A Conceptual Architecture for the Development of Interactive Educational Multimedia[1]

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Abstract

Learning is more than knowledge acquisition; it often involves the active participation of the learner in a variety of knowledge- and skills-based learning and training activities. Interactive multimedia technology can support the variety of interaction channels and languages required to facilitate interactive learning and teaching.

A conceptual architecture for interactive educational multimedia can support the development of such multimedia systems. Such an architecture needs to embed multimedia technology into a coherent educational context. A framework based on an integrated interaction model is needed to capture learning and training activities in an online setting from an educational perspective, to describe them in the human-computer context, and to integrate them with mechanisms and principles of multimedia interaction.

KEYWORDS: Computer-based Learning and Training, Web Course Development, Interactive Technology, Educational Multimedia.

INTRODUCTION

Interactivity is central for teaching and learning (Moore, 1992; Ohl, 2001) – the active involvement of learners is of paramount importance for a successful learning experience (Sims, 1997). This importance is reflected recently by more interactive resources provided for e-learning environments (Northrup, 2001). Platforms such as the World-Wide Web are ideal for making learning resources in various forms accessible without any restrictions in time or location. The current predominant focus on knowledge-based learning using Web-based e-learning environments is partly a result of a lack of interactive multimedia technologies. With the recognition of skills training as being equally important as knowledge acquisition, more work has recently been done on *activity-based learning and training* supported by *interactive multimedia* technology.

Multimedia technology has been widely used in computer-based teaching and learning (Okamoto et al., 2001; Trikic, 2001). Central to a learner's interaction with the

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environment is the interaction with learning content. In particular in e-learning environments, the learner-content interaction is often more central than the learner's interaction with instructors and peers (Ohl, 2001). Our focus here is on the development of *interactive educational multimedia*. A variety of learning and training activities can be supported by a variety of multimedia interaction channels and languages (Elsom-Cook, 2001). The acquisition of, firstly, declarative knowledge and, secondly, of procedural knowledge and skills-based experience and expertise through learning and training needs to be integrated through a coherent multimedia channel and language design.

Support frameworks for multimedia *development* for e-learning environments exist (Heller et al., 2001). However, the focus of these frameworks is mainly on knowledge acquisition-oriented environments. Our objective is to introduce a *conceptual development architecture* for *interactive educational multimedia* supporting *activity-based learning and training.* Our aim is to support the development of *educational multimedia content* including development activities such as description, classification, and comparison. The development of e-learning technology is a *participative* effort, requiring collaboration and co-operation among those involved. Instructors, instructional designers, and software developers shall benefit from such an architecture.

The proposed architecture is based on three layers, integrating three perspectives of interaction ranging from the educational context to the human-computer interface to the multimedia implementation. An activity model reflects the importance of learning and training activities. Development of educational multimedia content is usually a complex process – the three layers address the needs of three different stages in the development process. The purpose of the architecture is to provide a standardised description notation for various aspects and a guideline for a multi-stage development process. A database learning environment called IDLE – the Interactive Database Learning Environment (Murray et al., 2003; Pahl et al., 2004) – will illustrate the concepts and terminology of our architecture. Making knowledge about interaction, that is inherent in the design, explicit is our objective. *Explicit knowledge* is a prerequisite for evaluation and comparison, but also the deployment of content elements in *intelligent educational systems*. Domain and instruction-related knowledge shall be our primary focus.

INTERACTION IN E-LEARNING AND TRAINING SYSTEMS

We can distinguish three central aspects of activity-based e-learning and training systems: knowledge and skills learning and training, human-computer interaction, and multimedia implementation, see Fig. 1.

Knowledge and Skills

Pedagogical theories determine the learning process design. The individual learning activities in this process – the learner interaction with content – are often subject-specific. In general, we can distinguish various *types* of *learner activities*. Learning is about the acquisition of knowledge or skills. The *purpose* of acquiring knowledge on the one hand and skills on the other differs:

- *Knowledge*. We refer here to what is often called *declarative knowledge*, i.e. facts. The objective of the learner is to be able to *reason* about knowledge. The style of learning is usually classical studying. We use the term *learning* to refer to this activity.
- *Skills*. This shall denote here what is sometimes called *procedural knowledge*, i.e. instructions. The objective of the learner is the ability to *perform* instructions and procedures – in this case we speak about skills. The style of learning is *training*.

The basis for this distinction is the *meaning of the interaction* for the learner in terms of her/his *goals* and *tasks*.

