4

The INTUITEL Approach: Foundations and Design

This chapter explains the modelling in the INTUITEL approach. It picks up the idea of using ontologies and reasonig to model didactic expertise from the previous chapter. The concept of the ontology of pedagogies, the idea of learning pathways and the learner model are described. Didactic factors are introduced. The model how they are used to deduce recommendations and feedback in real-time is developed. In the fourth part we describe the software architecture and in the last part the data model and communication standard is explained. The decision for semantic technologies and the OWL2-specification is justified.

4.1 Pedagogical Ontology and Reasoning

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An ontology needs to be consistent from a technical perspective [35]. In contrast, teaching and learning is inconsistent due to the artistic nature of educational actions. Thus the challenge is to build an inconsistent consistency, that is an ontology that opens up a consistent room which is necessary to meet the logical structure of computer technology and that allows for the creative design of teaching and learning processes. The gap that is indicated by this contradiction can be filled by teachers and students when playing with the system.

We suggest to provide a meta data system, a learner model and a reasoning engine as tools to create learning environments. The meta data system allows teachers to describe different possibilities to learn certain content. It can be formulated logically in an ontology in the Web Ontology Language. The flexible elements are circled around learning pathways. The learning pathways, defined as relations between concept containers, between knowledge types, and between media types can be altered by teachers and by learners. If a teacher, for example, prefers other steps than suggested by a didactic model, he can mix those steps with steps from other pathways or create steps. While doing so, he plays with the teaching and learning models that were applied while creating the meta data system. Some basic teaching and learning models are suggested (Inquiry Based Learning, Multi Stage Learning), but the teacher neither has to follow these models nor to apply these models at all. He is always free to create his own learning pathways and offer them to the learner.

Thus, the meta data system allows teachers to play with various teaching models. Still, he has to describe his learning material with this meta data. In his game he still uses the meta data system, but as a toy. Since the teacher uses the meta data system an automatic reasoning engine is still able to react on the results from teachers play. Since the learning material and the meta data developed by the teacher is offered to learners they can use these to play too. If for example a teacher creates a learning sequence, the learner can learn the material backwards or in any creatively created order. This order can automatically be identified, converted in a personal learning strategy and applied to further material. Since the different learning pathways and the descriptions are offered to the learner, a flexible room is created where learners can play with learning models.

Understanding teaching and learning (at least partly) as play and computer technology as a toy used to create a playground sheds some light on the position that is taken when creating a pedagogical ontology for machine support in didactic practice: we are creating a game for people who play a ”create a game“ game. With computer technology, the playground can be best modeled by an ontology [69]. This form of a semantic network specifies the rules of the game. In order to do so, it is necessary to open up different possibilities for expressing ideas of teaching and learning creatively. Still, some rules have to be set when creating games. In order to keep the possibilities open, these rules can be developed from an analysis of computer technology as a medium, since the properties of a medium applied in teaching and learning always limit the possible actions.

The consistent part of the ontology we propose consists of a three level meta data system for learning objects [66]. Learning Objects include instructional scaffolding such as learning objectives and outcomes, assessments, and other instructional components, as well as information objects [67]. We accommodate the levels of learning objects by using three types of Learning Objects: (1) Knowledge Domain (Course Level), (2) Concept Container (Lesson Level), and (3) Knowledge Objects (Content Level).The term Knowledge Domain refers to a certain amount of knowledge, which is defined by a specific curriculum, syllabus and/or course requirements.

One Concept Container contains one instructionally framed concept within a Knowledge Domain. A Concept Container is a container for one or more Knowledge Objects (KO). A Knowledge Object is an item of knowledge, which typically corresponds to about one screen page of content and to an estimated learning time of 3–10 minutes for the average learner. A KO might contain learning content as well as learning activities such as a discussion in a forum, an assignment where a video has to be handed in or reading an explanation. Knowledge Objects are described by a pedagogical knowledge type and a media type. Concept Containers and Knowledge Objects can be connected by relations.

