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Agent-Supported e-Learning

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Contents

1 Introduction

This technical report is intended to present existing work about agent techniques and technologies in order to enhance the performance and the effectiveness of several aspects of e-Learning systems. Agents are not a new concept but their use in the field of e-Learning constitutes a basis for consequential advances.

More concrete [Wilson et al., 2004b] lists several benefits for learners and teachers, as well as for institutions. One main aspect for the first ones is the quality of information acquisition and delivering. That effects pedagogy.

- He argues that pedagogic diversity becomes possible. By agent technology a diverse set of learning models can be parallel implemented, because it becomes feasible to configure low-level elements of the architecture. Thereby distinct pedagogical and business models can be realized.
- A second advantage is the enabling of the implementation of pedagogy-driven implementations. Modular processes can be offered as services by agents to drive system implementation by pedagogical imperatives rather than by the construction technology itself.

The advantages for institutions more rely on technological, business as well as cooperation aspects.

- Agent technology can support collaboration between organisations. By them the implementation of a common framework becomes possible. Agents can decompose complex tasks in order to provide basic services in a kind of construction kit. Thereby for example needed applications can be easier defined and shared to provide functionality that is common to all institutions and to share information between them.
- Business advantages are mostly measured in terms of costs and time. Agent technology provides a better return on technology investment because applications or better functionality can be acquired as needed and integrated in the existing framework. That reduces purchasing and implementation costs, particularly in terms of staff development and training.
- Because of the independence of the particular components a faster technology development is possible. Functionality is separated from the interface and is replaceable more easily. By this a modular and flexible technology base is provided. Individual components can be implemented, added and replaced more easily.

These are only few introductory benefits. Detailed information about the usefulness of the agent-supported realization of several e-Learning aspects represent the core of this preprint and will be described in chapter 3.

1.1 Why Agent-Based Systems?

The basic question when applying a technology is its usefulness. When is it possible and beneficial to integrate it? [Milgrom et al., 2001] answered this basic question for the agent-oriented paradigm by defining some guidelines validated by case studies ([Chainho et al., 2000], [Kearney et al., 2000], [Caire et al., 2001]). Their argumentation starts with a statement that agent-oriented design and implementation will have its greatest scope of applicability in systems with following characteristics:

- Subsystems and subsystem components forming a system;
- High-level interactions between subsystems and subsystem components in terms of size and complexity;
- Changing interrelationships over time.

Common problems types that can be solved with agent technology where described in [Jennings and Wooldridge, 1998a] and [Ferber, 1999]. That may include system characteristics like dynamics, openness, complexity and ubiquitousness as well as problem qualities like physical distribution of components, data and knowledge. Agents can be helpful to solve these problems because of their scalability and their ability to improve latency [Anghel and Salomie, 2003].

The guidelines of [Milgrom et al., 2001] result in properties of solutions for complex software problems where the usage of software agent technology is expected to be useful.

Avoid overkill This principle refers to some philosophical background. It mainly concerns to the adjustment of requirements and solution. Not everything that is possible to design with agents should be implemented with it. Otherwise it is a waste of time and effort. “Always attempt to develop the simplest solution possible to any given problem.”

Need for distributed control Decentralised management of distributed systems can be appropriate due to platform, responsibility, privacy and physical constraints. For the first case this may emerge due to the intended integration of several applications running on incompatible platforms. Agents can be used to wrap existing functionality and enable their interrelation. Responsibility may cause effects that can be modelled explicitly by agent technology because complex software systems might work for different owners with different goals. Negotiation algorithms can offer a fair compromise at run-time. Privacy can be achieved by secure agents, privacy policies can be simply implemented. Physical constraints may require agent characteristics, too. A famous example are complex robot control systems for extraterrestrial deployment on missions to Mars.

Need for complex communications There exist many approaches to realize distributed systems (e.g.: n-tier architectures, Object Request Broker Architecture (CORBA), Enterprise Java Beans (EJB)). Their interaction style is mostly based on several assumptions. So the sender knows the intended receiver as well as his appropriate method/procedure to receive the message in addition to the message type to be sent. Agents are useful in situations with a more complex and flexible needed interaction. By limiting the set of message types and extending the included semantic it was possible to define communication patterns that are directly re-usable.