- *Knowledge-level interaction*. This is interaction in terms of concepts and relationships of the subject domain. Meaningful communication with these elements is essential for declarative knowledge acquisition and knowledge production.
- *Activity-level interaction*. This is interaction in terms of subject-specific procedures and activities. Meaningful activities are important for the acquisition and execution of skills, i.e. procedural knowledge and experience.

This distinction is necessary to reflect the different cognitive processes of knowledge and skills acquisition.

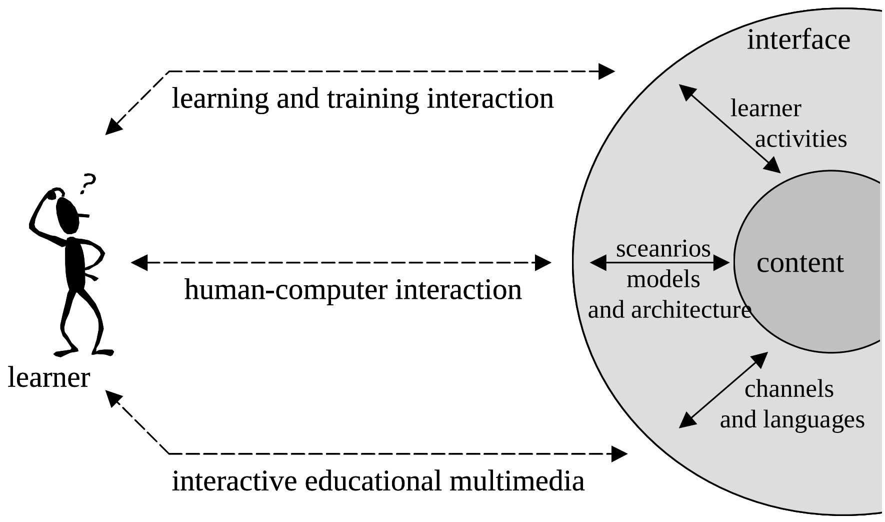

Figure 1. Learner-Content Interactions – a Layered View.

Human-Computer-Interaction

Languages and processes at the interface of a human-computer environment need particular attention in order to meet the requirements of the human user (Dix et al., 1993). Three models are central:

- *Cognitive models and architectures* represent the user's knowledge, intentions, and abilities. Acquisition and production of plans of activities are central.
- A hierarchical *task and goal model* structures the user goals and the corresponding tasks that have to be executed to accomplish the goals.
- *Linguistic models* introduce a vocabulary and constrain the interaction through a user-system grammar.

Multimedia

Multimedia systems (Elsom-Cook, 2001) are characterised by the channels provided to access and communicate knowledge and to enable activities.

- A *channel* is considered as an abstraction of a connection device used to communicate encoded information. Examples are text or audio.
- Specific *languages* are used to communicate information along the channels between the user and the multimedia system. For instance, English is a language that can be communicated along a text channel.

A *medium* is a set of co-ordinated channels. *Communication* using these media needs to be *meaningful*, i.e. should allow users to determine their behaviour based on communicated information. In this case, we call a communication an *interaction*. The user interacts with the system in form of *dialogues* to access knowledge and to engage in activities.

State-of-the-Art

In recent years, the focus of research in e-learning technologies has been on the provision of knowledge learning through suitable technologies – work on knowledge media (Ravenscroft et al., 1998) addressing adequate media representation and access for learning technology is an example. However, with a change of focus moving towards skills and activities, other types of interactions need to be supported. Ravenscroft et al. (1998) acknowledge that the style and level of interaction is central – a result that needs to be applied to this new context.

DEVELOPMENT OF E-LEARNING AND TRAINING SYSTEMS

The Development Context

The development of e-learning and training systems is a challenging task. These systems are complex, consisting of a number of different components (learning objects and supporting infrastructure). Consequently their design and implementation involves several activities.

- The development of individual learning objects from scratch is often the central activity. As content can vary from static to interactive or from textual to multimedia-based, it is difficult to provide a universal approach here. We will focus on supporting interactive multimedia content here.
- With increasing complexity of these systems, reusing components is gaining importance. A number of metadata and annotation standards – such as the IEEE Learning Object Metadata standard LOM (IEEE LTSC, 2002) – have been developed that allow providers to describe and publish their learning objects and potential users to discover suitable resources.
- The assembly of components (e.g. sequencing of learning objects) is another important task. The Learning Technology Standard Architecture LTSA (IEEE LTSC, 2002) is a reference architecture onto which learning objects and other infrastructure components can be mapped. The logical assembly of learning objects or units of learning can be expressed in terms of the SCORM SN (sequencing and navigation) standard (ADL, 2004).