In order to support different learning pathways, a vocabulary has been developed. The vocabulary for the Concept Containers is intended to express the structure of the knowledge domain. It considers the hierarchical relations has child, has parent, and has sibling as well as the chronological relations is before, is after and is beside. The vocabulary for the knowledge types is intended to express pedagogical concepts. The vocabulary for the media types is also intended to express pedagogical concepts.

4.1.1 Learning Objects

The INTUITEL ontology is based on the concept of learning objects. Learning Objects include instructional scaffolding such as learning objectives and outcomes, assessments, and other instructional components, as well as information objects [67]. INTUITEL will accommodate Metros dimensions of learning objects by using three types of learning objects:

1. Knowledge Domain (Course Level)
2. Concept Container (Lesson Level)
3. Knowledge Objects (Content Level)

Thus, learning objects contain learning objects of different object types (see figure 4.1).

The term knowledge domain in general refers to the part of the world investigated by a specific discipline. In INTUITEL, the term knowledge domain refers to a certain amount of knowledge, which is defined by a specific curriculum, syllabus and/or course requirements. In INTUITEL four part-

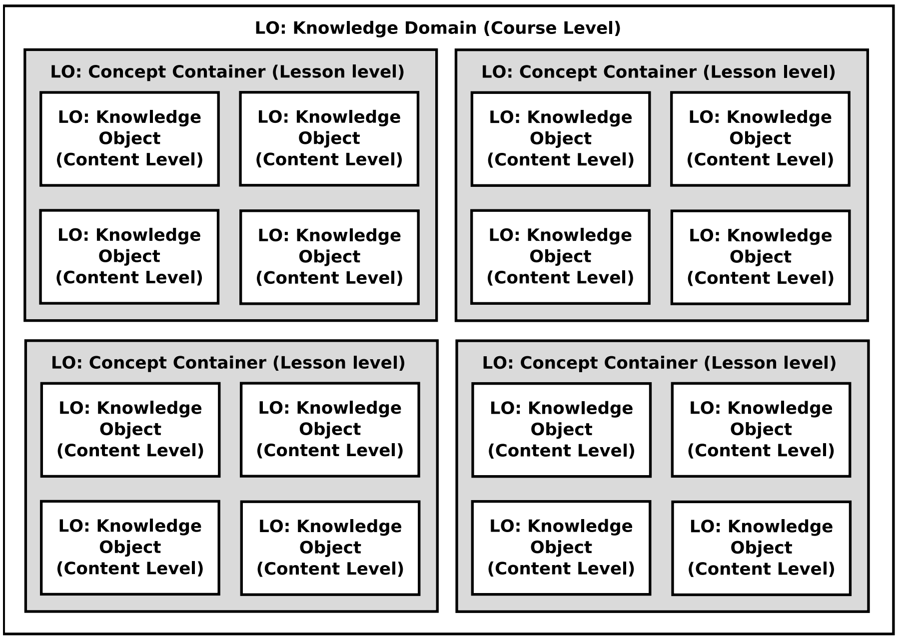

Figure 4.1 learning object hierarchy in the pedagogical ontology of INTUITEL

ners (IOSB[1], URE[2], UVA[3], UVIE[4]) will provide four cognitive models of four different knowledge domains, which correspond to the different example courses of INTUITEL. Knowledge Domains consist of several concept containers. Course is a synonym for knowledge domain. Knowledge Domains have a title and consist of knowledge containers.

One Concept Container contains one instructionally scaffolded concept within a knowledge domain. Concept containers are part of a knowledge domain. Concept containers are linked by typed relations within the knowledge domain. Concept containers are assembled and structured corresponding to the logic of different pedagogical concept container models that are derived from learning pathways and expressed by the typed relations. Concept containers have a title, typed relations to other concept containers, and are part of a knowledge domain.

