembled using portable information formats such as HTML, SGML, XML, VRML, MIDI, QuickTime or Java. In the GoK project, we are exploring the possibilities to make use of such portable formats in order to create the separation between content and context which enables the creation of modularized electronic learning tools with a higher potential for individualized learning.

A knowledge component can be likened to a skiing area, with several different pists down the same mountain - each one with its own level of difficulty marked off by a colour code which constitutes the internationally standardized metadata classification scheme for skiing pists. Nothing prevents a skier with green prerequisite knowledge to choose a red or a black pist, but the skier knows pretty well what to expect in these cases.

Hence, the main benefit of a well designed knowledge component is that it can be used and reused in a variety of different learning contexts. Such components are well suited to a networked environment where teachers and learners are free to choose content from a manifold (= world wide archive) of available resource-components that are described using relevant and standardized metadata.

As mentioned above, at CID we have been able to bring to this work a combination of 'soft' human perspectives - such as aesthetic, cognitive and pedagogical - as well as the 'hard' scientific, mathematical and computational perspectives that form the traditional backbone of Nada's expertise. It has therefore become a natural focus for our work to explore principles for the design of knowledge components and presentation environments that provide aesthetic stimuli and pedagogical motivation and which are designed in accordance with the IMS specifications. Just as the IMS project itself, our work is based on the object-oriented paradigm that has proved so successful in developing distributed systems in general

We are not interested in the freezing of live courses in computerized form - as e.g. totally self-contained video-taped courses. Instead, we want to explore the possibilities of designing powerful and flexible knowledge components that give live teachers a chance to improve on their narrative and tell the stories they have to tell in a more interesting and thought-provoking way.

The GoK project has also been involved in the construction of a knowledge component in mathematics called Projective Drawing Board (PDB), which is a program that makes use of dynamic geometry as a way to interactively explore geometrical constructions in new ways Naeve[(8)], Winroth [(20)].

4.4 The IMS project[1]

A distributed and component-based view of knowledge is of fundamental importance to the evolving net-based learning industry. In view of the large costs that are connected with all forms of software development, it is important to design the knowledge components in such a way that they can be used and reused in a variety of different learning contexts. To achieve multiple levels of interaction as well as to enhance the co-operational capability between the different components therefore become strategically important design goals in order to enable the learner-driven and individually customizable learning environments that everybody desires.

The IMS (Instructional Management Systems) project was formed as a catalyst for the development of a substantial body of instructional software, the creation of an on-line infrastructure for managing access to learning materials and environments, the facilitation of collaborative and authentic learning activities, and the certification of acquired skills and knowledge. Increasing access, improving quality, and reducing costs of learning environments requires the development of a substantial body of instructional software. One may be completely committed to improving learning environments and making them more learner-centred, but attempting to do so in a field without software is an extremely difficult task. Much progress has been made on the hardware side, especially in terms of the global networking potential for linking learners, teachers, and providers of materials and services. What is needed, however, is an increase in the availability of effective software.

The development of instructional software and its integration into the learning environment, however, have been impeded by a lack of standards that would permit sharing across institutions and across a wide range of technical environments. The current Internet-based solution to platform-dependence, namely the World Wide Web, has improved access to learning materials, but this access is limited at best. Finding relevant, valuable, and interesting information on the Web is a difficult process because there is no inherent structure or standards for describing available content.

Furthermore, the Web tends to be primarily used as an information repository rather than an interactive space supporting the collaborative and dynamic nature of learning. Interactive technologies are developing to augment standard HTML, but translating the resulting content across sites requires a significant amount of expertise and time. Finally, the development of on-line learning environments has also been hampered by the lack of electronic commerce solutions for compensating the production and distribution of content or programs.

1. The information of this paragraph is condensed from the IMS-website: www.imsproject.org

Overall, the IMS project attempts to address three obstacles for providing effective on-line materials and learning environments:

Lack of standards for locating and operating interactive platform-independent materials.
Lack of support for the collaborative and dynamic nature of learning.
Lack of incentives and structure for developing and sharing content.

What is needed to address the obstacles described above is a specific set of higher-order standards and tools that enable teachers, learners, software developers, content providers, and other parties involved in the learning process to create, manage and access the use of on-line learning materials and environments. The IMS aims to promote the emergence of this set of standards and tools.

4.4.1 Scope of the project

The IMS project has undertaken a broad scope of work. Building out from the requirement for inter-operability of instructional content and management systems and from the requirement for working within complex educational enterprises, the project has identified five main areas in which it is developing specifications and building prototype code:

Metadata, the labelling of educational materials.

Content, the actions and responses that IMS-compliant content may perform.

Management functions such as access control, session management, tracking students' progress through learning processes, control over the virtual learning environment, and security.

Profiles of students and instructors that include personal, performance, and preference information.

External Interfaces to services external to the core management system such as electronic commerce, back-office, full-text indexing systems, digital library services, and databases.

With these five areas of work the IMS project is addressing a broad scope of learning contexts. The initial strong emphasis on higher education has not diminished, but the project is also building partnerships to address requirements in corporate and government training and in K-12 schools. The scope includes any educational setting that can be reached by the Internet which extends to on-the-job, at-home, as well as in the traditional classroom settings.

The scope of the IMS project can also be described in terms of the kinds of work done within it. The project began and continues with a requirements analysis that includes meetings and focus groups to establish the requirements of learning contexts. Based on requirements, the project is developing specifications which are documents outlining the way software must be built in order to meet the requirements of inter-operability and usability. In all cases, the specifications are being developed to support international needs.

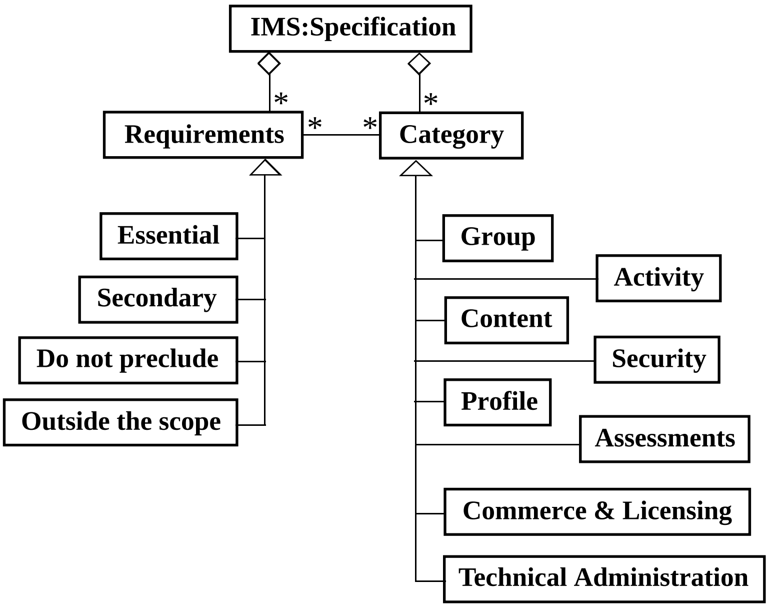

Fig. 4. The basic structure of the IMS project

4.5 Learning Environments

From a conceptual point of view, a learning environment can be regarded as a kind of protocol for the separation of "what to teach", i.e. the content, from "when to learn", i.e. the context. When designing a traditional course, one tries to connect the content with the context, identifying the target group, the prerequisite knowledge, the presentation schedule, etc. In contrast, when designing a knowledge component, one instead tries to separate the content from the context. This fundamental difference is discussed in detail in [(10), pp. 89-93]. The aim in this case is to describe the content in many different ways (= multiple resolution) at the same time. The modern hypertext techniques then makes it possible for the learner to regulate which resolution of the story that he or she wants to interact with - just like in a computer game, which offers individually adjustable preferences and levels of difficulty.

The GoK project makes use of conceptual modeling [www.omg.org] as a foundation for the construction of electronic archives of knowledge components as well as for the composition of such components into individualized and personalized forms of learning experiences that let the learner take control of his or her own learning strategy. The long term aim of the GoK project is to construct a testbed for modularized and distributed learning environments where different principles for description, search and composition of knowledge components can be developed and tested from a user-oriented perspective.

4.6 Helpdesk - man to man via machine

It is a fundamental assumption of the GoK project that automated presentation systems can raise questions but not give answers in any deeper sense. In fact, it is precisely when the questions break the frames of the pre-structured presentations that the real learning process begins. When a learner gets stuck with such a question, he or she must therefore be given a chance to communicate with a living person that has knowledge within the relevant field. Hence, an important task of the GoK project is to develop a helpdesk system that enables learners to get personal contact with resource persons (knowledge sources) that have declared competence that matches the domain within which the corresponding question occurred.

Such knowledge sources will be able to offer their services through some form of catalogue system that makes it possible to localize and contact them on line. There is simply no substitute for a personal contact with a live an knowledgable teacher. The problem is that there just isn't enough of them to cover the need through interactions in real (= physical) space. But we can make use of virtual (= digital) space in order to spread quality explanations and create a closer match between teacher knowledge and learner interest than what we have today. In the learning environments of the future it is of vital importance to support the interest of the learners in every possible way, in order that it can be made to survive and develop through the learning process.

By using conceptual modeling (concept maps) we can make sure that the questions that arise are concerned with the concepts within a well defined knowledge domain, and therefore they can be matched with appropriate human "answering capacity". Hence, instead of answering questions of a general nature from students that happen to be physically close - but often mentally distant - a teacher should be able to serve on-line and answer questions concerning his or her speciality - questions that come from all over the world. In this way we aim to achieve a better match between teacher knowledge and learner interest.

5 The Concept of a Knowledge Manifold

5.1 An Educational Framework for Individualized Learning

As described in the preceding chapter, the GoK project has developed certain design ideas for a man-machine interactive type of distributed and modularized learning environment. The basic structures behind these ideas are contained in a type of educational framework called a *Knowledge Manifold*, which was introduced by Naeve in [(10)] and which will be discussed briefly in this chapter.

An educational framework provides design-patterns that help to structure an educational configuration in certain ways. The overall aim of the knowledge manifold framework is to provide patterns that support and enhance individualized learning in every possible way.

The garden of knowledge can be regarded as an instance (= example) of a knowledge manifold, something which is implied by the title of [(10)]. Seen from this perspective, the garden of knowledge consists of a set of inter-linked knowledge patches - each maintained by its own local knowledge gardener who is responsible for the selection and the quality of the material presented within it.

5.2 Subjective ideas

In order to describe the conceptual structure of a Knowledge Manifold it is good to start by regarding the objective world as a kind of contract negotiated by individual subjects, as opposed to the old and (maybe too) well established scientific way of regarding each subjective world as a personal form of deviation from the objective, real world around us, the cognizing subjects. This is in agreement with the ideas of collaborative learning as expressed e.g. in [(14)].

The fundamental idea is contained in the following definition of an idea, which is taken verbatim from [(10), Def. 21, p. 80] and repeated here for the sake of clarity:

Def. 1: An *idea* (= *concept*) is a *representation* of an *experience.*

This idea of what an idea is establishes the philosophical foundation. It represents a totally anti-Platonian definition of an idea. Whereas Plato's ideas were eternal and 'objectively true' - although they were only 'hinted to us' in the mathematical mysteries - the definition of an idea given above is totally subjective. The collection of each individual's personal ideas constitute his or her own internal mental space, which in KM-terminology is called a *mental knowledge patch*. The description of this mental space in communicable form constitutes the corresponding medial space - the *medial knowledge patch.* Hence, in order to communicate an idea to others, we must first transform it from our mental space into our medial space.

5.3 Subjective versus objective - a historical overview

The problem of the interplay between the subjective and the objective has been a part of the philosophical discourse ever since the beginning of Greek philosophy in the 6:th century B.C. Over a period of about two centuries, the conceptual debate - spanned by the dimension of *substance* (Thales) contra *form* (Pythagoras) on the one hand and the dimension of *variance* (Herakleitos) contra *invariance* (Parmenides) on the other - evolved into the compromise of the atomists (Leucippos and Democritos): Unchanging, invariant entities - atoms - combine in changing forms - variant shapes - that move around in empty space. Under the influence of Plato, the material aspects of the objective world were gradually de-emphasized in favour of the eternal Platonic world of abstract ideas - such as the geometrical ideas of point, line and plane.

Two millennia later, the material aspects of the objective world were re-awakened during the renaissance and given a mechanistic interpretation by thinkers such as Descartes, Leibniz and Newton. The cartesian glass wall that separated the mental, subjective world - res cogitans - from the material, objective world - res extensa - became the corner stone of the modern scientific world-view, culminating in the logical positivism of the early 20:th century.

Behind this development lies what Erwin Schrödinger has called the principle of objectivation [(18), p. 117]. In his brilliant lectures, Schrödinger asks the fundamentally important question: What are the peculiar, special traits of our scientific world-picture? About one of these fundamental features - he goes on to state - there can be no doubt, It is the hypothesis that *the display* *of nature can be understood*[1]. It is the non-spiritistic, the non-superstitious, the non-magical outlook. A few pages later, Schrödinger continues[2]:

> There is, however, so I believe, a second feature, much less clearly and openly displayed, but of equally fundamental importance. It is this, that science in its attempt to describe and understand Nature simplifies this very difficult problem. The scientist subconsciously, almost inadvertently, simplifies his problem of understanding Nature by disregarding or cutting out of the picture to be constructed, himself, his own personality, the subject of cognizance.
>
> Inadvertently the thinker steps back into the role of an external observer. This facilitates the task very much. But it leaves gaps, enormous lacunae, leads to paradoxes and antinomies whenever, unaware of this initial renunciation, one tries to find oneself in the picture or to put oneself, one's own thinking and sensing mind, back into the picture.

5.4 Calibrating subjective experiences into group-consensus reality

The concept of a Knowledge Manifold is modelled on the mathematical concept of *Manifold*. A mathematical manifold consists of a number of local descriptions (= coordinate maps) of a set of points in some space - descriptions that are coordinated (= calibrated) into a coherent whole through a so called *atlas*. The atlas describes how the maps are related to each other, i.e. how one can change the description of the same thing (= point) from one map to the other.