- The final step that follows the design activities in the system implementation. The SCORM RTE (run-time environment) standard (ADL, 2004) addresses the delivery of learning content, possibly based on assemblies expressed using SCORM SN.

Our focus will be on the first aspect even though the context is important as our approach will need to be embedded into a more comprehensive framework.

Knowledge and Intelligent Systems

An intelligent e-learning and training system is based on three knowledge components: domain, learner, and instructional knowledge (Burns & Capps, 1988). While we do not address the implementation of an intelligent learning or tutoring system here, our aim is to address knowledge aspects that arise during development – in particular with respect to domain and instructional knowledge and their explicit representation.

State-of-the-Art

Recent work addressing the development of educational multimedia (Trikic, 2001; Okamoto et al., 2001; Pahl, 2003) does not provide an adequate conceptual framework that can form an underpinning for the development of these systems. A coherent architecture integrating the different notions of interactivity is, however, necessary to support the seamless implementation of educational concepts in multimedia technology.

A CONCEPTUAL ARCHITECTURE

Interaction is central in the development and implementation of learning activity. An *interaction model* focussing on learner-content interaction forms the core of our *conceptual development architecture*. It shall capture and relate meaningful activities and interactions with educational multimedia. This will seamlessly embed interactive multimedia into the educational context.

The Architecture

The notion of interaction has a meaning in different contexts. Clarifying these meanings in a terminological framework is important. We can distinguish *three perspectives* on interaction – presented in *three layers* of the architecture: learning and training interaction, human-computer interaction, and interactive educational multimedia. Overall, the *conceptual architecture* – see Fig. 2 – is a combination of

- a *taxonomy*: a structured terminology that allows the description, classification, and comparison of interaction-related knowledge of educational technology systems,
- a *conceptual model*: an integrated model that captures the various perspectives on activities and interaction in the three layers,
- a *process model*: a development framework that guides instructors, instructional designers, and software developers through the stages of educational multimedia development based on the layered model.