Need to concurrently achieve multiple, possibly conflicting goals Sometimes system behaviour and the corresponding interaction schemes are too complex to be completely modelled at design time. Agent technology solves this problem by defining *how to decide* what to do instead of mapping inputs to outputs by defining *what to do*. By this approach a more flexible implementation becomes possible by adapting the behaviour of the corresponding agents.

Need for autonomous behaviour This need arises in the case of absence of explicit requests for action. Software is more flexible if it is able to perform certain actions in a goal-directed manner without continuous human supervision.

Need for high flexibility and adaptiveness Agent technology's advantage of intrinsic modularity and the possible cognitive capabilities lead to very effective and learning software systems. Agents can be added and removed at run-time and thereby lower costs because of the easy system expansion and modification.

Need for interoperability Sometimes systems are intended to interact with other software which specification is unknown during its own design. Using agents is a possible solution because they can provide services beyond their own capability due to their relations in a multi-agent system.

Non technical guidelines Technical aspects are not the only ones that need to be considered. Analysis and weighting of management issues is necessary, too [O'Malley and DeLoach, 2002]. That includes the cost of acquiring and adopting the methodology for use in an organization, the existence and cost of support tools, the availability of reusable components, the effects on existing organizational business practices, the compliance with formal or de facto standards as well as the support for tracing of changes during software life cycle.

There is almost never an advantage without any trade-off. The nature of the agent paradigm may lead to several problems (e.g.: [Jennings and Wooldridge, 1998a], [Markham et al., 2003]):

- No overall system controller which keeps global constraints and avoid livelocks and deadlocks,
- No global perspective to the whole system or to the complete knowledge,
- Trust and delegation of agents seeking guidance during the time that work on their behalf,
- Ethical and privacy issues,
- Sometimes bad reputation and lack of trust (viruses are sometimes called agents).

The presented guidelines can be applied in several domains. One of them might be e-Learning. Therefore the rest of this chapter deals with chosen technical aspects of agent technology before chapter 2 describes e-Learning foundations. Existing crossover approaches of these two topics represent the core of this preprint and are part of chapter 3.

1.2 Foundations on Agent-Based Systems

This section will present basic information about agent technology as an overview. Initial definitions as well as core features and functionalities will be described.

Technologically agents are related to the scientific fields of artificial intelligence, systemics, distributed systems and robotics.

1.2.1 Software Agent Technology

To reasonable employ agent technology it is necessary to understand the underlying concepts. The agent idea goes back to works of Carl Hewitt in the field of artificial intelligence in 1977. He described an object “actor” being interactive, independent and executable. Furthermore it was intended to have an internal state and being able to communicate with other objects [Nwana and Ndumu, 1998]. Technological research origin are the distributed artificial intelligence and artificial life. The first main discipline deals with the creation of organizational system for problem solving while the second one tries to understand and create models that describes life being able to survive, adapt and reproduce.

1.2.1.1 Definitions

There exists no single definition for agents, but a lot of discussion (e.g. [Wooldridge and Jennings, 1994], [Wooldridge, 1996], [Franklin and Graesser, 1996], [Castelfranchi, 1996]). Almost every author seems to propose own needs and ideas what leads to a variety of definitions depending on the targeted problem area. The expressed spectrum determines reasonable application areas as for example user interfaces, telecommunications, network management, electronic commerce and information gathering [Sánchez, 1997]. Russel and Norvig described this multiplicity aspect in this way [Russell and Norvig, 1995]: “The notion of an agent is meant to be a tool [. . .], not an absolute characterization that divides the world into agents and non-agents.” Nevertheless there are existing definitions.

The Foundation for Intelligent Physical Agents (FIPA) provides a set of specifications representing a collection of standards which are intended to promote the interoperation of heterogeneous agents and the services that they can represent. Their definition is provided as an initial one.

Definition 1 *An **agent** is a computational process that implements the autonomous, communicating functionality of an application [Foundation for Intelligent Physical Agents (FIPA), 2006].*

Another classic definition of Wooldrigde and Jennings is based on technology features, too [Wooldridge and Jennings, 1995].