In a Knowledge Manifold, the mathematical points correspond to (configurations of) phenomena in the world, and the coordinate maps correspond to individual representations of these phenomena. Each cognizing subject thus forms a number of such coordinate patches, but there is an important difference with regard to a mathematical manifold: Whereas a mathematical coordinate patch is always a one-to-one description of some local neighbourhood of a point, an individual knowledge patch represents a projection that maps a larger world-space of phenomena into a smaller mental space of their representation within a cognizing subject. The famous mathematican David Hilbert has said that "most people's thoughts move around in a circle with radius zero, which they call their stand-point". Within this context, Hilbert's statement could be translated into something like: People's thoughts move around in a space of personal ideas, which could be called their individual knowledge patch or their own subjective reality.

Such knowledge patches do not grow in isolation. Although each person is the gardener of his or her own personal knowledge patch, each individual patch is constantly *calibrated* with other patches in a multitude of different ways. This is how all the various forms of *group-knowledge patches* are formed - by the corresponding *calibration process* that is going on within the group.

Let *A* denote an observer that can take on the value of either an individual or a group (= set of individuals). Introducing a notation slightly different from [(10)], we can make the following definition:

1. Schrödinger, *Nature and the Greeks*, [(17)], p.90.
2. *Loc. Cit.*, p.92.

Def. 2: Consider an observer *A* that is observing some thing called *P*. The transformation from *P* to *A* that maps *P* onto the medial concepts of *P* assembled by *A* is called a *description* of *P* by *A* and is denoted by $[P]_A$.

Fig. (5) shows two different descriptions $[P]_A$ and $[P]_B$ of the same thing *P*, and the corresponding two calibration process transformations $[P]_A$ ---> $[P]_B$ and $[P]_A$ <--- $[P]_B$. As an example, the engineers and the economists working for the same company can - and most often do - develop different descriptions of their company, e.g. $[\text{Ericsson}]_{\text{Engineers}} \neq [\text{Ericsson}]_{\text{Economists}}$.

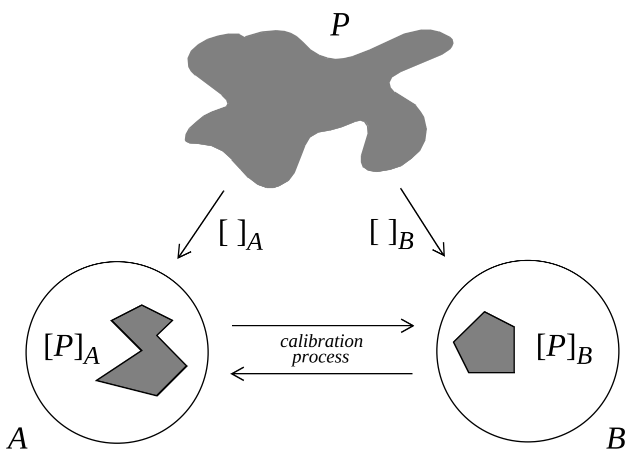

Fig. 5. The calibration process between two different descriptions of the same thing.

As discussed in [(10)], any instance of a Knowledge Manifold can be seen as a kind of network that reflects its own particular aspects of the informational coherence of a culture. It is constructed - just as a standard mathematical manifold - by the successive calibration of local patches, and in [(10)] it is defined in terms of its *calibration protocols*. These are the set of rules which are either *agreed* upon or *obeyed*, depending on how the participators choose to *interact* (= *act* and/or *react*) with them.

In this way, the Knowledge Manifold acts as a framework for creating all forms of *group* consensus realities; realities that lie somewhere between the subjective (= *individual* consensus) and the objective (= *all* consensus) reality.

A *Group Consensus Reality* - described by a *Group Knowledge Patch* - emerges from a collection of Individual Knowledge Patches that are linked together by a calibration protocol that is *sufficient* to establish mutually tolerable conditions for *co-existence*.

This way of conceptual modeling focuses on the individual - as opposed to the collective - way of relating to knowledge. It is designed as a framework to support subjective education, i.e. individually based learning strategies that are developed in a cooperative process.

5.5 Language-based Concept Formation

In his famous Erlanger program of 1872, the great geometer Felix Klein proposed to define a geometry as a collection of statements concerning ‘objects’ that remain invariant under a group of transformations. This marks the beginning of the modern viewpoint - where each geometry is regarded as a sort of language, with its own collections of *transformations* (= *verbs*) and *invariants* (= *nouns*).

Our languages are intimately related to our methods of concept formation. The *verbs* describe the *operations* (changes) that we can observe - or imagine - while the *nouns* describe the *invariants*, i.e. the substances that *survive the operations* (*transformations*) of the verbs. The *adjectives* describe *values of aspects on the nouns,* like in the phrase “the red car stopped” where the adjective ‘red’ represents a value of the aspect ‘colour’, which can be associated with the noun ‘car’

This situation carries strong similarities to geometry. A geometric theory behaves like a language: It has its own verbs, that express the types of motions that the geometry admits, and its nouns that express its invariants, i.e. the concepts that survive the motion-transformations of the verbs. To give an example, the concept of *square* is a noun of *Euclidean geometry,* because the transformations of this geometry consist of ordinary (rigid) motions, reflections and uniform scalings, and each of these types of operations transforms a square into a square - “leaves the squareness invariant”, as a mathematician would put it. ‘Square’ is thus a euclidean geometric concept, because it survives the action of the euclidean verbs. However, in the world of geometric shadows, *projective geometry,* the concept of ‘square’ is not a valid noun. Projective geometry considers *all shadows equivalent*, and its verbs (motions) are represented by combinations of shadow-projections. Projective geometry therefore has no room for squares, since the shadow of a square - cast from a point outside of its plane onto another plane - is not in general a square, unless the planes happen to be parallel in space. Hence a square does not survive the (=*all*) actions of the projective verbs, and ‘square’ is therefore not a projective noun (= invariant).

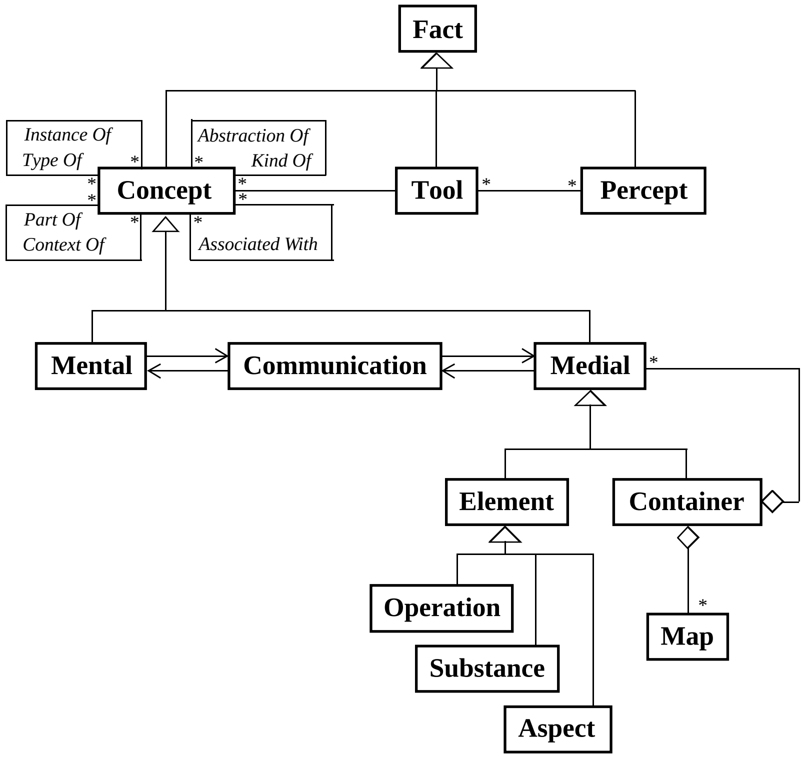

Fig. 6. The basic epistemological structure of a knowledge patch

The basic epistemological structure of a Knowledge Patch is depicted in Figure (6). The four types of conceptual relationships from Figure (2) are shown in Figure (6) as conceptual associations with *role names* (of the 3 hierarchical ones) corresponding to Figure (3).

The concepts are subtyped into *mental* (= internal) and *medial* (= communicable) concepts, and the latter are in turn subtyped into *containers* and *elements*. A container-concept consists of a number of medial concepts that can be either of the elemental or the container type. A container-concept is also associated with a number of maps, describing different contexts (= relations) that involve the concept in question. An element-concept is classified as an operation-, a substance- or an aspect-concept according to the principles described above:

An operation-concept corresponds to a verb and describes some form of change (= transformation). A substance-concept corresponds to a noun and describes something that remains invariant under the transformations of the verbs. The value of an aspect-concept corresponds to an adjective and describes some form of invariant property of a substance-concept.

5.6 Dynamic Restructuring of Knowledge

Each conceptual classification scheme is by its very nature dynamic and is therefore subject to evolutionary changes in the form of both refinements and paradigm-shifts. The concept of knowledge-evolution represents partly the formation of new concepts, and partly the 'transformation by refinement' of the old ones. The history of science provides many examples of this evolutionary process. As an example: in physics the concept of ‘atom’ a hundred years ago used to refer to some ‘entity’ that was ‘indivisible’ (= had no parts). Hence, in these days, ‘atom’ could be described as a substance-element-concept. As atomic physics progressed, the concept of ‘atom’ was transformed into a container-concept, which initially came to aggregate over (= form a context for) the substance-element-concepts of ‘electron’ and ‘nucleus’. By the evolution of nuclear physics, the concept of ‘nucleus’ was in turn transformed into a container-concept, aggregating over such substance-element-concepts as ‘proton’ and ‘neutron’ - and eventually a whole bunch of other so called ‘elementary particles’.

6 Educational Design Patterns

6.1 The Educational Paradigm shift - From School Duties to School Rights[1]

Many teachers still seem to implement the pattern of the traditional teacher-preacher - depicted in Figure (7). It goes well with the compulsory-learning pattern which is another essential component of the overall pattern of the educational process, especially in its early parts. It also reinforces the employment-security attitude that is inherent in the tenure-based pattern of permanent teaching positions. Getting a permanent staff position (getting your tenure) is still considered to be the main measure of qualification within the teaching community.

At the same time, the TenuredPreacher/LearnerDuty pattern of Figure (7) is consistent with the following attitude: “Since the learners have to listen to you anyway, you might as well tell them a thing or two that you think they should know about - whether they like it or not”. This may in fact be one of its major advantages as opposed to the purely interest driven RequestedPreacher/LearnerRight pattern of Figure (8). Sometimes you need a push to get you through some ‘dull’ part of your journey towards knowledge. How to supply such pushes is a problem that is associated with any purely interest-driven educational system.

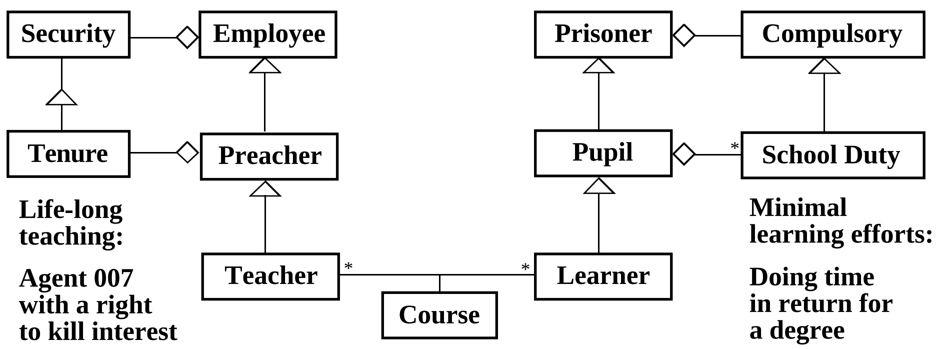

Fig. 7. The static structure of the *TenuredPreacher/LearnerDuty* educational design pattern.

<u>Interpretation of Figure (7):</u>This is the traditional pattern of *life-long teaching* and *compulsory learning* which is practised in most forms of earlier education of today. The *teacher* is seen as a *tenured* (= *securely employed*) *preacher*, who can teach as he or she wants to without having to

1. The discussion of this paragraph is essentially a shortened version of the one given in [(10)], chapter 6.

worry about whether the *learners* like it or not - at least not as long as their signs of dislike can be kept within socially controllable bounds. This role-model is referred to as *'agent 007 with a right to kill interest'*. The *learners* are seen as *pupils* with a number of *school duties* which makes them *prisoners* of a *compulsory* detention system. In this way they adopt a strategy of *minimal learning efforts - doing their time in return for a degree*.

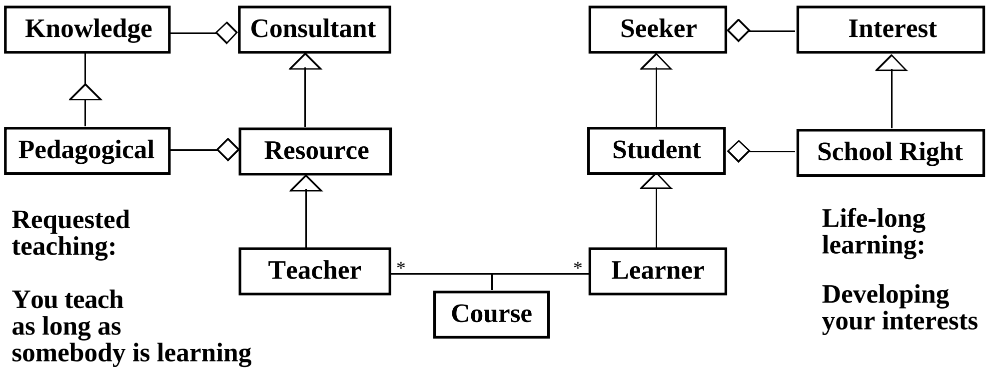

Fig. 8. The static structure of the *RequestedPreacher/LearnerRight* educational design pattern.