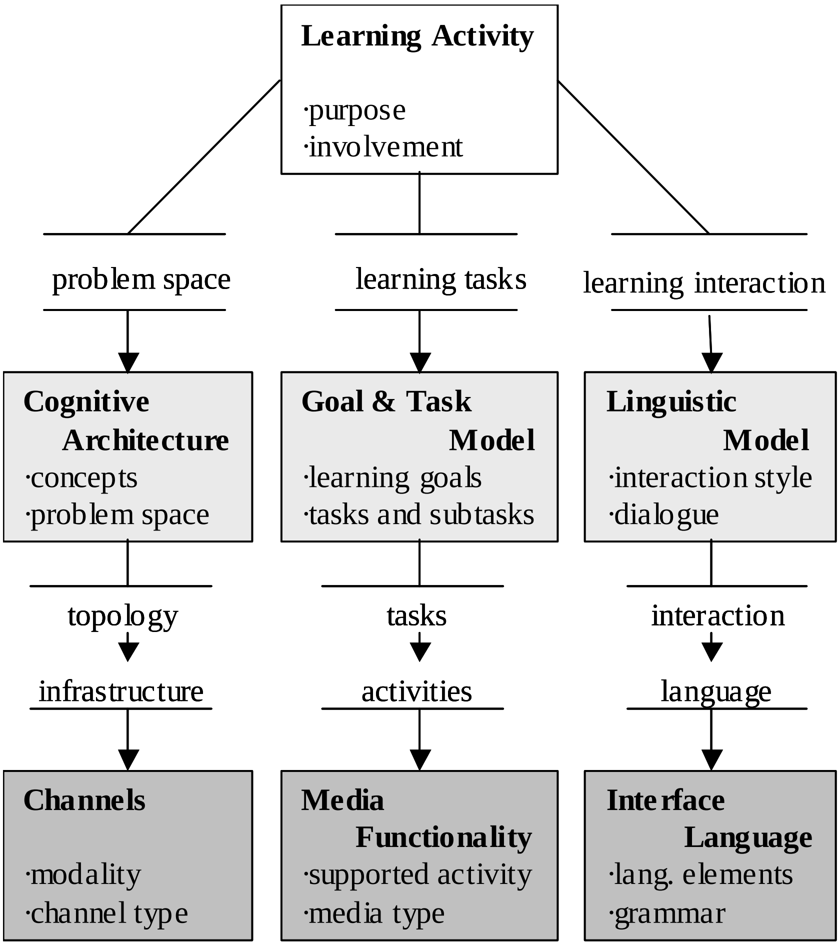

Figure 2. A Conceptual Architecture for Interactive Educational Multimedia

The Case Study

Our case study – the Interactive Databases Learning Environment IDLE – is a Web-based e-learning and training system providing an online undergraduate introduction to databases (Murray et al., 2003; Pahl et al., 2004). It supports learning and training activities such as design, implementation, and analysis of database applications, enabled by a variety of media features including interactive applets for graphical modelling, audio-supported lectures, simulations and other animation types to explain the behaviour of a database system, and a variety of text-based submission, execution, and feedback features. We describe the development of IDLE in stages that follow the layers of the conceptual architecture.

LEARNING AND TRAINING INTERACTION

Learning should be an active process in which interactivity is central (Northrup, 2001). The aim of an *interaction model* at this level is to support the *design of learning activity*.

Moore (1992) distinguishes three types – learner-learner, learner-instructor, and learner-content interactions. It is often argued (Sims, 1997; Ohl, 2001) that *content* has a more *central function* in computer-based education than interaction with peers or instructors. Ohl defines interaction as an internal dialogue of reflective thought that occurs between learner and the content.

Activity Model

The learning and training activities facilitated by educational multimedia interactions between learner and content shall be captured in form of an *activity model*. We distinguish two aspects:

- We can define *activity types* based on the *purpose of the learning process*. We introduce three types, see Table 1. The second category is important in particular in the sciences and engineering domain where an understanding of the subject activities is required for a learner.

Activity Type	*Description*
declarative knowledge acquisition activities	the aim is the acquisition of declarative knowledge in order to reason about it
procedural knowledge acquisition activities	the aim is the acquisition of procedural knowledge in order to reason about it
skills acquisition activities	the aim is the acquisition of procedural knowledge and experience in order to perform the instructions

Table 1. Activity Types based on Learning Purpose

- The *style of the activity execution* can be based on the *degree of involvement and influence* of the learner on the environment, see Table 2. We can distinguish types ranging from system-controlled to learner-controlled environments.

Activity Type	*Description*
observation	a form of knowledge acquisition with no influence on the environment activities by a passive learner
controlling	a form of knowledge acquisition mixed with knowledge production, based on observational elements, but allowing the learner to influence the environment activities to control their ordering
creation	a form of activity where knowledge or skills are created by producing some form of artefact that can be processed by the learning environment

Table 2. Activity Types based on Degree of Involvement

Often the two aspects are related. Declarative knowledge is often acquired through observation, procedural knowledge for reasoning purposes through controlled animations, and skills through artefact creation and processing. The individual types for each of the categories are not meant to be exclusive – a more fine-granular classification can replace our types if needed.

Learning and Training Interaction – The Case Study

The learning-by-doing idea is part of the active learning approach. It captures the interplay of knowledge acquisition and knowledge creation in an interactive process with the learning environment. We have widened this focus in IDLE by considering *knowledge acquisition* on the one hand and *skills and experience acquisition* on the other hand as dual sides of learning and training.

The *virtual apprenticeship model* (Murray et al., 2003) is a pedagogical theory – based on terminology defined in the activity model – that defines an activity-based and skills-oriented learning and training framework for the IDLE system. An apprentice is a learner who is coached by a master to perform a specific task. In an e-learning and training environment, the master's role is often replaced by an intelligent software tool such as IDLE. Tools reflect the experience people, such as the apprentice's master or the instructor, have made in trying to solve a particular problem. The apprenticeship model determines a number of aspects including the activity purpose and the degree of involvement, interaction styles (e.g. the organisation of learning into sessions and cycles), and the interconnectedness of activities and features. The virtual apprenticeship model puts an emphasis on skills-oriented activities with a high degree of involvement of the learner. The main activity categories are summarised in Table 3. Further categorisation is, however, necessary for a detailed design. For instance, the lab activity could be refined into specific activities such as graphical design, programming, or optimisation.