Definition 2 *The **Wooldridge-Jennings-Agent** is a software-based computer system with certain properties like autonomy, social ability, reactivity and pro-activeness.*

A next aspect of agent technology evolves from the following definition. [Maes, 1997] clearly states out that there is an environment needed for any autonomous action. [Franklin and Graesser, 1996] use a quite similar definition. Agents and their environmental context are shown in figure 1.1.

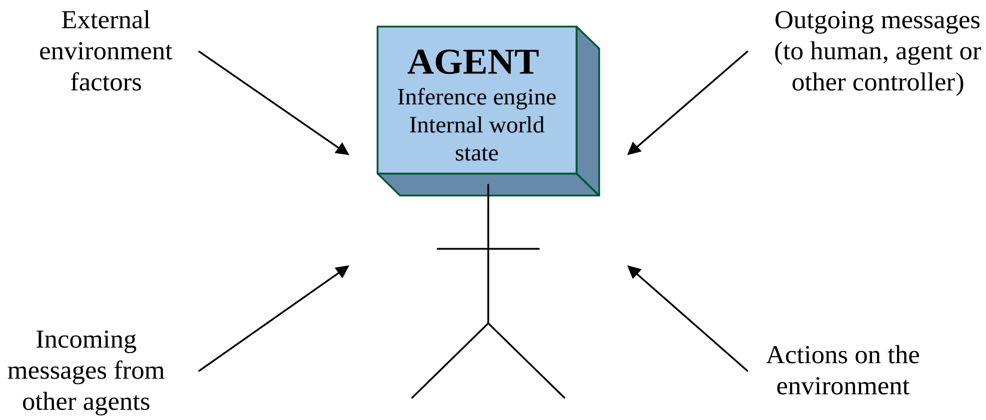

Figure 1.1: Agents and their interaction with the environment (cp. [Hayzelden and Bigham, 1999a])

Definition 3 ***Autonomous agents** are computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed [Maes, 1997].*

Other definitions identify agents as "Human Surrogates" that operate autonomously, as "Intelligent Assistants" to support human beings or as an architectural pattern for software development ([Smolle and Sure, 2002], [Jafari, 2002]). Furthermore often viruses or virus scanning programs are seen as agents [Markham et al., 2003].

Almost all agent definition have one aspect in common. They are based on certain properties. Every theoretician or developer proposes individual beliefs about potential benefits of his system or what is necessary to describe it. That explains the abundance of existing definitions [Kernchen, 2004].

A definition that tries to define an almost "complete" property set for agent characterization is given in [Ferber, 1999].

Definition 4 *An **agent** is a physical or virtual entity*

1. *which is capable of acting in an environment,*
2. *which can communicate directly with other agents,*
3. *which is driven by a set of tendencies (in the form of individual objectives or of a satisfaction/survival function which it tries to optimise),*

4. *which possesses resources of its own,*
5. *which is capable of perceiving its environment (but to a limited extent),*
6. *which has only a partial representation of this environment (and perhaps none at all),*
7. *which possesses skills and can offer services,*
8. *which may be able to reproduce itself,*
9. *whose behaviour tends towards satisfying its objectives, taking account of the resources and skills available to it and depending on its perception, its representations and the communications it receives.*

Literature differentiates required and optional properties. The mostly referenced required ones are listed in the further course.

Autonomy The first and most important property is the autonomy. It is common to almost all agent definitions. Agents act autonomously when they perform their actions without direct interventions of humans or other agents. They should have control over their actions and their internal state. They significantly differ from "normal" objects in the sense of software engineering in having a behaviour. Agents have control over the execution of their methods ([Jennings and Wooldridge, 1998b], [Franklin and Graesser, 1996]).

Social ability This ability refers to the interaction potential of this technology. Agents need relations to other agents or humans to perform their actions or to help them performing their tasks ([Jennings and Wooldridge, 1998b], [Franklin and Graesser, 1996]). They are communicative for coordination and for exchange and validation of knowledge.

Reactivity Planning agents are widely known. But there is a need for instant reactions to changes in the environment, too. Therefore they need perception capabilities ([Jennings and Wooldridge, 1998b], [Franklin and Graesser, 1996]).

Pro-activeness The property of pro-activeness is a counterpart of being reactive. Agents should reveal a goal-directed behaviour and do something on their own initiative ([Jennings and Wooldridge, 1998b], [Franklin and Graesser, 1996]).