<u>Interpretation of Figure (8):</u> This is the emerging educational pattern that characterizes much of the present course-development for industry, as well as the many-fold activities of various kinds of 'study-circles'. The *teaching* is not life-long, but rather performed *on request.* The *teacher* is seen as a *pedagogical resource* which is a form of *knowledge consultant*. When somebody(ies) are interested to learn, then is the time to teach. *Man lär så länge man har elever!* (≈ You teach as long as somebody is learning.) On the complementary side of the pattern, the *learners* are seen as *students* with a number of *school rights,* a kind of knowledge *seekers* basing their studies on *interest.*

The effective implementation of educational systems founded on the pattern of Figure (8), will demand different ways of thinking about the role of the teacher. In the educational systems of tomorrow, the switch-boarding possibilities of cyberspace will be used in order to connect knowledge-sources of great quality and communication skills with learners of great interest and curiosity, in an effort to promote effective knowledge-transfer. Within such an environment, the role of the traditional teacher can be split up in many different roles or aspects, Three of these teaching roles - *Teacher/Preacher*, *Teacher/Gardener* and *Teacher/Plumber* - are emphasized in the pattern presented in Figure (9) below.

In order to make effective use of the new learning possibilities, the traditional, collectively oriented, class based teaching plans (= curricula) should be complemented by individually oriented module based learning strategies. These learning strategies should be created around the unique interests and capabilities of each individual. This represents a step in the direction of obtaining a class-less educational system - with first class education for all. After all, school is the only place where we consider a transformation from first class (= grade) to second class as a form of improvement. Just imagine being treated the same way by e.g. an airline.

6.2 Question Based Learning

There are a great variety of different pedagogical approaches that emphasize various aspects of the educational process. Although Lecture Based Learning (by Imitation) still seems to hold a dominating position in many quarters, pedagogical alternatives such as Problem Based Learning and Project Based Learning are being increasingly applied. See [(14)] for a good overview of different pedagogical methodologies.

A problem with the dominating educational design patterns is that it is most often the teachers that formulate the problems (or the projects). This decreases the motivation of the learners in general, and stifles the more creatively oriented among them. It also leads to tension because of differences between what the teachers want and what the learners deliver.

Starting from the questions of the learners, leads to a pedagogical design pattern that could be naturally called *Question Based Learning*. In QBL, the learners make use of conceptual modeling to formulate their questions and their learning strategies. The learner questions are treated as “official letters to the authorities”, i.e. they are registered and monitored in an analogous manner.

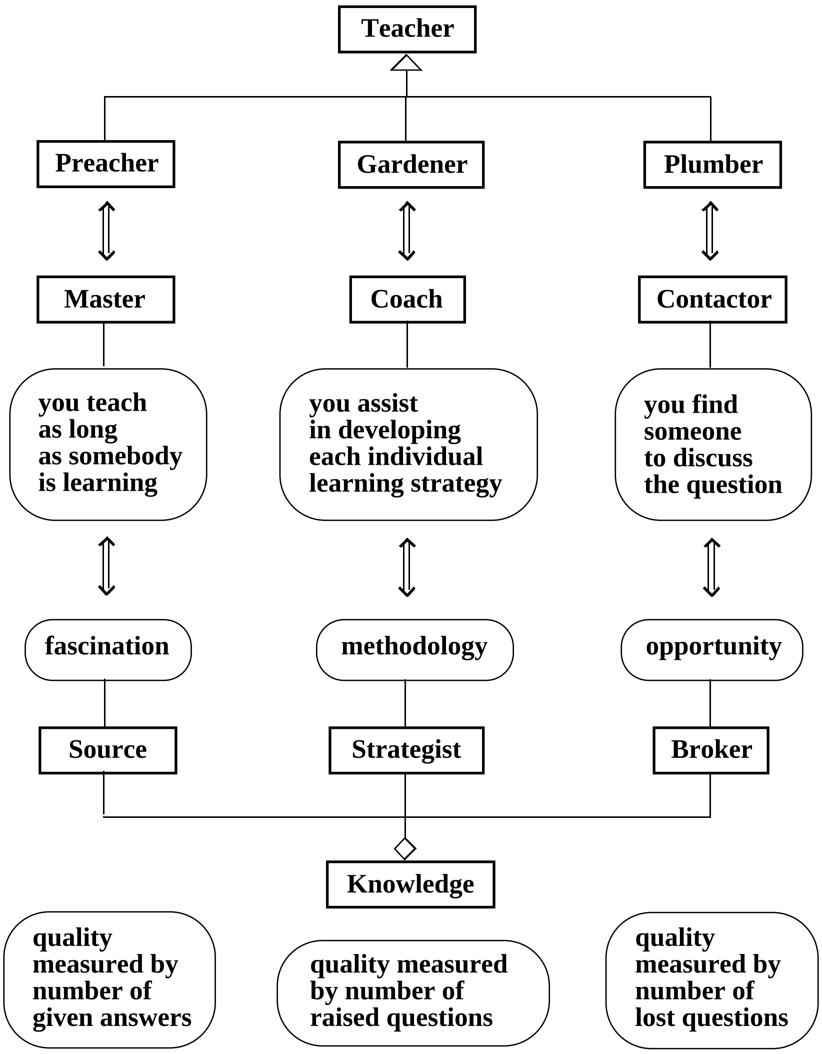

Fig. 9. Three different dimensions of the teaching role in QBL.

The Teacher-Preacher/Gardener/Plumber pattern is depicted in Figure (9). It expresses three important dimensions of teaching that correspond to the Teacher-Resource/Learner-Right pattern of Figure (9).

The *teacher-preacher* is still in the picture, but now as a resource (= consultant) who is a *master* of some kind of *knowledge* that is interesting to others. This knowledge source is driven by fascination and teaches as long as somebody else is learning.

The *teacher-gardener* is the *coach*, who nurtures and supports the growing knowledge of the learners. The teacher-gardener *assists in developing each learner's own individual learning strategy.* As a *knowledge strategist*, the teacher-gardener concentrates on *methodology* and is measured - in terms of *performance quality* - by the *number of raised questions.*

The *teacher-plumber* represents the contact with the external world. Whenever a learner question is unsatisfactorily processed, the teacher-plumber *finds someone to discuss the question*.

This ‘someone’ is most often another source of knowledge that was not known - or available - to the corresponding teacher-gardener. In this way the teacher-plumber creates *opportunity* for learning, and is therefore described as a *knowledge opportunist*. The *performance quality* of a teacher-plumber is measured in terms of the *number of lost questions*.

Teaching-preaching is performed on a non-tenured basis, which means that the teacher-preacher is preaching on request. Of course, the preaching could be performed in terms of lectures (staged performances), as well as various forms of interactions with the questioners. The important thing is that the lecture focuses on their questions.

The teacher-gardener works to develop the quality of the questions that are formulated, and assists the learners in the design of their own personal learning strategies. When a teacher-gardener cannot answer a question himself, he turns to his personal network of teacher-preachers. If this still doesn’t lead to any relevant answers, then the teacher-plumber takes over and works on establishing a meaningful contact with some other teacher-preacher - thereby ensuring a forum of discussion that prevents the question from getting lost.

In short: the teacher-gardener tries to encourage the formulation of questions, the teacher-plumber tries to makes sure that as few questions as possible get lost, and the teacher-preacher tries to answer the questions that are put to her in a way that stimulates further studies of the concepts involved.

All - or some - of these teaching roles can be performed by the same physical person. However, considering the rapidly increasing demands that are being made for more education, there probably will not be enough of such ‘super-teachers’ that can be present in the physical environment of the learners. Here the emerging virtual environments offer a possibility to distribute these teaching roles across physical space, and make use of cyberspace as an electronic switchboard that can connect learner interest and curiosity with teacher knowledge and communicative ability. This would provide support for teachers that want to transform their present role as knowledge-filters (“you should learn what I know”) and assume the role of knowledge-coach (“I will help you to find out what you want to know”). Naturally, as a learner I do not like to feel that I have to learn what the teachers already know. Instead I like to feel that the teachers are an important resource in helping me find out what I want to know.

A decisive advantage of question based learning is that it contributes to giving the learners more control over their own learning process. Focusing on the questions of the individual learners - and treating these questions with the respect they deserve - helps to foster a personalized relationship to learning that counteracts the default mode of the pedagogical process which is “learning by imitation”.

This does not mean that the learners are left to themselves during the process of question formulation. On the contrary, the learners are constantly being stimulated by listening to and discussing with the teachers in a multitude of different ways. This process works to establish a sort of Knowledge Smorgasbord, as a learner you have the possibility to listen and take part of many different ideas, but it is always your own interest that governs your choices, and your own personal set of questions that are filtered out and refined.

6.3 Designing your own Learning Strategy

Designing a learning-strategy involves coming up with an answer to three important 'whats', namely *'What am I interested in?'*, *'What is there to know about it?'*, and *'What do I want to know about it?'*. Naturally, the answers to these questions are interconnected and mutually dependent in various highly complex ways. In fact, the process is subject to regular iterations which serve to modify and update the learning strategy, and nurturing the questions in an ongoing dialogue with each learner is an important task of the teacher-gardener.

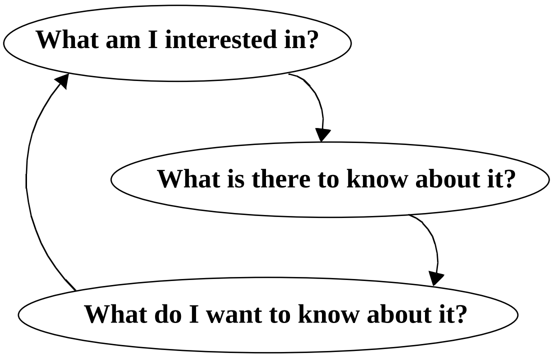

Fig. 10. Three fundamental questions in designing a Learning Strategy.

6.4 Structuring a Knowledge Component

Separating between knowledge components and learning strategies is complicated by the fact that any form of answer to a given question must build on some kind of assumption regarding the contest within which the question was formulated. The implies an unavoidable dependence between "what is being taught" and "when it is being learned". A well designed knowledge component minimizes this type of dependence by avoiding unnecessary assumptions about the learning context within which it will be used.

In object-oriented systems development, designing a good system has a lot to do with finding the fruitful compromises between the static and the dynamic contexts (= views) of the system. What it boils down to, is mapping the activities of the dynamic context onto the objects of the static context.

In a similar way, designing good knowledge components has a lot to do with balancing the conflicting forces between the content and the context of the component. Presenting some content in the form of a component that is "large enough to make sense", and yet at the same time is conceptually irreducible to the point of being maximally flexible, i.e. usable within the maximum number of different contexts.

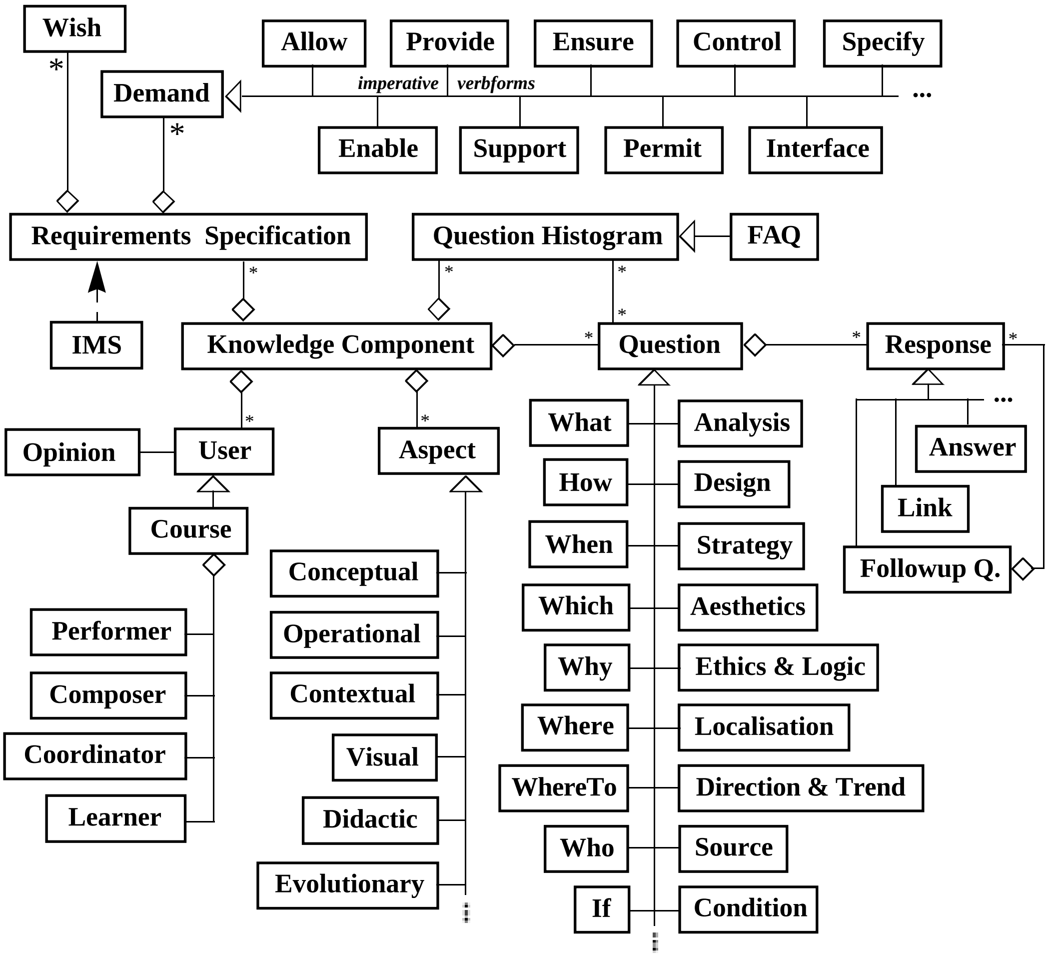

Fig. 11. A context diagram for a knowledge component.