Activity	*Activity Type (Purpose)*	*Activity Type (Involvement)*
lecture participation	declarative knowledge acquisition	observation
tutorial participation	procedural knowledge acquisition	controlling
lab participation	skills acquisition	creation

Table 3. IDLE Activities and their Types based on Learning Purpose and Degree of Involvement

One of the skills acquisition activities in the IDLE system is SQL (i.e. database) programming. Integrated with a database system, the student – a virtual apprentice – works through guided material covering a range of individual problems. Each problem is based on a submission- and execution-cycle with a high degree of involvement of the learner through knowledge creation. Each solution – content-specific knowledge that is created by the learner – is analysed and, based on an individual activity history and integrated assessments, personalised feedback is given by the virtual master. At this level the concern is the abstract classification of learner activities in the context of the pedagogical model. For the database course IDLE the central design decision at this level is to focus on an integrated approach with a strong support of skills training activities.

HUMAN-COMPUTER INTERACTION

Architectures and Models

The notion of learning as a dialogue between learner and content (Ohl, 2001) needs to be adapted to the human-computer environment (Dix et al., 1993). Models for this context formulate these interactive dialogues as cycles consisting of computer-based executions and human evaluations (Norman, 1998). Three models are essential for human-computer interaction:

- A *cognitive architecture* for the educational context addresses cognitive learning processes as interactions in the human-computer environment. The architecture provided by a computer-supported learning and training system defines a problem space based on the central concepts of the subject domain in which a learner should be able to accomplish a learning goal. The architecture is defined by the actions that allow the learner to traverse the space, i.e. to learn and train, and by the desirable states that represent the successful accomplishment of the goal, i.e. to find a solution for the learning goal.
- The *task and goal model* is based on learner goals and activities. A task is an operation to manipulate concepts of the subject domain, i.e. a goal is the desired output from a task. A hierarchy is defined by dividing goals into subgoals and tasks to accomplish these subgoals. A learning strategy defines how learning goals on the same level are connected. The tasks have to be mapped onto the actions supported by the multimedia infrastructure.
- Different interaction styles and learning activity dialogues, e.g. different pedagogical activities, are captured in a *linguistic model* through basic vocabularies and user-system grammars. Style examples include commands, direct manipulation, menus, or form fill. The purpose of a language capturing the interaction processes is the specification of learner dialogues, including the sentence elements, the legal user actions and the system responses.

Scenarios

A representational form to express learning activities at the human-computer interface are *scenarios* (Bødker, 2000). Scenarios are brief descriptions of interactions of a user with a system. We use a scenario language that is close to the SCORM sequencing and navigation standard (SN). We use sequencing operators such as *choice* and *flow*. We also use rules that constrain behaviour. SCORM SN, however, is a declarative format, whereas we prefer here an operational format. It suits the design view for individual content components better, since SCORM SN assumes a navigation approach between components, while we focus on internal behaviour not restricted to navigation.

Scenarios can be used to refine the learning activities from the first stage. Scenarios relate to different models on the human-computer interaction layer of our conceptual architecture:

- The cognitive architecture defines the basis including concepts and procedures on which scenarios can be expressed.
- The possibility to refine abstract activities allows tasks and subtasks to be defined.
- Scenarios formulate the grammar of a linguistic model.

A scenario language based on the problem space combines two aspects. Firstly, knowledge and content creation and processing aspects are covered. Secondly, dialogue activities and interaction patterns can be described.

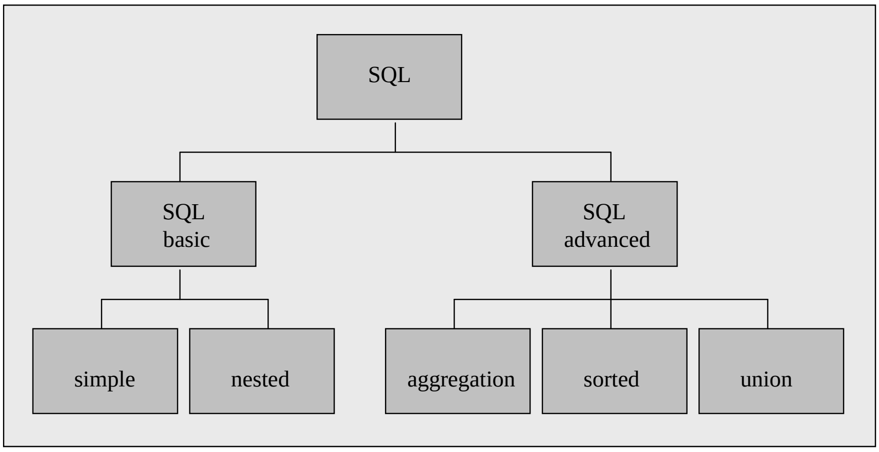

Figure 3. Conceptual Architecture in form of an Activity Tree

Human-Computer Interaction – The Case Study

The interface between learner and multimedia system is defined by three models:

- *Cognitive architecture*: The IDLE learning and problem space is based on subject-specific concepts such as data models and implementation languages, but also subject-specific activities. An example is presented in Fig. 3 that classifies queries in the database language SQL.
- *Task and goal model*: Learners will traverse the problem space in order to accomplish learning goals. To develop a database application using IDLE is one of the central course goals; it involves tasks such as modelling, implementation, and optimisation. These tasks have to be mapped onto activities that are supported by the educational multimedia environment.
- *Linguistic model*: The linguistic model has to enable and structure activities. Different linguistic styles can be deployed: for example direct manipulation for the data modelling tasks or a forms-based input facility to submit SQL database programs for execution.

The *problem space* defined by the *cognitive architecture* resembles a domain ontology for the subject domain – it identifies the central concepts and their properties. Figure 3 is an example. This complements other explicit knowledge, e.g. on learning and interaction, that is made explicit. For the database context, the cognitive architecture is defined by concepts such as database table or query statement. Dependencies between the concepts define the problem space topology. For instance, the table concept is more basic than an SQL query (which is an operation on tables).

An example shall illustrate the *scenario language* to support the *task/goal model* and the *linguistic model*, see Fig. 4, which is based on an underlying cognitive architecture for SQL organised in form of an activity tree, see Fig. 3. The scenario specifies *exercise* *activities* for SQL queries that defines the user-system dialogue – it combines the tutorial navigation with lab programming activities.

Scenario SQL training
```
SQL : flow
      basic    : flow
            simple_query(table)
            nested_query(tables)
         if completed then continue
      advanced : choice
            aggregation(table)
            sorted_output(table)
            union(tables)
        if completed then exit
```

Figure 4. Scenario SQL Training

INTERACTIVE EDUCATIONAL MULTIMEDIA

Learner-content interaction in computer-supported learning and training actually occurs as interaction with the interactive multimedia features that implement the cognitive architecture and the linguistic model and that enable the tasks to be executed and the learning goals to be accomplished. Multimedia systems for education are usually hypermedia systems providing structure through hierarchy and guidance for learning tasks through navigation topologies (Jonassen & Mandl, 1990). Different media supporting different activities are connected through hypermedia structures. Crucial for educational multimedia are the multimedia interface and the interaction dialogues a multimedia system allows through channels (text, mourse, etc.) and languages (natural, formal, etc.).

Interactive multimedia for activity-based learning and training can be distinguished into interaction with knowledge media and with activity media. Activity-based training focuses on skills-oriented activities, but needs to be integrated with knowledge learning aspects. *Knowledge media* focus on knowledge information to be communicated. *Activity media* focus on artefacts that are produced and processed in activities. The purpose of interactive educational multimedia is twofold:

- In addition to knowledge-level interaction, domain-specific activities need to be facilitated, i.e. activity-level interaction with the educational multimedia feature through artefacts and instructions has to be enabled.
- The instructor can be replaced by a virtual form of an intelligent educational multimedia feature that provides advice and feedback, thus adding more meaning to the interaction.

Facet	*Type*	*Range*	*Description*
channel	general	common range	the abstraction of a communication device, characterised by modality
language	general	not restricted but can be categorised	information is encoded in common language for communication over a channel
activity purpose	education	predefined	distinguishes whether declarative knowledge reasoning, procedural knowledge reasoning, or skills acquisition is aimed at
activity style	education	predefined	classification of activities into observation, controlling, and creation that describes the degree of influence of a learner on the environment
content topic	education	no restriction	topic or domain within which activities or knowledge-level access is provided

Table 4. Educational Multimedia Facets

Educational Media Taxonomy

We can classify educational multimedia through different *metadata facets* – see Table 4 – essentially different dimensions that allow us to describe educational media. We distinguish two *facet types*:

- *General multimedia facets* cover multimedia aspects such as channel and language. These facets together describe a medium as a co-ordinated set of channels and their languages. It is important, however, to develop an education-specific view on multimedia.
- *Education-specific facets* cover aspects specific to learning and training such as the activity purpose, the activity style, and the content topic.