In reflection to special intended usage areas some more optional properties can be identified.

Adaptability Sometimes agents are characterized by their flexibility, adaptability and facility to set up their own goals based on their implicit purpose (interests). One of the major characteristics of agents is their ability to acquire and process information about the situation, both spatially and temporally. That results in non-scripted actions ([Hayzelden and Bigham, 1999a], [Franklin and Graesser, 1996]).

Agent Granularity degrees Agents may have degrees of complexity. Most simple agents are characterized by the lack of intelligence regarding their behaviour. These agents are called reactive. More complex agents are called cognitive or intelligent agents. They are characterized by their ability to know their environment, to act on themselves and on the environment; their observed behaviour is a consequence of their perception, knowledge and interactions [Hayzelden and Bigham, 1999a].

Learning Either the agency itself may perform some learning ability (as society) or each individual agent may be embedded with a learning algorithm (e.g. a neural network or their re-enforcement algorithm). Learning often allows the agent to alter its future action sequences and behaviour such that future mistakes can be alleviated. Learning is often a factor that provides an agent's ability to demonstrate adaptive behaviour [Hayzelden and Bigham, 1999a].

Persistence An often as required defined property is persistence. It describes the retention of identity and internal state for a longer period of time as a continuous process ([Jennings and Wooldridge, 1998b], [Franklin and Graesser, 1996]).

Collaboration A major characteristic of agent technology is the system decomposition in smaller, more specialized components. One drawback or advantage (depends on the viewpoint towards this characteristic) is that not every agent hast the complete functionality to solve a problem. The needed interaction to reach the goals is titled collaboration [Jennings and Wooldridge, 1998b].

Mobility Another major advantage of agents is their ability to migrate between environments over a network([Jennings and Wooldridge, 1998b], [Franklin and Graesser, 1996]). It is an extension of the client/server paradigm of computing by allowing the transmission of executable programs between client and server. Mobile agent usage can reduce network traffic and allow asynchronous interaction, disconnected operation as well as remote searching and filtering. By this bandwidth and storage requirements maybe positively impacted [DeTina and Poehlman, 2002]. Other fields of application are the access and administration of distributed information [Buraga, 2003] or the dynamic configuration of a entity network [Sadiig, 2005].

Character, Personality This property refers to a believable personality and an emotional state ([Jennings and Wooldridge, 1998b], [Franklin and Graesser, 1996]). So it is describable within terms of an intentional stance in an anthropomorphic manner attributing to it beliefs and desires [DeTina and Poehlman, 2002].

Another detailed overview about properties described in literature is given in [DeTina and Poehlman, 2002]. They list 21 properties according to the varying definitions of researchers (cp. table 1.1).

PROPERTY	A	B	C	D	E	F	G
Autonomy	*	*		*	*		*
Social ability	*	*		*	*	*	*
Reactivity	*		*	*			
Pro-activeness	*			*		*	
Mobility	*			*	*		
Veracity	*						
Benevolence	*						
Rationality	*		*				
Commitment		*					
Successful			*				
Capable/competent			*			*	*
Perceptive			*			*	
Reflexive			*				
Predictive			*				
Interpretative			*				
Sound			*				
Temporally continuous				*	*		
Ability to learn				*			*
Flexible/adaptable				*	*		
Character	*			*	*		*
Graceful degradation							*

Table 1.1: Properties of agents [DeTina and Poehlman, 2002]
(A: [Wooldridge and Jennings, 1995], B: [Genesereth and Ketchpel, 1994],
C: [Goodwin, 1993], D: [Franklin and Graesser, 1996], E: [Etzioni and Weld, 1995],
F: [Maes, 1996], G: [Foner, 1993])

Agents are situated in a certain environment which they are part of. Those agent platforms supply the needed infrastructure. A service directory, an agent directory, message transport and agent communication languages are those infrastructural elements as defined in the FIPA-Standard [Foundation for Intelligent Physical Agents (FIPA), 2006].

Definition 5 *An **agent platform** is the infrastructure being necessary for agent execution [Foundation for Intelligent Physical Agents (FIPA), 2006].*

For the implementation of certain agents, agent frameworks are provided. Next to infrastructural aspects they allocate API's and further specialised services for agent and MAS programming.