Figure (11) shows a map of several contexts for a knowledge component, including *requirements*, *use*, *aspects*, *questions* and *responses*. Within the use-context of a *course*, four different actors (= participators) are identified: *performer* (= lecturer), *composer* (= architect), *coordinator* (= administrator) and *learner* (= student). The aspects of the content of a component include (but are not limited to) *conceptual* (= what is it), *operational* (= how is it used), *contextual* (where is it used), *visual* (= what does it look like), *didactic* (= how should it be explained) and *evolutionary* (= how did it develop)

The question context of a knowledge component is subdivided by the basic interrogative pronouns into *what* (= analysis), *when* (= strategy), *which* (= aesthetics), *why* (= ethics or logic - depending on whether it is will-powered or automatic), *where* (= localisation), *whereto* (direction in space or trend in time), *who* (= source) and *if* (= condition). Such a distinction makes possible a more detailed analysis of the types of questions that are asked in connection with a knowledge component, making possible other types of question histograms that the familiar FAQs (Frequently Asked Questions).

The Requirements context is shown in terms of a number of verbs used by the IMS (Instructional Management Systems) project [www.imsproject.org], which is the major effort to ensure inter-operability of different distributed educational components.

6.5 Component Archives - the Knowledge Wherehouse

The GoK project aims to develop principles for the constructing of component archives. Such an archive could take the form of a net-based Knowledge Wherehouse - a sort of IKEA-analogue that contains knowledge components instead of furniture - but with the same kind of catalogue (metadata) descriptions. The Knowledge Wherehouse also contains various tools that support conceptual browsing and knowledge patch construction and editing. Here the teachers can construct their own knowledge patches and tailor their own learning environment (= combination of learning offerings). As a learner, you are then able to browse the teacher's patches and by the help of various forms of diagnostics (tests + helpdesk advice) to formulate your own learning strategy (= plan). Then you are ready to follow your own learning path through the material - at your own individual pace - and eventually to document the learning experiences encountered along this path.

6.6 Design goals of the Garden of Knowledge project

The Garden of Knowledge

- is the name of a multi-mediated learning-tool project which aims to develop IT-supported methods to create an interdisciplinary understanding of the perceptual and conceptual world.
- has a first prototype that uses symmetry in order to illuminate and explain some of the structural connections between mathematics and music.
- is aiming to develop an educational framework for the creation of interactive and individualized forms of learning experiences.
- is being developed in accordance with the evolving (de facto) standard for Knowledge Components on the Internet that is administered and coordinated by the IMS project. [Instructional Management Systems: www.imsproject.org]
- is structured on the patterns of a Knowledge Manifold with access to a global network of Knowledge Components.
- can be regarded as a kind of Knowledge Patchwork - consisting of a number of linked Knowledge Patches - each with its own individual Knowledge Gardener.
- is built from Knowledge Components which are designed with the overall aim to separate "what to teach" from "when to learn" - making use of multiple narration techniques.
- contains an archive of Components which Composers can navigate through in order to connect "what to teach" with "when to learn" by composing components in order to construct different kinds of Learning Experiences.
- contains a mixture of theoretical and experimental forms of interactive environments that give the users the opportunity to:
    - ask questions and search for corresponding Learning Sources.
    - formulate and store different responses to their learning experiences.
    - follow and place links into the reference literature or the network.
- uses conceptual modeling in order to enable:

• navigation of conceptual contexts
• content based information search
• aspect-filtration of conceptual content
• competence-profiling of Knowledge Sources.
• foundational calibration of Knowledge Gardeners.

- is carried out in cooperation between CID, SUN Microsystems and DataDoktorn AB.

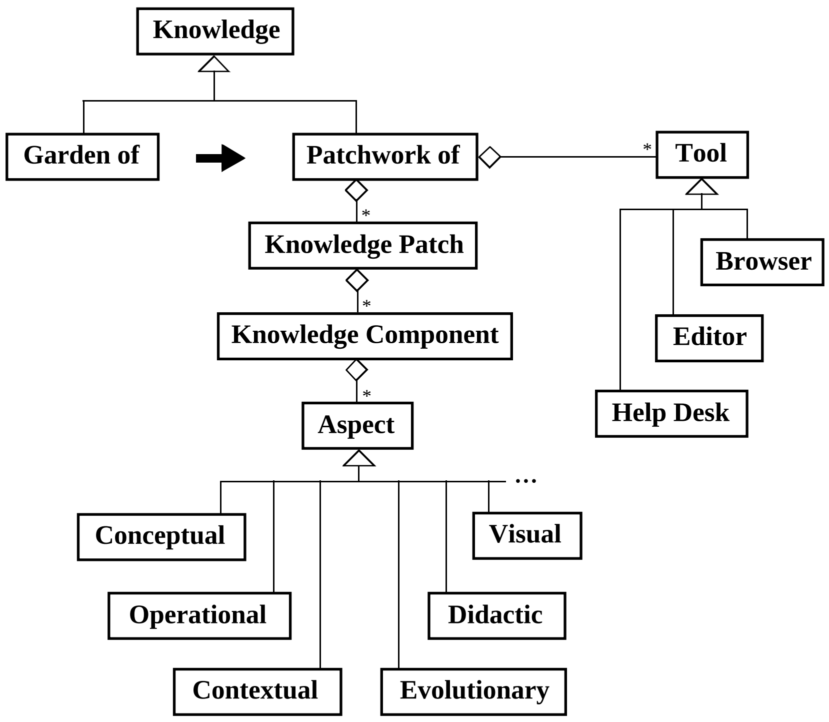

Fig. 12. The Garden of Knowledge being transformed into a Patchwork of Knowledge.

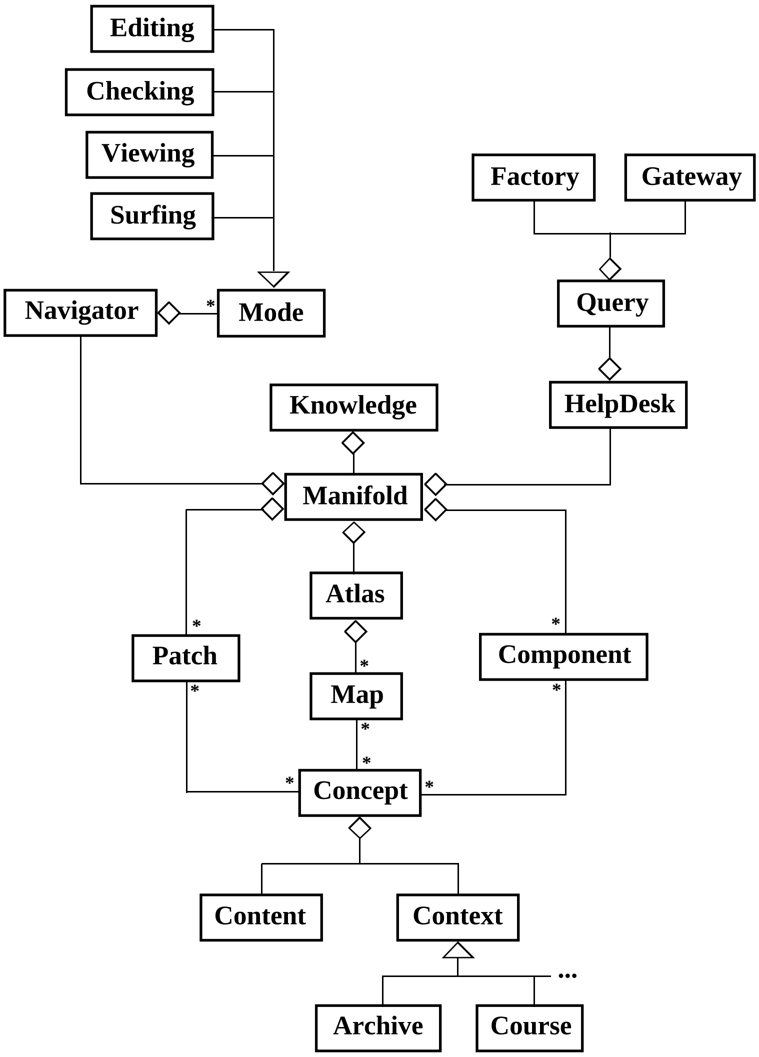

Fig. 13. The basic structure of a Knowledge Manifold

7 Conceptual Organization and Exploration

7.1 Conceptual topologies

7.1.1 Basic definitions and terminology

Let *S* be a set of concepts, and let *C* be a concept in *S*.

Def. 3: A conceptual neighbourhood of *C* in *S* is a diagram that expresses conceptual relationships between *C* and some other concepts from *S*.

Note: A conceptual neighbourhood will also be referred to as a *local context*. If a concept *C* has no conceptual neighbourhood involving other concepts from *S*, then *C* is called an *isolated concept* in *S*.

Def. 4: The *conceptual topology* on a concept set *S* is the set of all conceptual neighbourhoods (in *S*) of concepts of *S*.

In our earlier discussion of knowledge components, we have implicitly assumed the perspective of the teacher(s). Seen from the perspective of the learner(s), such a component is just a piece of information and could therefore be more appropriately called an information component. In fact, it is the gradual transformation of learner information into learner knowledge - and the eventual transmutation of learner knowledge into learner understanding - that is the overall aim of the learning process. From now on we will talk about content components - or just simply components - when we want to emphasize neither the teaching nor the learning perspective.

7.1.2 Traditional conceptual topologies

Presenting informational content requires some form of containing structure - or context - for the information that is to be presented. A traditional dictionary, for example, uses lexicographic ordering of the labels representing the content to create the structure of the presentational context. This lexicographic context has the advantage of making the content easily accessible through the corresponding label, but at the same time it has the drawback of not showing any conceptual relationships between the different pieces of content.

Therefore, a dictionary creates a *totally disconnected* (= *discrete*) conceptual topology on the set of the corresponding components - with each separate component corresponding to an isolated concept.

A textbook, on the other hand, normally makes use of some form of *taxonomy* (= classification scheme) in order to create a suitable context for the presented information. For example, if the textbook is about animals, they might be presented as a taxonomic type-hierarchy of insects, fish, reptiles, birds, marsupials and placentals on the first sublevel. Each of these types would then in turn be appropriately subtyped according to the level of presentation and targeted reader profiles. The chosen classification scheme creates a context that gives a relational structure to the informational content, and this context reflects the corresponding taxonomic connections between the various information components. In this way a textbook creates what could be called a *taxonomically connected* conceptual topology on the set of components.

7.1.3 Dynamic conceptual topologies - hyperlinked information systems

Of course, the components of a book are frozen into a single context by the order in which they are presented in relation to each other. In the case of a hyperlinked multimediated system - such as e.g. the WWW - the situation is very different. Here there are in general many different contexts for the components, and both their number and their form are constantly changing by the addition and removal of pages and links.

For example, a web-browser maintains a dynamic conceptual relationship between the page that is viewed now (= this page) and the page that was viewed the moment before (= the previous page). The corresponding dynamic conceptual neighbourhood is traversed by using the browser buttons ‘back’ respectively ‘forward’. Another (larger) example of a dynamic conceptual neighbourhood is given by the browser’s history list.

In fact, each web-page functions both as a container of its content and as a context for the contents that are reachable (by a mouse-click) from it. Consider a typical web-page *Q*. Each web-page *P* from which *Q* is reachable forms a context for *Q*. If *Q* contains a link to another web page *R*, then *Q* forms a context for *R*, and if *R* contains a link to *Q*, then the relationship is reversed and *R* forms a context for *Q*.

In this way the underlying link structure leads to an inextricable mixture of content and context - creating what could be termed a *reachability connected* conceptual topology on the set of components.

This tends to make each web-page more self-contained, and could be expected to favour a contextual design that focuses more on various forms of eye-catching techniques (animational eye-magic) than on illuminating the conceptual relationships. Of course, when designing a conceptual presentation system - as in fact when designing any kind of system - the overall aim is to use visual techniques in order to support the underlying conceptual context, and not as a substitute for this context.

The basic presentation tool for information on the web is called a web-browser. The most commonly used web is the World Wide Web, and the two dominating WWW-browsers are Netscape Navigator® and Microsoft Explorer®. It will be assumed that the reader has been exposed to one (or both) of these browsers, and therefore is familiar with their basic functioning.

7.2 Problems with the above mentioned conceptual topologies

The conceptual topologies that were discussed above can are extreme in terms of their relationship between content and context. Books are totally (= linearly) ordered and do not allow reuse of components in different contexts. Hence the context of a book is fixed. The WWW, on the other hand, presents a totally fluid and dynamic relationship between context and content, which makes it hard to get an overview of the conceptual context within which the information is presented. This results in the all too well-known surfing-sickness on the web, that could be summarized as “Within what context am I viewing this, and how did I get here?”

8 Designing Concept Browsers for a Knowledge Manifold

A multitude of different information presentation systems have been proposed in order to deal with the problems mentioned above. Although this paper makes no attempt to survey this field, we mention the *Merz* system [(6)], which displays the connections of the different components in terms of a connectivity map. This is a good example of an attempt to highlight the connectivity context in order to support the overview of the information landscape. However, the *conceptual* relationships between the components are note supported in the Merz system - nor by any other information presentation system that I am presently aware of.

A conceptual organization and presentation scheme that supports the conceptual context will be referred to as a *concept browser.* The kind of concept browser that is presented here is based on some general design principles which are presented and discussed below:

8.1 Design principles for concept browsers

(i) Separate content from context.

(ii) Describe each separate context in terms of a concept map.

(iii) Assign an appropriate set of components as the content of a concept and/or conceptual relationship.

(iv) Filter the components through different aspects.

(v) Label the components with a standardized data description (= metadata) scheme.

Of course, no information presentation system can claim an absolute distinction between content and context. As we have seen above in the case of a hyperlinked information system, the content of a concept may well form the context of a set of other concepts. Therefore it is important for the flexibility of a conceptual navigator to allow a content component to be a concept map in itself. However, in order to maintain the separation between context and content, when a concept map (= context) appears as a form of conceptual content, it should not at the same time be treatable as a context. In order to be able to treat it in this way, we should first contextualize it, which transforms the (concept map) content component into a context. Hence we should add a sixth basic idea to the five listed above:

(vi) Transform a content component, which is a concept map, into a context by contextualizing it.