[1] Fraunhofer Institute of Optronics, System Technologies and Image Exploitation
[2] Universiy of Reading
[3] University of Valladolid
[4] University of Vienna

Knowledge objects contain about one screen page of content and correspond to a learning time of 3-10 minutes. A knowledge object covers mainly one knowledge type and one media type. The content of a knowledge object can be anything like

- a discussion in a forum (knowledge type: discussion, media type: text),
- an assignment where a video has to be handed in (knowledge type: hand in assignment, media type: video)
- reading an explanation (knowledge type: explanation, media type: text).

Knowledge objects are assembled and structured corresponding to the logic of different pedagogical knowledge type models and media type models that are derived from learning pathways. Knowledge objects have a learning time, a knowledge type, a media type, are part of a concept container and consist of content.

4.1.2 Vocabulary of Knowledge Types

Knowledge Types are due to didactical requirements. However, this structure of knowledge must be always seen as preliminary, because it can only be structured according to the goals of the knowledge type structure. Knowledge types are structured by means of the function within the learning process. This is the didactical goal of the organization of knowledge for the learning process. Functions within the learning process are presentation (receptive knowledge), trial (interactive knowledge) and communication (cooperative knowledge).

Receptive Knowledge Types

Receptive Knowledge Types (e.g. Orientation, Explanation) contain media for presentation. Within the media, the knowledge is displayed but without changing the presentation because of the media. The presentation is static. The learner is receiving the knowledge but is not active beyond that. Receptive knowledge may be orientation, explanation or source knowledge.

Orientation Knowledge gives orientation in one field. Knowledge is orientation knowledge, if it is naming and relating the field with other knowledge and if it can be connected to previous knowledge of the learner. This knowledge is represented in terms of: facts, history, news, log, overview, knowledge map, abstract, and scenario.

Knowledge is an explanation, if it gives reasons for representations or claims. An explanatory statement is necessary, because representations can always be different. An explanatory statement for a representation names the method, which is used by the representation. Explanatory Statements are arguments, examples, descriptions, interviews, comments, definitions, exemplifications or ideas/tips.

Sources answer the question as to find information. If a person is in possession of sources, he/she can answer the question ”where to find knowledge“. Therefore, the sources must be published and known. References on sources are made through indications of sources. Sources differ in types. Important types of sources are link lists, list of literature and downloads (which can be addresses or archives).

Interactive Knowledge Types

Learning items with interactive knowledge contain knowledge, whose presentation is influenced by the activity of the learner. The activity of the learner within the learning process is very useful if knowledge can be learned in an explorative way and if this knowledge can be proved in action, or the knowledge is tested within an assignment.

Cooperative Knowledge Types

A didactical cooperation is a communication between humans, in which they work together on a certain topic in order to understand each other above expertise. Cooperative knowledge items are essential in order to react on unscheduled required knowledge. Cooperative Knowledge can be procured planned or spontaneous.

4.1.3 Media Type Vocabulary

Communication

Communication Media Types are described as tools for people to communicate directly with each other. In this list are only media types which are used online within networked computer technology. This may – for example – comprise chats, audio-conferences, video-conferences and shared applications.

Interaction

An example for interactive media types are forms, where structured documents with blank spaces have to be filled out for further processing via a

LMS. These blank spaces, which have to be filled out by the learner can be check boxes, radio buttons, lists, etc. Another example are interactive videos, where the user can at least interact via stop-and-go-functions with the computer. It would get better if the learner could also influence the plot of the interactive video.

4.1.4 Learning Pathways

Theoretically learning pathways can be deduced from the logical structure of a knowledge domain that is expressed in the typed relations. In practice this would require a very well written hypertext with precise typed and set relations. Unfortunately, authors tend to make little mistakes considerably in larger courses. Additionally, authors would need to know a lot about the logic of the Adaptive Assistant System in order to predict the outcomes that will be created based on their input. Finally, the automatic deduction of learning pathways would restrict authors to the pathways that are predefined in the system. Since there are hundreds of models for teaching and learning available and new ones created very often, this restriction does not make much sense. It would just create a tendency to undermine the theory-pratice transformation competence of teachers. And that should be avoided.