Definition 6 *An **agent framework** include the necessary resources for the agent infrastructure as well as for the implementation of agents and multi-agent systems [Kernchen et al., 2006].*

1.2.1.2 Classification of Agents

There exist several approaches to classify agents. A widely referenced approach is proposed by [Franklin and Graesser, 1996]. For this purpose they describe an initial "natural" taxonomy based on the same biological model as the classification of "living creatures". Figure 1.2 shows their approach.

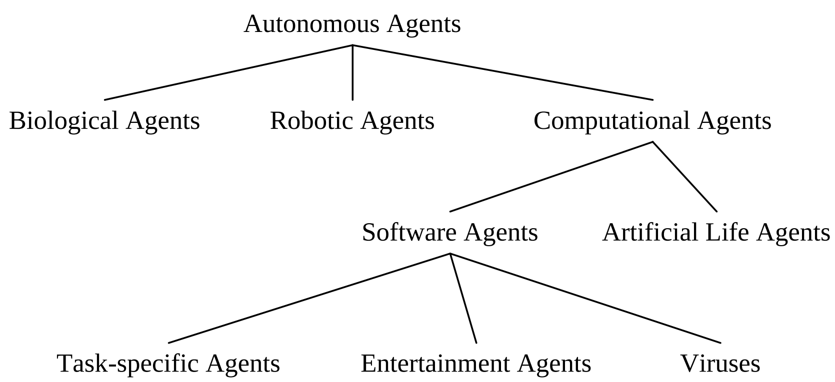

Figure 1.2: "Natural" taxonomy of agents (cp. [Franklin and Graesser, 1996])

Other classifying schemes may base on, but are not limited to the:

- Tasks to be performed (e.g. information gathering, email filtering)
- Control architecture (e.g. fuzzy subsumption agent, planning agent)
- Range and sensitivity of agents' senses
- Environment the agents are situated in
- Communication complexity (e.g. discrete vs. fully connected)
- Communication bandwidth
- Topology (by defining n properties and creating a n-dimensional matrix, each cell corresponds to a feature set that can be used as a classification category (cp. figure 1.3))
- ...

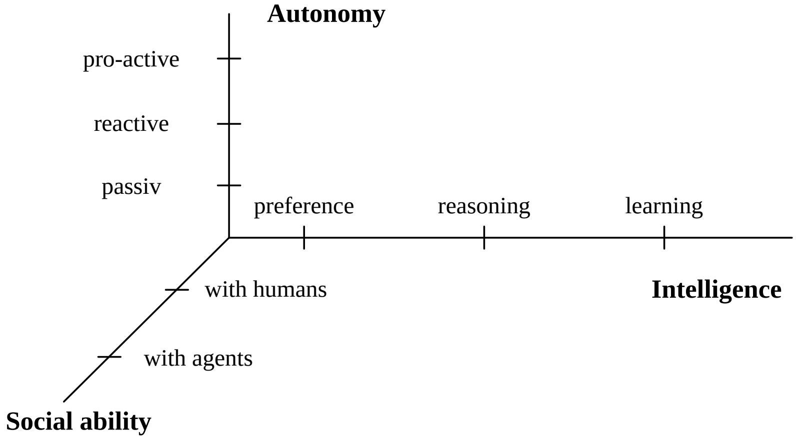

Figure 1.3: Chosen model of agent characteristics (cp. [Darbyshire and Lowry, 2000])

A taxonomy for Web agents was described in [Huang et al., 2000]. They also use a topology-based approach that encompasses text-based information retrieval agents as well as graphical avatars for user support. The authors focus on specific characteristics of used protocols (2d vs. 3d), locality (client vs. server) and the number of interacting agents (cp. figure 1.4).