8.2 Merits of the above principles

8.2.1 Separate content from context

The basic principle of the conceptual presentation scheme presented here is to separate the relations between a set of concepts from the presentation of the content of these concepts (and relations!). The relations can then be expressed graphically, making use of some form of verbal-to-graphics mapping scheme, for instance UML as has been introduced above

In this way, the conceptual browsing process is naturally divided into two different modes that are termed *surfing* respectively *viewing*. as depicted in Figure (14). You surf the contexts (= concept maps) and view their respective contents (= components). Note that this usage of the term ‘surfing’ is consistent with ordinary web terminology.

In Figure (14) there is also a third mode of concept browsing, called *checking*, which is a “metadata mode” that allows the study of the labelling of the content, or the automated search for such components based on their respective labels. These labels include such information as *author*, *coverage*, *description*, *granularity*, *interactivity level*, *platform requirements*, *pedagogy*, *use rights*, *use support* etc. - all of which are part of the IMS metadata scheme.

When you "surf the web" in the normal mode, you have direct access only to the next level of forward links, a process which could be termed surfing with "forward-single-depth" link visibility. In contrast, when you surf/view the web according to the principles for conceptual browsing presented here, i.e. you surf the conceptual context and view the corresponding conceptual content, you have direct access to the content of all the concepts and relations that are represented on the context map, without losing the overview of the context. This could be described as conceptual browsing with "multiple-depth" link visibility.

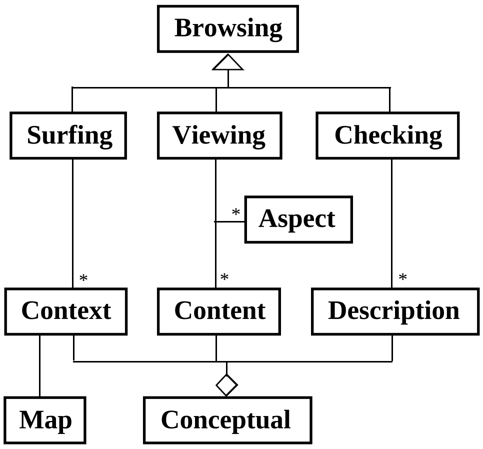

Fig. 14. Three different kinds (= modes) of conceptual browsing

8.2.2 Describe each context in terms of a concept map.

A concept map has several advantages in relation to a verbal presentation of the corresponding conceptual relationships. Two of these advantages deserve to be emphasized here.

First, a concept map breaks up the linear order of any verbal presentation of the depicted relations. It shows them all at the same time, as opposed to a verbal presentation that is forced to choose to describe them in a certain order. Any verbal presentation of a relationship between two concepts can be regarded as a journey (= navigated path) from one of the concepts to the other. A fundamental reason behind the advantage of a concept map in comparison to a verbal presentation when it comes to the creation of a contextual overview lies in the fact that our capacity to visually survey a conceptual relationship in different directions is considerably greater than our capacity to change the direction of the corresponding description verbally.

Hence, we can easier integrate the contextual information visually than verbally. In fact, this is the very reason why we use the term ‘overview’ instead of something like ‘overwords’ for the description of a such a contextual survey.

8.2.3 Assign contents, and filter it through a combination of aspects.

Second, a concept map creates an overall logical relationship between the depicted concepts. Both the concepts (= nodes) as well as the relationships (= arcs) of a context (= concept map) can be assigned a multitude of different components of content. Then the context can be navigated and the content be presented in a way that is filtered by a set of (configurable) aspects. Since the conceptual content is presented in a way that is totally separated from the conceptual context, it becomes possible to partake of the content without losing the overview of the context. The aspect filtration makes possible all forms of multiple scale narration techniques. An example of multiple scale narration (= story telling) from the field of mathematics is presented in the next chapter

8.2.4 Label the components with a standardized metadata scheme.

In Figure (14) there is also a third mode of concept browsing, called *checking*, which is a “metadata mode” that allows the study of the labelling of the content, or the automated search for such components based on their respective labels. These labels include such information as *author*, *coverage*, *description*, *granularity*, *interactivity level*, *platform requirements*, *pedagogy*, *use rights*, *use support* etc. - all of which are part of the IMS metadata scheme.

9 Conzilla - a first prototype

The first prototype of a concept browser designed according to the principles of Chapter (8.1) is the result of a cooperation between CID and TDB (Dept. of Scientific Computing) at Uppsala University. The prototype - called Conzilla[1] - has been developed and implemented under my supervision during the last year by Mikael Nilsson and Matthias Palmér - two students at TDB as part of their masters thesis work in computational science at TDB. Conzilla is discussed briefly below, and in detail in [(11)].

Conzilla makes use of the concept of *neuron* in order to represent general associations (= mindmaps), whose contents and relations can be associated with other maps (= contexts) as well as be equipped with (= assigned) a viewable form of content. A strong point of Conzilla is that it represents both its concepts and its maps in XML, which is the emerging standard language[2] for information mark-up, i.e. creating information labelling schemes such as e.h. HTML. Moreover, all the components of Conzilla can be labelled (= tagged) in accordance with the emerging IMS-metadata standard discussed above.

Conzilla can use any kind of mind-maps for contextual navigation and is capable of displaying separately the contents of the various nodes - as well as arcs! - of the maps. It supports the principles (i)-(iii) of Paragraph (8.1). Naturally, in view of the complexity of the programming tasks

1. The name was invented by Mikael and Matthias to suggest an analogy with the Mozilla project [www.mozilla.org]. However, CONZILLA can also be interpreted acronymically as CONZeptual ILLuminAtor.
2. For more information on XML, see e.g. [www.xml.org].

involved, this first version of Conzilla is still incomplete in several ways - lacking e.g. the aspect-filtering capability described in (iv). However, the program is logically well-structured (15.000 lines of Java-code) and forms a sound basis for future development. A future version of Conzilla will support principle (iv) as well, and hence will offer the possibility to filter the components of content with respect to a configurable set of different aspects. In fact, I don't think it will present much of a problem to attract good student-programmers that want to carry the program further within some programming project that forms part of their programming project education.

We plan to make Conzilla available on the web as soon as the support for the construction and editing of the concept-maps has improved a bit. Presently everything can be done - but the interfaces are still rather painful and un-intuitive. In fact, what it boils down to is editing the XML coded text-files "by hand"!

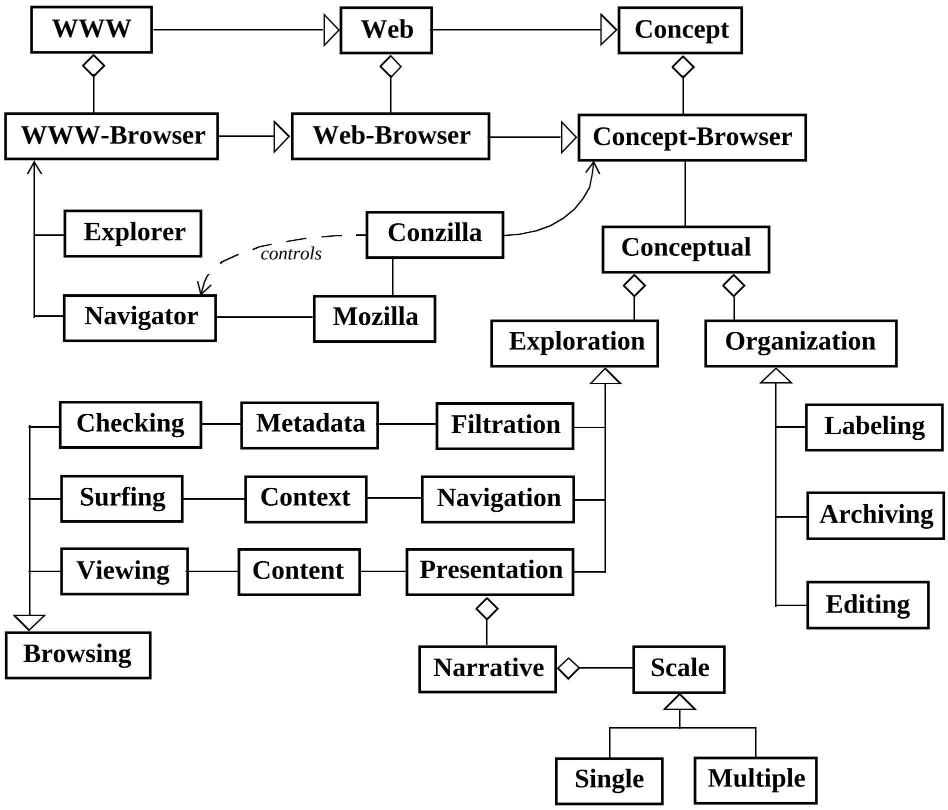

Fig. 15. A contextual overview of conceptual browsing

10 Browsing an Archive of Components at Multiple Scales

10.1 Introduction

In order to illustrate the design principles for conceptual browsing that have been discussed above, I will present an example of conceptual browsing of a mathematical component archive. I intend to construct this type of archive with the help of Conzilla, and I will present the example in terms of a future version of Conzilla, which will support all of the six design principles for the surfing/viewing/checking type of conceptual browsing that were discussed in Chapters (8.1) and (8.2).

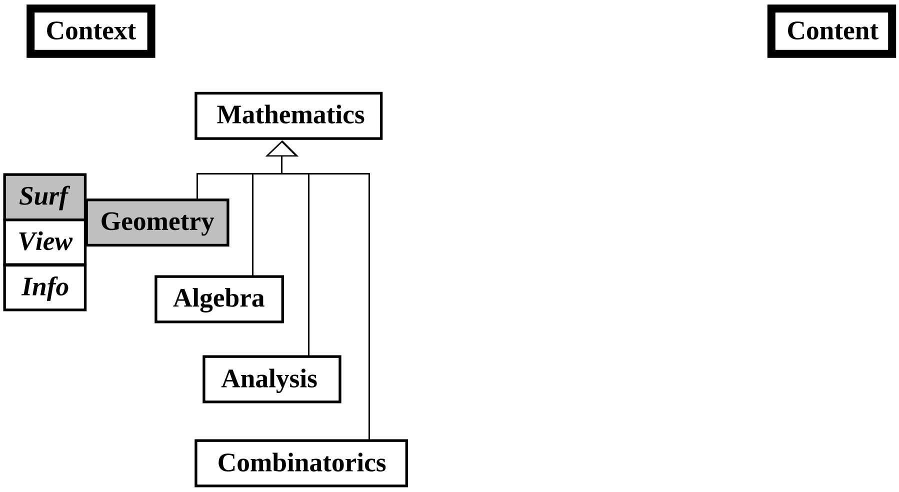

Fig. 16. Surfing the Context - Mathematics divided into four different subtypes.

10.2 Surfing the context

Figure (16) shows the field of *mathematics* subdivided into four different (sub)fields: *geometry*, *algebra*, *analysis* and *combinatorics*. A concept map has been loaded into the context (= left) part of the display window. Moving the cursor over the geometry box highlights it, which is shown shaded in the figure, and causes the appearance of the popup-menu to the left of the geometry box. This menu displays the options of *surf*, *view* and *info* (= *check*). Clicking on *surf* changes the context and leads to the concept map of Figure (17).

10.3 Viewing the content under 1-dimensional aspect filtration

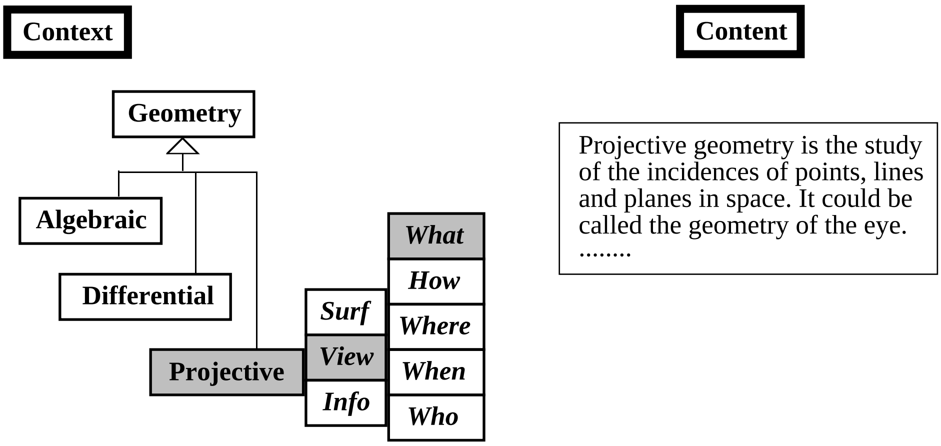

Fig. 17. Viewing the content under one-dimensional (list-based) aspect filtering. What is projective geometry (= conceptual aspect).

Here, the concept of *geometry* is subdivided into the (sub)fields of *algebraic* geometry, *differential* geometry and *projective* geometry. Pointing to the *projective* box highlights it and brings up the same pop-up menu as before. But now we choose *view* (instead of *surf*), which brings up the sub-menu shown to the right of the surf/view/info super-menu. The sub-menu represents a set of *aspects* through which the *contents* of the projective box can be *viewed* (= filtered). Figure (17) shows the conceptual (= *what*) aspect of projective geometry, which is displayed in the right part of the window.

10.4 Multiple scale narration

Figure (17) displays an explanation - at a certain level of *resolution* - of what projective geometry is about. By double-clicking on the content box we could change the resolution of the narrative and e.g. increase it in order to bring up more detailed explanations. This is an example of *multiple scale narration* based on one-dimensional resolution. An example of a two-dimensional form of multiple scale narration - based on the resolution dimensions of *clarification* and *depth* - is discussed below in connection with Figure (22) and Figure (23).