The *range* in Table 4 refers to the possible set of values of each facet. The aim of this *taxonomy* is to describe, distinguish, and classify educational multimedia. It supports the development and the comparison of educational media objects. This aims at an abstract description of multimedia from an educational perspective. Strict adherence to description standards is here not the primary concern since design is our focus.

The two general facets of multimedia – channel and language – shall be revisited in the context of education. In comparison with classical uses of multimedia for knowledge-oriented learning (Heller et al., 2001), here the interaction between learner and content, determined by the channels and their languages, is more central.

Educational Multimedia Channels

Multimedia is about channels and meaningful communication along these channels. Often, a natural language such as English is used over a text channel (written English) or over an audio channel (spoken English). For our context, we will identify a number of specific *educational channels* – supporting partly more formal languages, partly languages specific to the subject or instruction context – see Table 5. We distinguish two types of channels – those that support *core* content-oriented learning activities and those that are part of the *meta*-context of instruction; the latter including instruction-related learner actions and coaching actions by a master or instructor.

Channel	*Type*	*Description*
declarative knowledge	core	declarative knowledge usually communicated in a domain-specific natural or formal language
procedural knowledge	core	procedural knowledge usually communicated in a domain-specific natural or formal language
skills	core	artefacts to be processed in form of activities are communicated with corresponding execution instructions
actions	meta	instruction-related actions executed by the learner (navigation or location of learning units)
feedback	meta	response of the system for each core activity
coaching	meta	meta-level information capturing an instructor's advice and guidance

Table 5. Educational Channels

Educational Multimedia Interface Language

Multimedia interface languages capture and constrain the channel communications. A language defines the interaction dialogues; it describes the legal actions, how a learner can engage in an activity or how a learner can perform a task towards a learning goal. These interaction languages detail dialogue structure captured in the scenario language. The difficulty in defining an adequate language is to capture all three interaction model layers. The learning and training interaction model provides the conceptual model in which the language semantics is to be defined.

We can classify languages for the educational context based on *content-related aspects*:

- Natural languages – in text or audio form – are often the basis of content.
- Formal languages – in text form – are often involved if some sort of mechanical processing is part of the subject domain.
- Simulations – automated processing of some real-world activities – are based on objects and procedures from the subject domain.

Besides the content aspect, *dialogue* and *interaction patterns* form the instructional aspect addressed by interface languages. On the most basic level the learner interacts with multimedia usually through keyboard- and mouse-based input; output can be static visual (text, graphics), dynamic visual (animations, video), or involving other modalities such as audio. The basic inputs are part of low-level activities such as navigation (knowledge acquisition request) or text input/submission (knowledge generation). A learning activity can be composed of more basic activities. The *dialogue and interaction part* of the language consists of

- *basic activities*: select (knowledge acquisition by learner), submit (knowledge generation by learner), reply (response to knowledge acquisition/generation) ;
- *activity combinators*: ; (sequence), ! (iteration), | (choice) ;

- *system components*: learner and multimedia system in a simple e-learning architecture.

Interactive Educational Multimedia – the Case Study

Activities are supported by multimedia features. IDLE supports three classical forms of third-level teaching – lectures, tutorials, and labs – in a virtual form. These three forms can be described using the educational multimedia classification scheme – see Table 6, which describes how some selected learning activity styles for particular topics are mapped onto multimedia features. For example, a simulation can be a subcategory of a moving pictures/images language. However, the elements of simulations can be identified and have meaning in the context of content (e.g. tables or records in the database context). Equally, operations (simulation activities) are represented in the procedural knowledge.

Facet *Activity*	*Channel*	*Language*	*Purpose*	*Type*	*Topic*
lecture	text and audio	natural language	declarative knowledge	observation	introduction to databases
tutorial	dynamic animation	simulation	procedural knowledge	controlling	relational algebra
lab	text	formal language	skills-oriented activities	creation	SQL

Table 6. Sample IDLE Media Classification

The channel and language characterisation using the taxonomy in Table 6 is high-level. These two aspects can be described in more detail. Table 7 provides a channel-oriented view on IDLE; it lists the educational channel types and some sample features that are based on these channels.