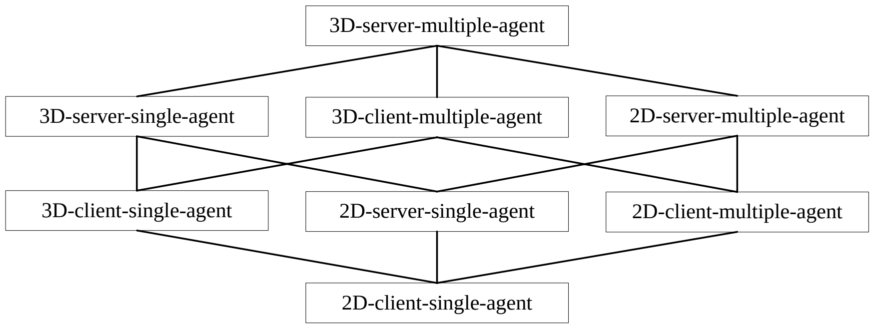

Figure 1.4: Lattice of Web agents (cp. [Huang et al., 2000])

Sánchez bases his agent taxonomy on literature research regarding different views of agency focused on the term of agent autonomy [Sánchez, 1997]. Therefore he distinguishes between the views towards agent technology as an abstraction to conceptualize, design and implement complex systems (programmer agents), on the attribute of mobility (network agents) and the view of end users as an abstraction to interact with systems. The latter classification of user agents is done from an application's point of view (cp. figure 1.5).

In [Wong and Sycara, 2000] the authors presented a specialised taxonomy for what they call middle-agents, the agent-based connection between service providing and service requesting agents. Therefore they defined six dimensions characterized by questions. The considered aspects are message sender type, information type, information

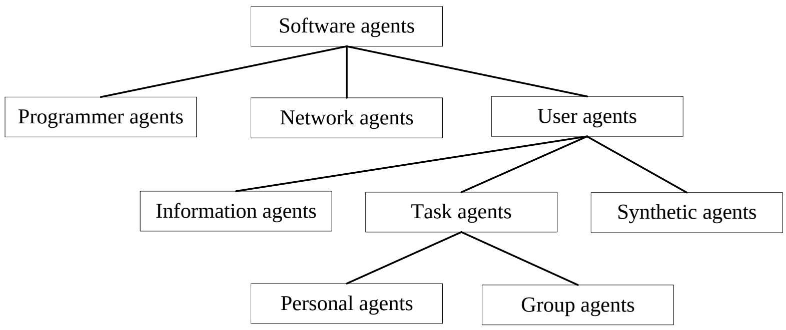

Figure 1.5: Agent taxonomy of Sánchez (cp. [Sánchez, 1997])

processing type, information usage type, information processing type again and the question whether an middle-agent intermediates messages between service requesting agents.

Another special taxonomy related to agent technology is described in [Montaner et al., 2003]. After the analysis of 37 systems they identified eight classes for recommender agents on the internet. The classes in terms of profile exploitation are information filtering method, item-profile matching and the user profile matching techniques. Following the aspect of profile generation and maintenance there are the dimensions: the representation, the technique to generate the initial profile, the source of the relevance feedback which represents the user interest, the profile learning technique and the profile adaptation technique.

Decker introduced a taxonomy with four dimensions as there are ([Decker, 1987], [Stone and Veloso, 2000]):

- Agent granularity (coarse vs. fine);
- Heterogeneity of agent knowledge (redundant vs. specialized);
- Methods of distributing control (benevolent vs. competitive, team vs. hierarchical, static vs. shifting roles); and
- Communication possibilities (blackboard vs. messages, low-level vs. high-level, content).

An application-based classification was presented by Parunak in [Parunak, 1996]. The main characteristics were system function, agent architecture (degree of heterogeneity, reactive vs. deliberative) and system architecture (communication, protocols, human involvement) [Stone and Veloso, 2000].

Stone and Veloso argue that all aspects of agents are touched by their heterogeneity/communication taxonomy [Stone and Veloso, 2000]. Based on literature research they identified four agent classes: homogeneous non-communicating agents, heterogeneous non-communicating agents, homogeneous communicating agents and heterogeneous communicating agents.

These wide-spread classification approaches imply the already mentioned variety of points of views regarding agent technology.

1.2.2 Basic Agent Architectures

An often asked question refers to the difference between the concepts of agents and objects as well as between agents and actors.

Within the science of informatics an object is described by the concepts of a class-instance-relationship, inheritance and message transmission. The first concept esteems a class as a model of structure and behaviour meanwhile an instance is seen as concrete representation of the class. By inheritance a class is derivable from another one and thereby able to use its properties. Message transmission allows the definition of polymorphic procedures whose code can be differently interpreted by different clients. By these common concepts of objects they cannot be interpreted as agents because they are not designed to fulfil certain goals or to satisfy a need. Furthermore message transmission is only a procedure invocation [Ferber, 1999]. Agents are able to decide about message acceptance and about an appropriate reaction.