10.5 Two-dimensional aspect filtration

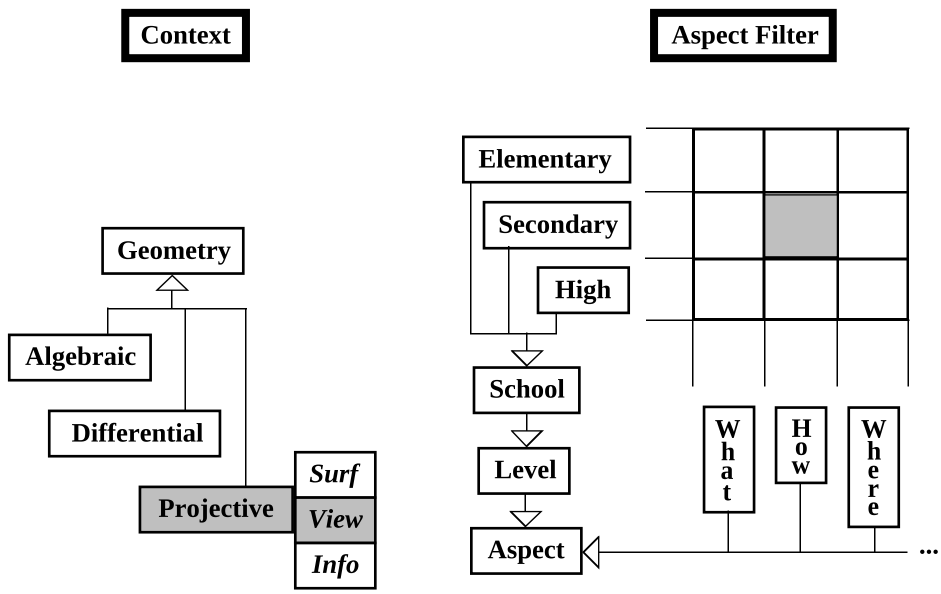

Fig. 18. Viewing the Content under 2-dimensional (matrix-based) aspect filtering. All other aspects are combined with the school level aspects.

Figure (18) illustrates another type of multiple scale narration, which is called 2-*dimensional* (or *matrix-based*) *aspect filtering*. The *elementary*-, *secondary*- and *high-school-level* aspects are combined with the rest of the aspects (*what*, *how*, *where*, ...). For example, the content corresponding to the combination of *secondary-school-level* aspect and the *how* aspect is displayed by clicking the corresponding position in the matrix, which is shaded in the figure. It is interesting to observe that many computer games exhibit a similar type of filtration, where the level aspects (novice, beginner, middle, advanced, expert) affect the behaviour of the game in many ways.

10.6 Multiple scale narration with 2-d resolution based on clarification and depth

In Figure (19) the concept of *mathematics* is shown in the context of itself. A new display structure has been added here in comparison with before, namely the 2d-scrolling window at the upper right, which is for changing the "resolution of presentation" of the content. By scrolling to the right, we increase the clarification of the presentation, and by scrolling upwards we increase its depth. The idea is that if you don't understand a certain presentation, you can increase the clarification and get different types of explanations involving the same concepts. When you understand, you can instead increase the depth, and get descriptions that bring in more concepts and expands on the simpler (= less deep) description.

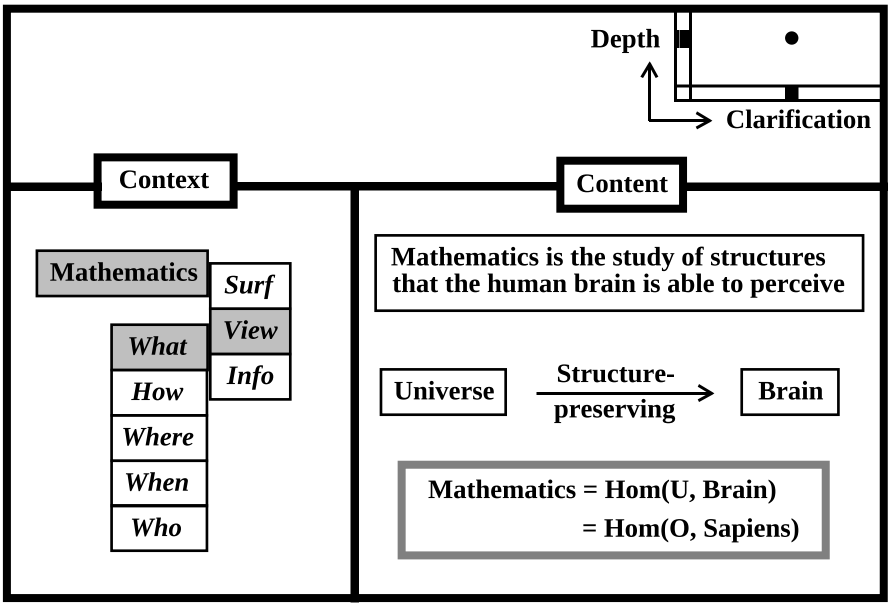

Fig. 19. Conceptual Browsing - What is mathematics?

Figure (19) displays the content of the mathematics box under the aspect of *what*. Changing the aspect from *what* to *how* leads to the display of Figure (20), which shows *how* mathematics is performed (= the *algorithmic* aspect).

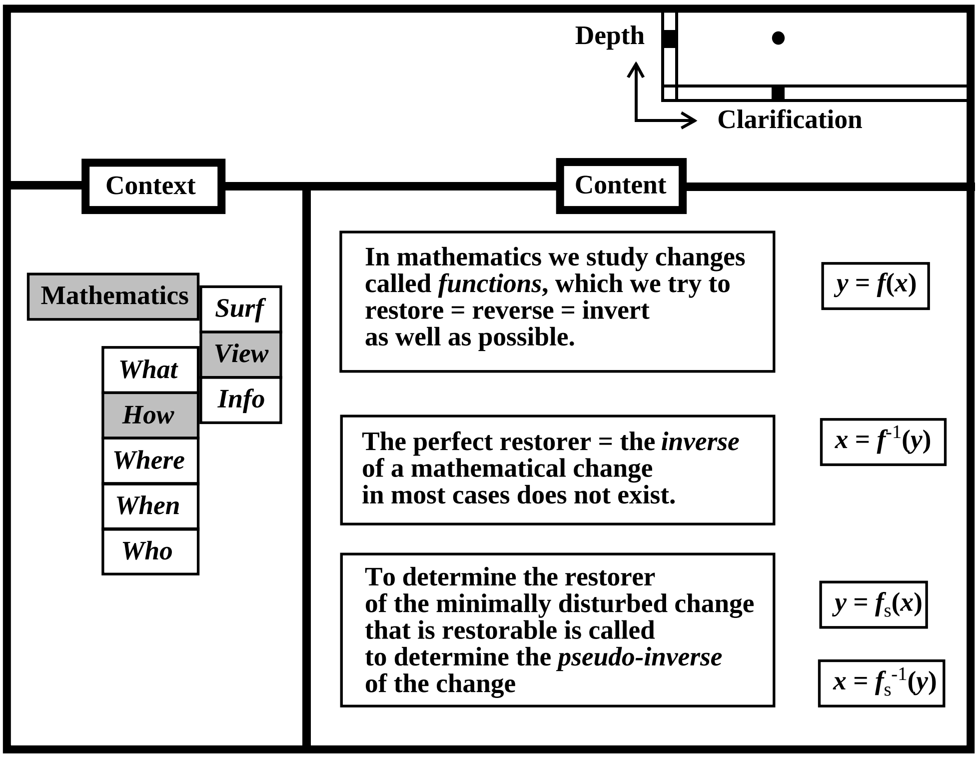

Fig. 20. Viewing the Content: How do we perform mathematics? Operational (= algorithmic) aspect.

Changing again the aspect from *how* to *where* leads from Figure (20) to Figure (21). Since the content is a concept map, a *contextualize* button appears at the top of the window - in accordance with design principle (vi) of Chapter (8.1).

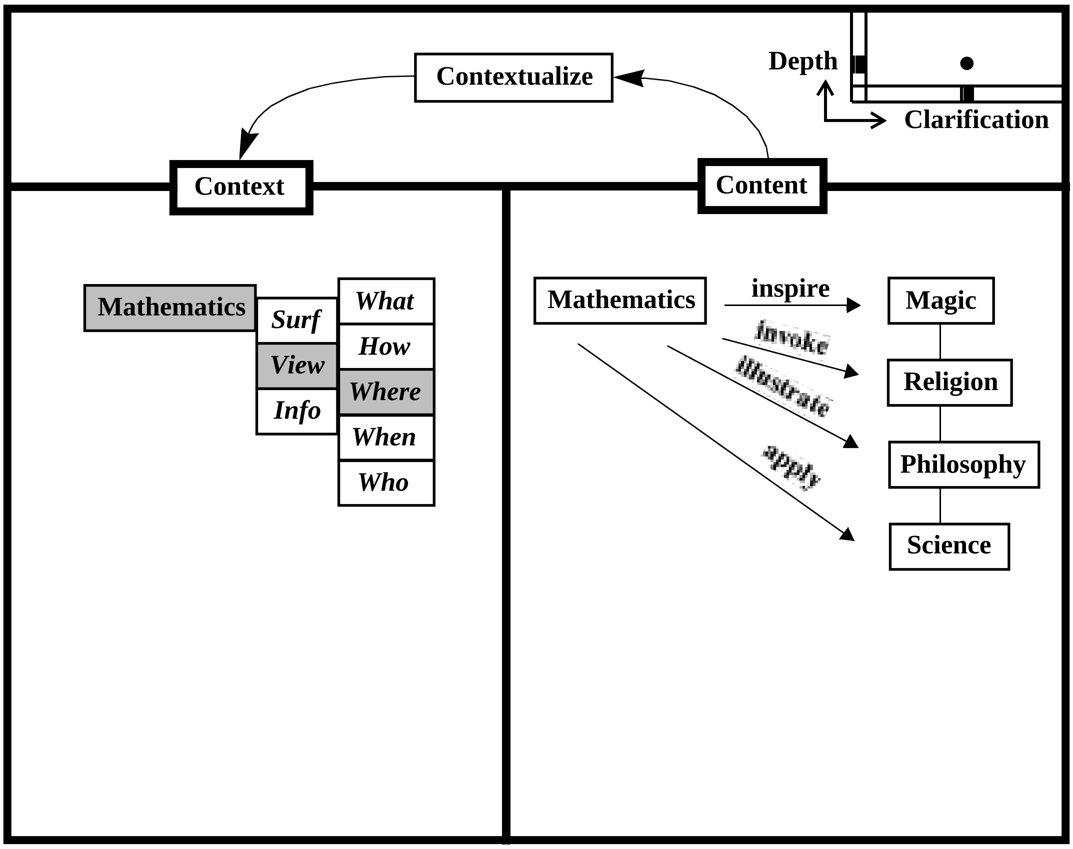

Fig. 21. Viewing the content of mathematics under the aspect of *where*: Where do we perform mathematics?

Clicking the *contextualize* button moves the concept map of Figure (21) from the content window to the right into the context window to the left, and makes it amenable to context-surfing and content-viewing. Following this action by pointing to the arc (= relationship) named *apply*, and viewing the content of this relationship under the aspect of *how*, leads to the display of Figure (22), which shows *how mathematics is applied to science*.

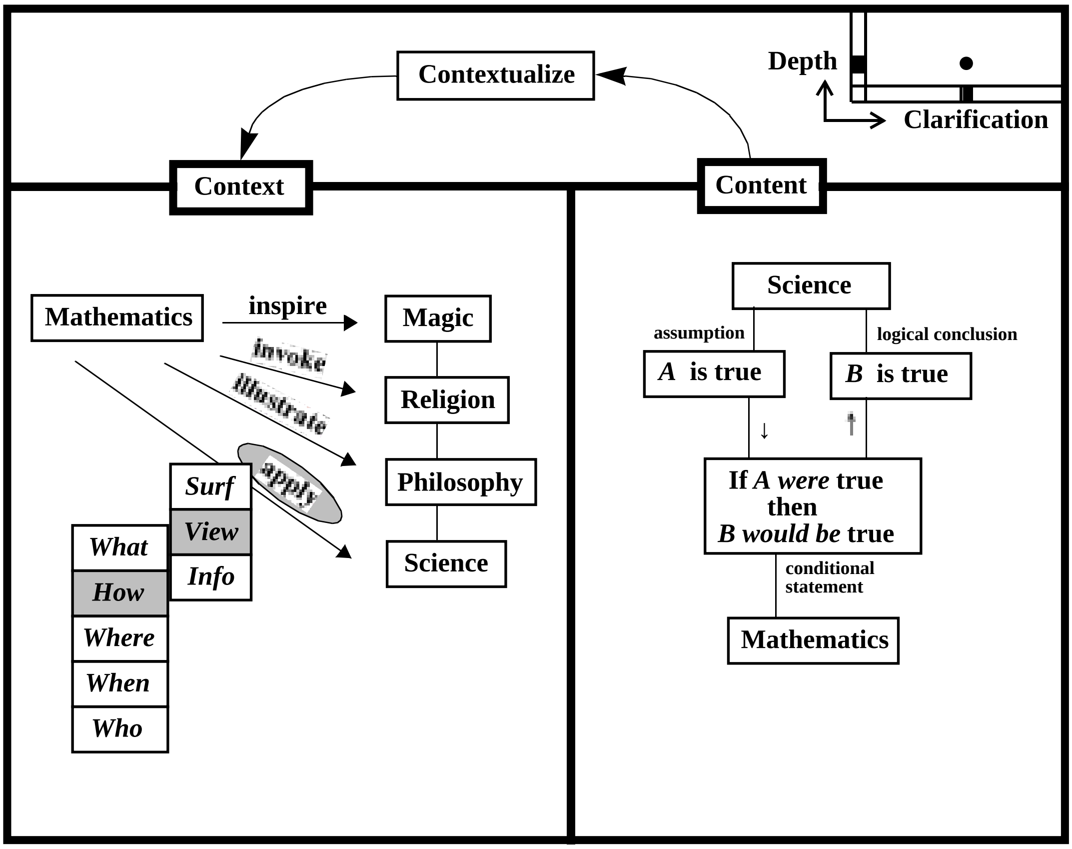

Fig. 22. Viewing the content of the arc named *apply* (ing mathematics to science) under the aspect *how*: How do we apply mathematics to science? - First level of depth

Figure (22) displays an explanation of this question at a minimum (= first) level of depth. Mathematics is described as a set of conditional (= hypothetical) statements. Science makes use of the logical reasoning of mathematics (A => B) in order to transform an assumption (A is true) into a logical conclusion (B is true).