Thats why in INTUITEL the simple possibility to set different learning pathways among the same learning objects is considered. The learning pathways have to be set as directed acyclic graphs. No further restrictions apply. In addition to setting the learning pathways the teachers have to create a description that supports the learner in the pathway selection. Since Concept Containers and Knowledge Objects are distinguished, Macro Learning Pathways among Concept Containers and Micro Learning Pathways among Knowledge Objects are possible. The Macro Learning Pathways are on the level of the Content Container within one Knowledge Domain. The Macro Learning Pathways describe how the learner might proceed within one Knowledge Domain. Within one Knowledge Domain, there can be more than one Concept Container. These CCs are assembled and structured by learning pathways. The pathways are expressed by typed relations. In an example Knowledge Domain four Macro Learning Pathways have been used by the teachers:

- Chronologically from old to new
- Chronologically from new to old
- Hierarchically top down

- Hierarchically bottom up

Concept containers have a title, typed relations to other concept containers, and are part of a knowledge domain. The Micro Learning Pathways are on the level of the Knowledge Objects in one Concept Container. The Micro Learning Pathways describe how the learner might proceed within one Concept Container.

Within one Concept Container, there can be more than one Knowledge Object (KO). If there are many Knowledge Objects, they are assembled and structured by learning pathways. In INTUITEL there were three Micro Learning Pathways created by teachers for testing purposes:

- the Multi Stage Approach
- the Inquiry-Based Learning Approach
- the Programmed Instruction Approach.

An example meta data set for one Knowledge Object is listed in table 4.2.

This meta data describe a seven minute video about Comenius. For an improved readability, only one Micro Learning Pathway is reproduced here. These meta data are used as an input for the learning analytics integrated in INTUITEL. The results of learning analytics are used for adaptations, recommendations and feedback.

Meta Tag	*Value*
ID	KO_ComeniusOrientierungVideo LMS
Project	INTUITEL
Licence	Creative Commons Attribution Non-Commercial Share-Alike 3.0 Unported License
Author	Christian Swertz
Date	4.9.2013
KnowledgeDomain	General Didactics
ContentContainer	Comenius
KnowledgeType	OrientationReceptive
MediaType	VideoReceptive
MicroLearningPathways	KO ComeniusOrientierungVideo isMoreConcreteThan KO ComeniusOrientierung-Text
Level	All
EuropeanQualificationFramework	LearnerEqfLevel6
EstimatedLearningTime	00:07:00
SuitableForBlind	Learner IsNotBlind
SuitableForDeaf	LearnerIsNotDeaf
UnableToSpeak	All
Age	LearnerIsChild
Gender	All
Lang	De-de
ScreenMinimum	320x240
ScreenRecommended	640X480
Subtitle	None

Table 4.2 Example meta data for a knowledge object about Comenius

6.4 Conclusion

We have defined four universal criteria a learning environment has to satisfy to be adaptive with respect to learning style, behavior and preferences of individual learners. Firstly, Didactic Factors have to be retrieved by measuring correlated indicators. Secondly, these factors have to be transformed into a machine-processable form. Thirdly, the Didactic Factors have to be annotated to learning content, together with didactic relations between pieces of learning content. Fourthly, the learning environment deduces the according instructional design from this formal representation.

INTUITEL satisfies the second, third and fourth of these requirements. With the Hypercube Database project we aim to close the gap to the first requirement, designing and developing a research tool for the analysis of learning histories. We model learning histories as spatio-temporal trajectories treating the time dimension as an immanent part of learning. Besides the learning content itself, the concept of the advanced hypercube also includes arbitrary additional data that may result from measured indicators. By this — inside the space of the advanced hypercube — data is lifted to a highly abstract level, mapped to purely geometric information.

This leads to a compact representation allowing us to analyze a wide range of data solely on the grounds of hyperpolylines, their spatio-temporal characteristics and their relations to each other. Not only is this a new application of a spatio-temporal database. It also offers a new approach for finding common learning pathways and Didactic Factors correlating with them. By this, we can predict learning pathways by observing a learners' current actions and retrieving the according Didactic Factors, which constitutes the enhancement of adaptive learning environments in the future.

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