Actors are parallel systems communicating by asynchronous buffered messages. They do not wait for an answer but order the receiver to send it to another actor. Actors are no agents due to the same reasons as explained above.

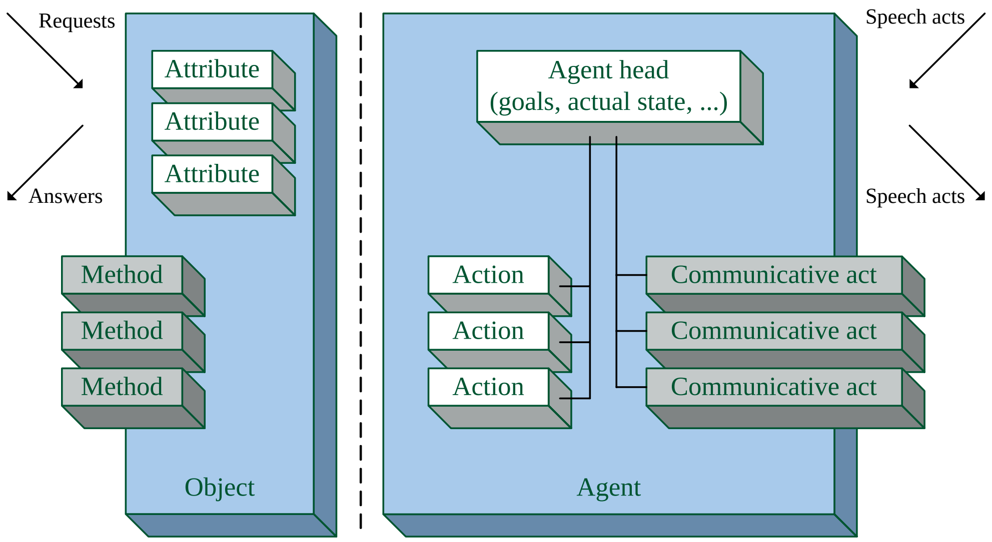

Figure 1.6: Comparison agent and object (cp. [Ferber, 1999] and [Bauer and Müller, 2004])

Agent architectures represent the transition from agent theory towards their practical application [Kernchen and Vornholt, 2004]. Therefor three main research and application directions exist.

1.2.2.1 Deliberative Agents

Deliberative agents base on the classic Artificial Intelligence by explicitely requiring a symbolic model of the environment as well as the capability for logic reasoning. Fundamental aspects are described by Newell and Siman within their "Physical-Symbol System Hypothesis" [Newell and Simon, 1976]. This theory describes a system being able to recognise symbols which can be combined to higher structures. An additional intention is its capability to run processes for symbol processing. The symbols itself can be used to create a symbolically encoded set of instructions. Their final statement is that such a systems is capable to perform intelligent actions.

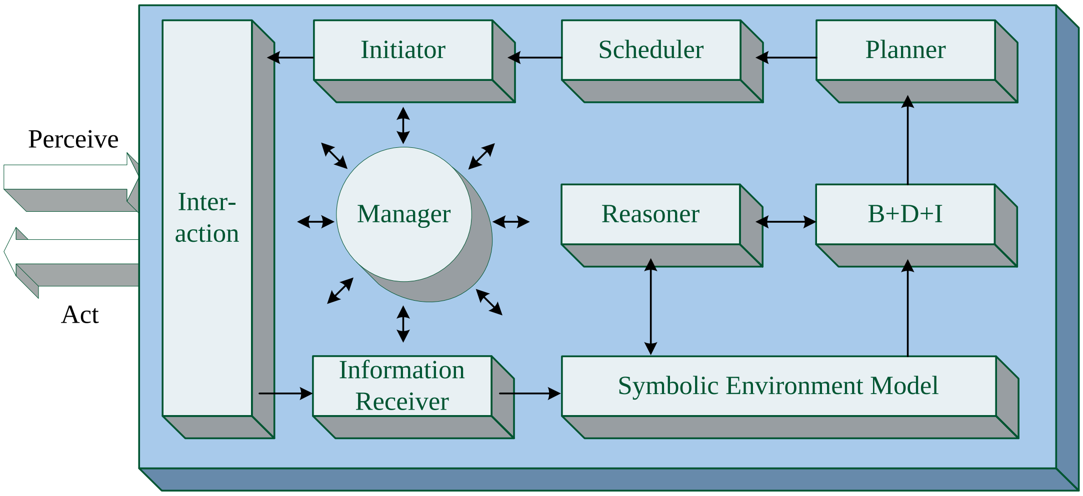

Figure 1.7: Deliberative agent architecture (cp. [Brenner et al., 1998])