Note that on this (minimum) level of depth there is no explanation of *why* science wants to transform assumptions into logical conclusions. If we increase the level of depth (by scrolling along the depth-dimension of the resolution window), we get the configuration of Figure (23), which displays such an explanation - as an addition to the earlier content of Figure (22). From Figure (23) it is seen that science transforms hypothesis into logical conclusions in order to be able to subject them to *falsification* attempts by the process of *experiment*. The point is that the logical conclusions are (in general) much easier to subject to experimental testing than the initial hypothesis from which they have been logically (= mathematically) derived In this way science "closes the loop" and the hypotheses whose logical conclusions survive the experimental attempts at falsification are (gradually) transformed into scientific *facts*.

By increasing the clarification (instead of the depth) we would end up with another illustration of the content of Figure (22) - maybe in terms of a concrete example of the transformation of hypothesis into logical conclusion. The important point is that the learner controls the resolution window, and therefore can postpone the deeper levels - and move along the direction of clarification, until he or she is ready for more depth of explanation.

Note that the *point* of the resolution window can be thought of as a *graph* (= map) that introduces a kind of “conceptual dependence topology” on the various components of content (= explanations), which displays the conceptual dependence between them.

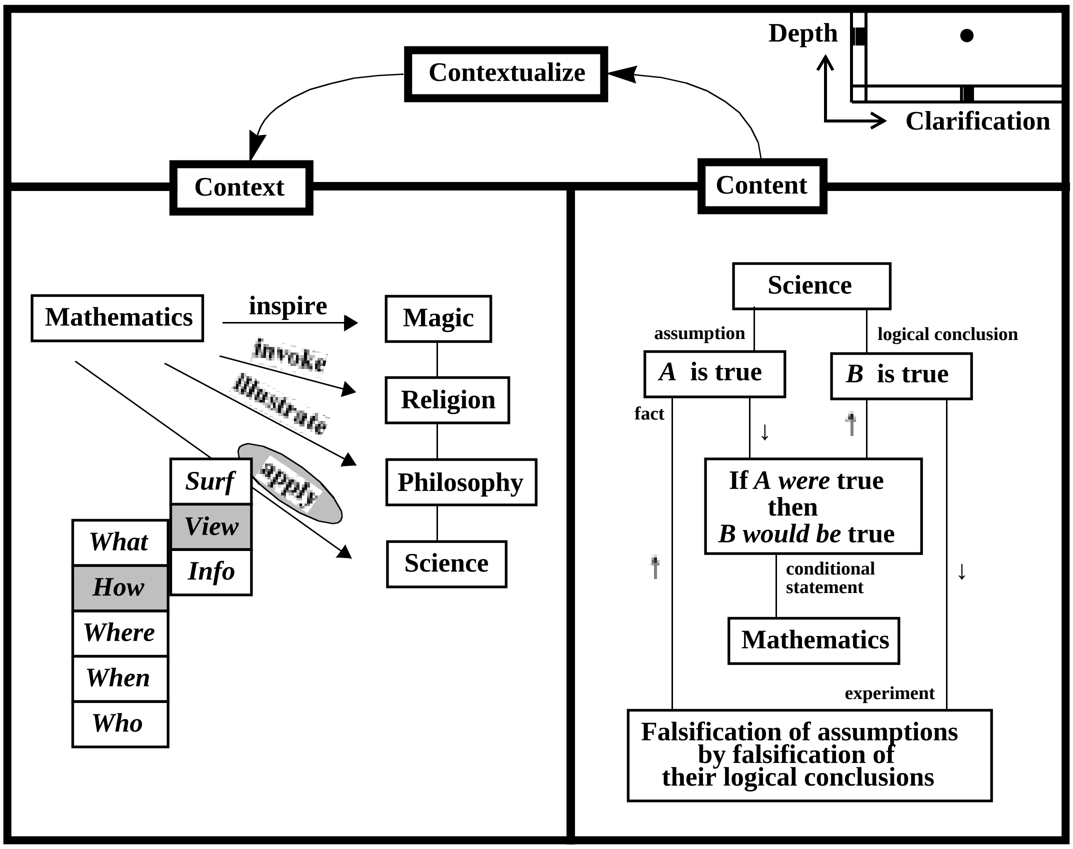

Fig. 23. Increasing the depth: How do we apply mathematics to science? Next level of depth

10.7 Philosophical interlude

Further increasing the level of depth might lead to the diagram displayed in Figure (24), which is shown in isolation for reasons of convenience - since it is too big to fit into the content window.

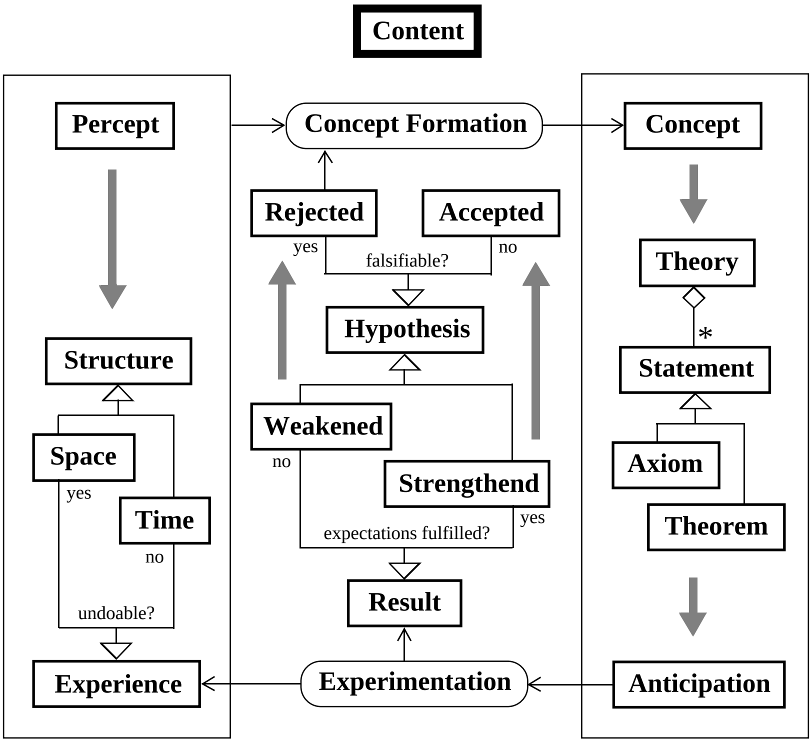

Fig. 24. Viewing the content: How do we apply mathematics to science? Deeper level.

Figure (24) illustrates how we strive to give structure to our perceptions by theoretical reasoning, which organises a set of concepts into a theory by grouping them into two classes: axioms (= starting points) and theorems (= logical conclusions). A theory in turn generates anticipations (= hypotheses), which sometimes can be tested by experimentation. If the outcome of an experiment is ‘as expected’, the corresponding hypothesis of the theory is strengthened, and if the outcome is unexpected, the tested hypothesis is weakened. Through repeated iteration over time, this leads in the former case to a canonization (= acceptance) of the hypothesis as a fact, or in the latter case to a rejection of the hypothesis. A rejection in turn leads to concept formation, where new concepts are introduced in order to clarify the structure of the perceptions, which in turn modifies the theory.

Figure (24) also displays the perceptions grouped into two fundamentally different classes: the *undoables* and the *un-undoables*. The undoable perceptions correspond to the changes that can be reverted, while the un-undoable perceptions correspond to the ones that cannot. Hence, the undoable perceptions constitute the foundation for our concept of *space*, while the un-undoable perceptions form the foundation for our concept of *time*. See [(10), pp 97-101] for a more thorough discussion of these matters in terms of participator consciousness.

By surfing on the concept of *concept formation*, which connects the perceptions from outside with the concepts from inside, we might arrive at something like the diagram shown in Figure (25).

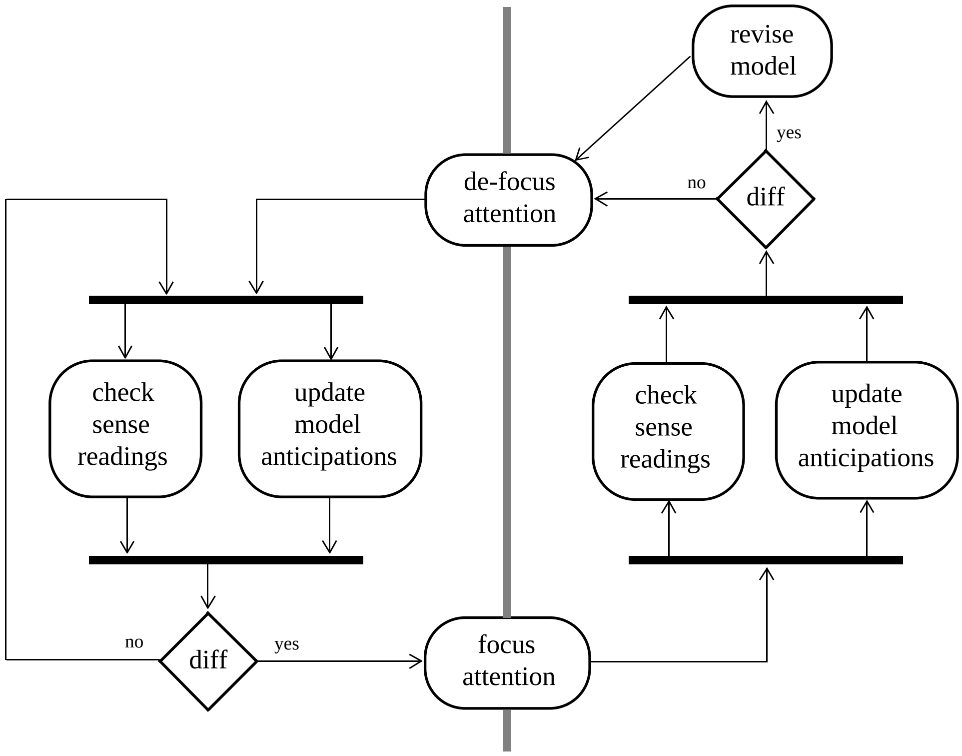

Fig. 25. An activity diagram that models our way to use conceptual models.

This is an example of a type of UML chart which is called an *activity diagram*. It makes use of rounded boxes to denote activities, thick black lines - called synchronization bars - to denote activities that are performed in parallel, and diamond shaped boxes to denote decisions. The thick dashed line in the middle is non-standard UML and is used here to separate between the conscious part (≈ foreground) and the subconscious part (≈ background) of our mind.

The purpose of a model is to simplify experience in a way that focuses on the essentials by disregarding the unessentials. Simplification is fundamental to our consciousness, since we have to deal with our sensory input channels, that have a total bandwidth of more than 10 million bits/second, by making use of our conscious mind with its bandwidth of about 15-30 bits/second.

Figure (25) shows how we run a kind of "mental background process" that checks the differences between what we perceive and what our model anticipates. Until we experience a difference, this process can be kept in the mental background (= de-focused attention space). When we experience a difference between what we perceive and what the model anticipates, we react by focusing attention and running the same process in the mental foreground (= focused attention space). If the difference is not there, then it was a "false alarm", and the process can be returned to the mental background again, but if the difference persists, then there was really “something else” going on out there, and we are forced to revise our model before we can return the process to the background by de-focusing our attention from it.

10.8 Manipulating the context of a concept

After this rather philosophical detour, let us return to the concept of mathematics. Figure (26) shows a more sophisticated way to manipulate the context of concept. By selecting e.g. *mathematics*, and choosing *change-context*, we get a display of all the different contexts (= concept maps) within which the concept of mathematics appears. By checking the boxes corresponding to *subfields* respectively *thinking*, we bring up the corresponding contexts, which are displayed in the figure.

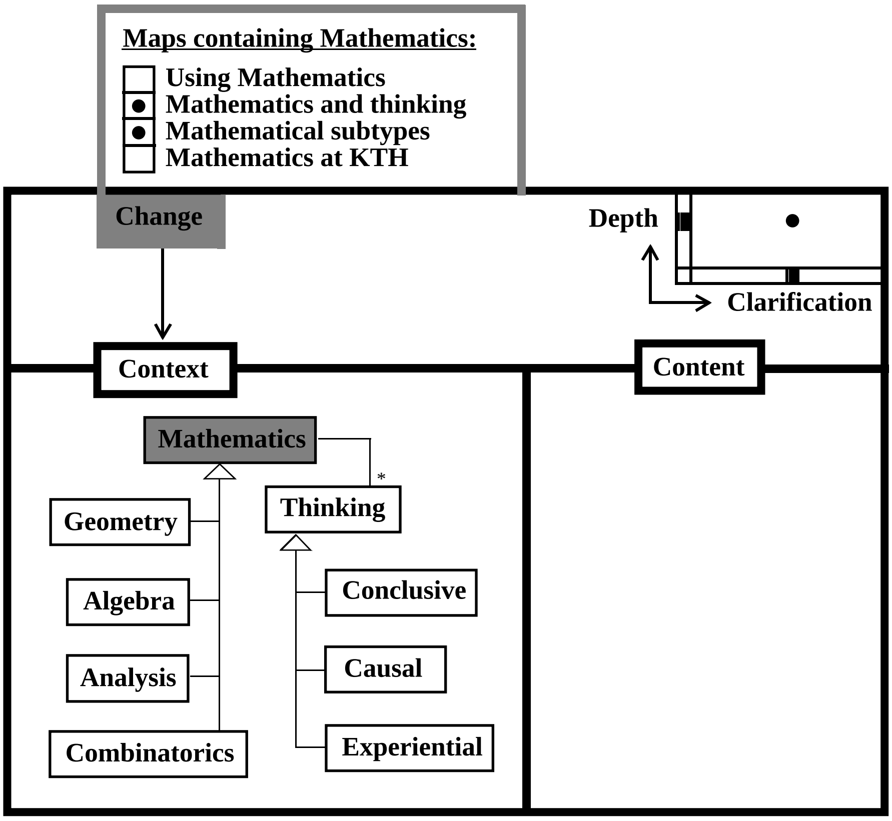

Fig. 26. Conceptual surfing - manipulating the context of mathematics

10.9 Assigning contents to combinations of concepts

Figure (26) illustrates a way to break up the contexts into simple parts, which can be displayed in arbitrary combinations. This makes it possible to assign contents not only to single concepts and single conceptual relationships - as we have done up to this point - but to arbitrary *combinations* of concepts (and conceptual relationships).