Channel	*Feature*	*Activity*	*Language*
declarative knowledge	database introduction lecture	HMTL and audio-based synchronised virtual lecture	natural language (written and spoken)
procedural knowledge	relational algebra animation	interactive simulation of algebra operator execution	formal language (interaction – animation control)
skills	SQL programming lab	submission of query solutions and dynamic page update by system	formal language – SQL (solution and result)
action	SQL tutorial navigation	guided tour through a series of connected exercises	formal language (interaction – navigation)
feedback	SQL programming lab	correction and provision of partial solutions for SQL exercises	semi-formal language (text and error classification)

coaching	self-assessment	multiple choice questions and virtual master's feedback	natural language (written)

Table 7. Sample IDLE Media Channels

The interaction language is based on the scenario language. The expression

! (LR.select(exercise); LR.submit(solution); MM.reply(result))

is the interaction specification of an exercise activity scenario. A language needs to facilitate declarative and procedural knowledge communication, skills-oriented activity execution, learner actions, and meta-level pedagogical interactions (coaching). *select* denotes a learner action; *submit* and *reply* support skills-oriented activities; *reply* could, in addition to results for e.g. SQL submissions, also convey meta-level feedback and coaching. In contrast to scenarios, we distinguish here between learner (*LR*) and multimedia system (*MM*) components. For instance, the SQL multimedia lab system (*MM*) replies with a result that includes the result of the solution execution and feedback.

FUTURE TRENDS

Developments on both the educational and the technological side will influence educational multimedia design and implementation in the future.

- The importance of learner involvement and activity has long been recognised (Northrup, 2001). In the corporate sector, activity- and skills-based learning and training is learning increasingly essential.
- A number of issues will impact multimedia technology development (Elsom-Cook, 2001). The fact that knowledge is becoming central in our societies will be reflected in multimedia through the integration of knowledge management and the support of processes of communications.

The development of e-learning technology moves closer to systems where multimedia technology excels. On the other hand, multimedia also moves towards knowledge, languages, and the Web – which are all central aspects of computer-supported learning and training technology. Knowledge management is central for intelligent e-learning systems, both for content and learner modelling. Practically, knowledge representation frameworks such as ontologies and other metadata languages and standards will impact the area.

Development of interactive educational multimedia is the context of the presented conceptual architecture. Other uses of the architecture can, however, be considered:

- *Standardisation and metadata*: There is a similarity between the taxonomy we introduced and metadata frameworks, such as the IEEE Learning Object Metadata (LOM) standard. Our focus is here on multimedia, interactivity, and the process of development. An integration with LOM is nonetheless possible. Multimedia development is expensive, i.e. sharing and reuse is desirable and, consequently, annotations are needed to facilitate this.

- *Multimedia integration and assembly*: Multimedia features can be combined to complex systems through channel assembly and language integration. This type of context would form part of a development framework for multimedia architectures.

The process of educational multimedia development and management needs to be supported by a coherent engineering framework, integrating different development activities.

CONCLUSIONS

Activity-based learning and training based on interactive educational multimedia can provide an answer for the current need to support not only knowledge acquisition, but also skills and experience acquisition in computer-supported educational environments.

We have investigated here the development of interactive educational multimedia as a platform to implement activity-based learning and training through a conceptual architecture.

- A taxonomy based on the conceptual models allows us to describe activities, interactions, and multimedia objects and their channels and languages and compare different systems.
- Detailed technical descriptions allow the implementation and integration of educational technology components. An intricate understanding of the interaction characteristics of each of these components on all three layers is essential.

This architecture provides support for instructors, instructional designers, and software developers in a participative, multi-stage development environment. It is meant as an open architecture, i.e. open to further extensions, integration with other frameworks and standards, and adaptations to particular needs.

One of the central lessons we have learned over the years of developing, managing, and maintaining educational multimedia systems is that there are a number of reasons that ask for a domain-specific, systematic, and co-operative approach to activity-based learning and training systems development.

- Firstly, interactivity is central and especially complex in the educational domain. The learning and training activities need to be embedded into a pedagogical framework in order to achieve a high quality learning experience. A domain-specific approach is therefore needed.
- Secondly, the need for activity-based education is increasing. Consequently, the integration and maintenance of educational multimedia is becoming increasingly a problem. Only a systematic approach to development and maintenance can provide a solution.
- Thirdly, learning and training are multi-channel and multi-language activities. Seamlessly integrated interactive multimedia is therefore an ideal support technology.
- Fourthly, instructors, instructional designers, and software developers need to co-operate in the development of these systems that are characterised by complex learning and instruction processes on the one hand and advanced multimedia technology on the other.

One of our objectives was to provide a central element for such a development approach and to guide educational system design through our architecture. Interactive multimedia has the potential to support innovative approaches of teaching and learning, but in order to be successful, it needs to be embedded into a systematic and comprehensive framework for development and management.

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