The capacity to handle contents of conceptual combinations greatly increases the usefulness of a concept browser. An example of this is shown in Figure (27).

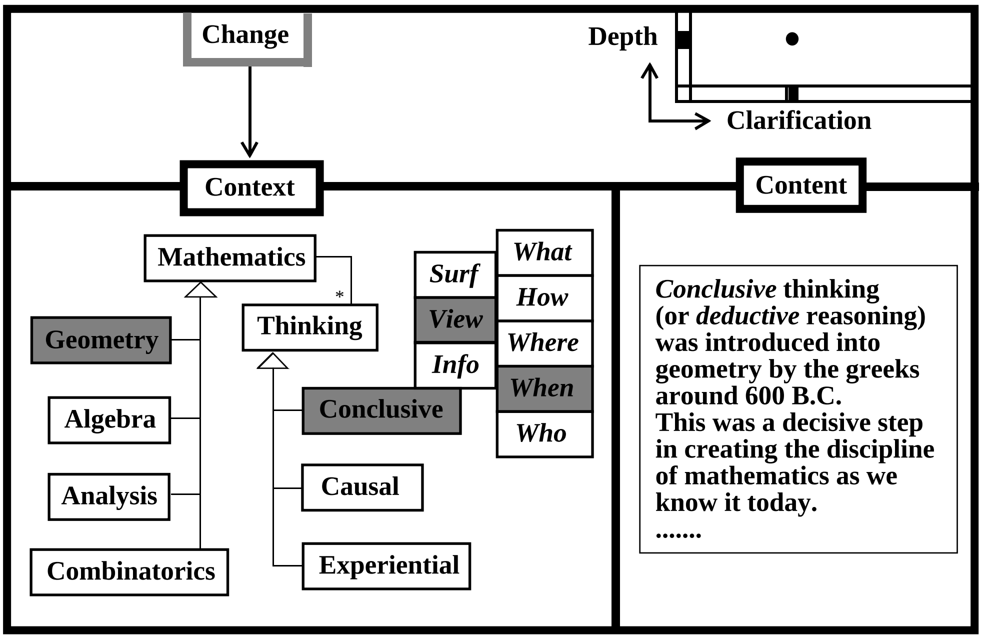

Fig. 27. Viewing the Content: *When* was *conclusive thinking* introduced into *geometry*?

Here, we have selected *geometry* and *conclusive,* and then chosen to *view* the content of this combination of concepts under the aspect of *when*. The corresponding content of this aspect of the selected conceptual combination appears to the right (in the content-part of the window).

10.10 Overview of mathematical concepts at the university level

For pedagogical reasons, the mathematical concept maps shown so far have been rather simple. Figures (28), (29) and (30) show three examples of what a more complicated mathematical concept map might look like. Besides displaying the basic conceptual ingredients of a mathematical university curriculum, they illustrate the importance of being able to manipulate the context in some way - as exemplified above - in order to suppress unwanted details. At the same time these maps convey a contextual overview which would be hard to produce in the same available space using non-diagrammatic techniques. Hence, the depicted diagrams are of value to students as a way to internalize their understanding of how the mathematical concepts fit together. They could also serve as a basis for mathematical knowledge sources to declare their respective competence profiles, which forms the basis for a helpdesk answering system, as discussed in chapter (4.6) above.

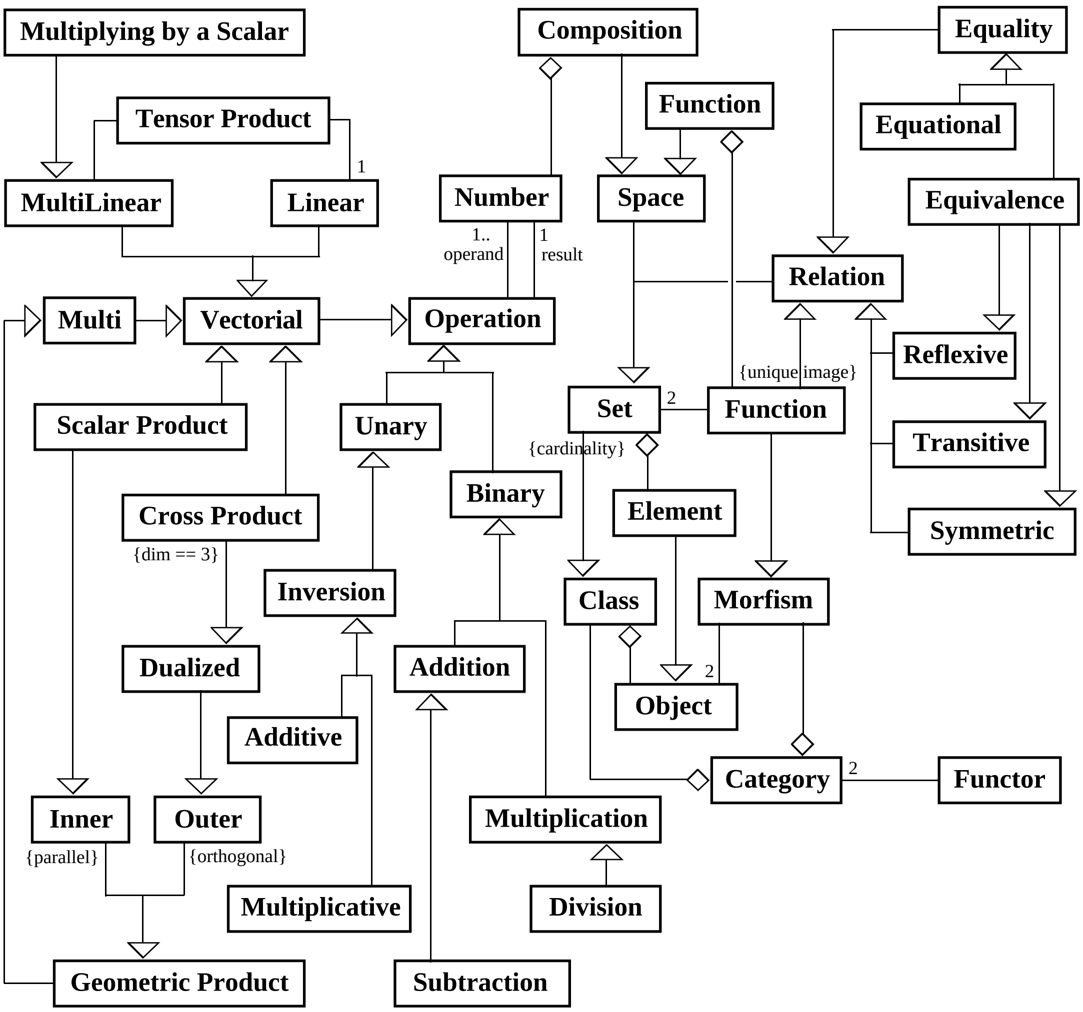

Fig. 28. A relational overview of some important mathematical concepts

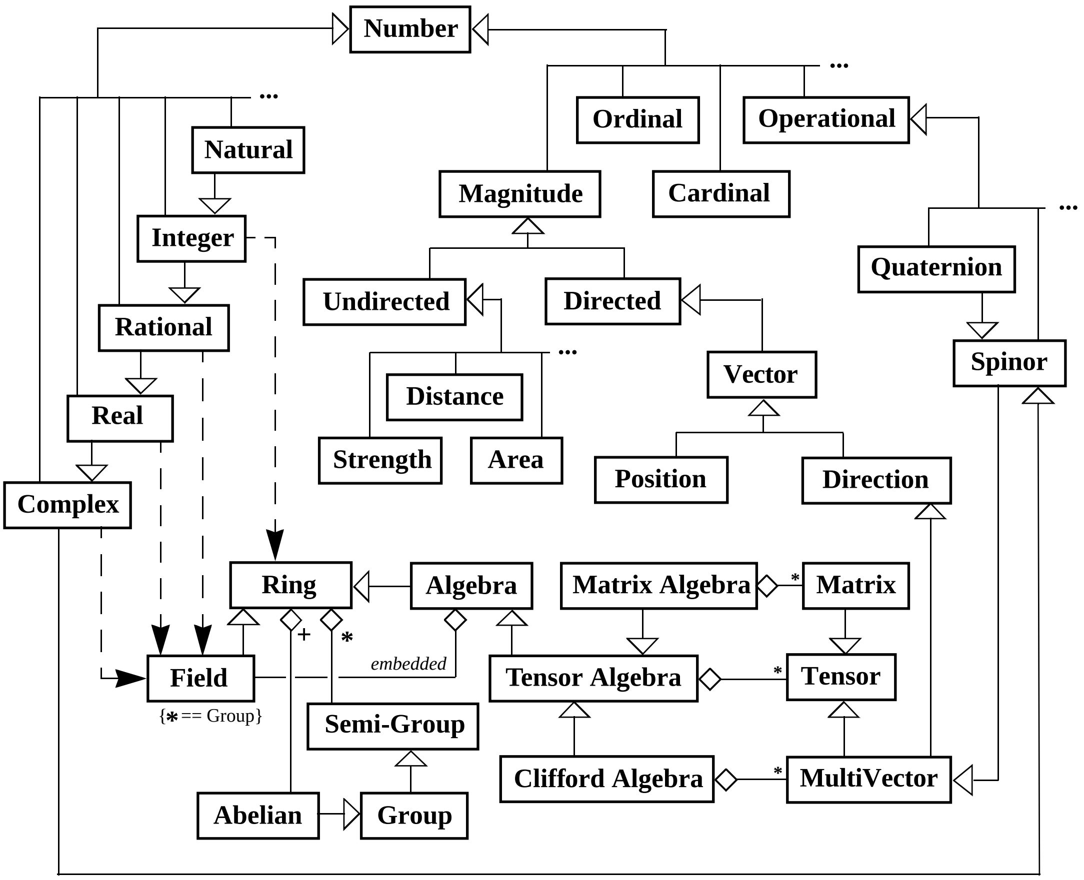

Fig. 29. A relational overview of the concept of number

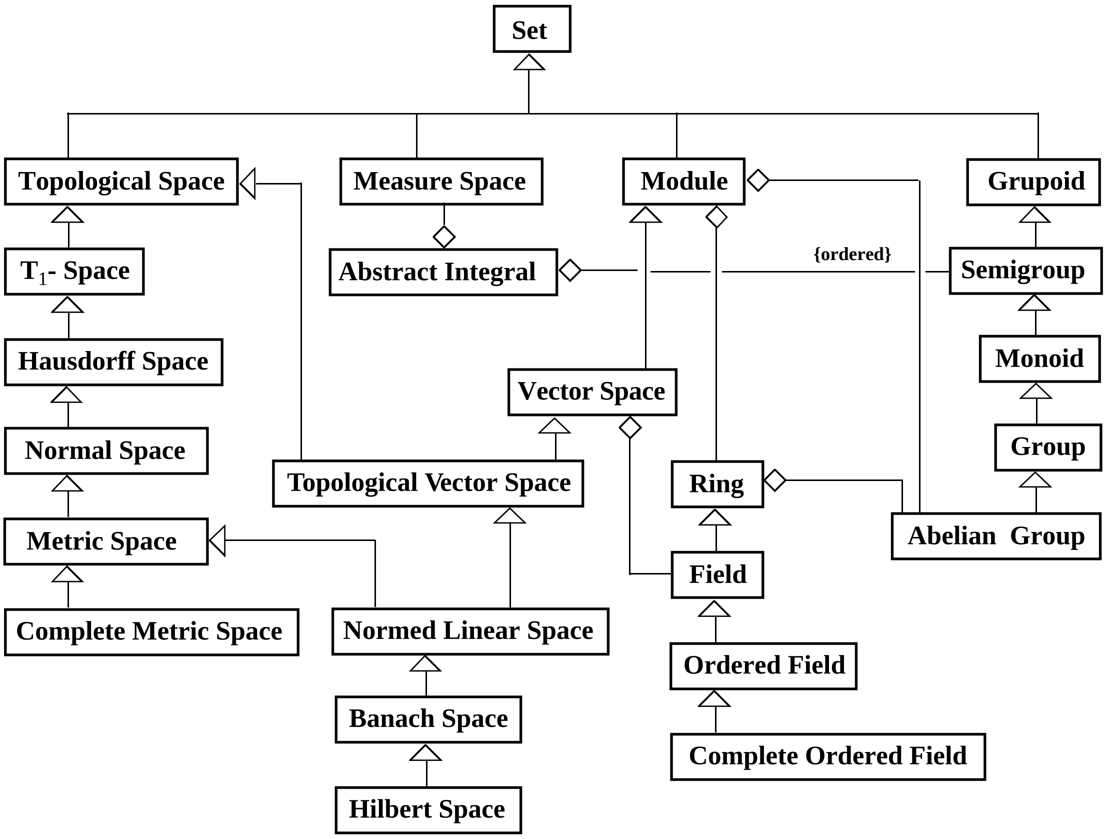

Fig. 30. Relations between some of the modern mathematical concepts that have evolved from the concepts of continuity and arithmetic.

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