Deliberative agents are the next step of this development. They contain an explicit symbolic model of the environment and decide following certain logical rules. The targeted types of problems to be solved are:

- **Transduction problems:** describing the translation of the real world into an adequate symbolic description,
- **Representation problems:** describing the symbolic representation of information about real world objects and processes and how agents reason with those data.

The vision, especially of representatives of the classic AI, was to create automically planning, automatically reasoning and knowlegde-based agents.

The most important deliberative architecture is the BDI architecture of Rao and Georgeff [Rao and Georgeff, 1991]. It is exemplary described below.

The basic elements of this architecture are the Beliefs, Desires and Intentions. They form the basis for the agent's capability for logical reasoning. Beliefs contain data about environmental information, action possibilities, capabilities and resources. An agent must be able to manage the heterogenous, changeable knowledge about the domain of its interest. The agent's desires derive from its beliefs and contain "individual" judgements of future environmental situations from the agent's point of view. The desires can be mutional, non-realistic and even come into conflict with each other. The intentions are a subset of the agent's actual goals and points to the goal that is actually intended to be achieved.

Additonal components completing the mental state of an BDI agent are its goals and plans [Brenner et al., 1998]. Goals are a subset of the agent's desires and describe its po-

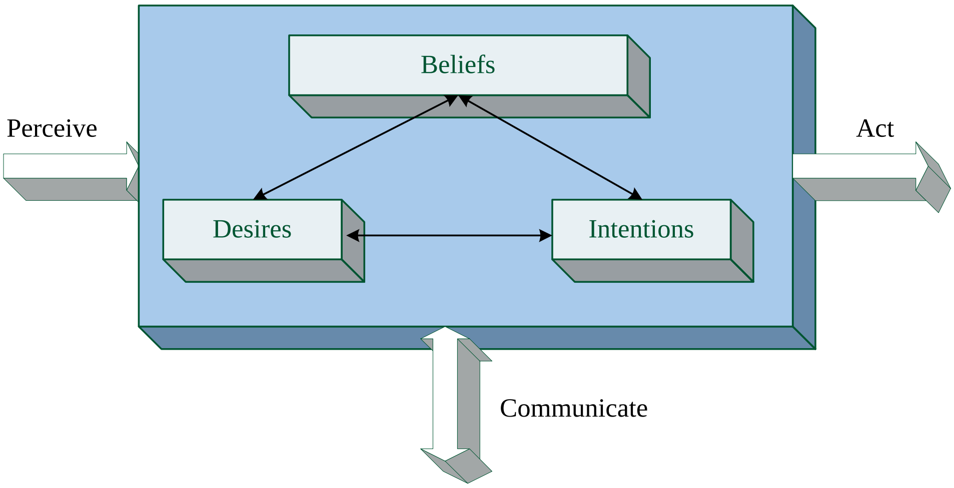

Figure 1.8: BDI architecture (cp. [Rao and Georgeff, 1991])

tential, realistic, not conflicting latitude. Plans subsume intentions and describe actions to solve a problem.

The agent needs sensors to perceive data about its environment to create its world model (cp. figure 1.8). These data need to be interpreted and may cause adaptions or extension of the agent's actual beliefs. Actuators are used to realise plans with certain actions. Thereby the agent changes its environment in a goal-directed, methodical way.

Because of the high complexity of appropriate environmental representations, deliberative agents are rarely sufficiently applicable within dynamic environments.

1.2.2.2 Reactive Agents

Reactive agents are an alternative approach to solve problems that are not or only insuffiently solveable with symbolic AI. Therefore a reactive agent architecture does not include an explicit description of the environment as well as no mechanisms for logical reasoning.

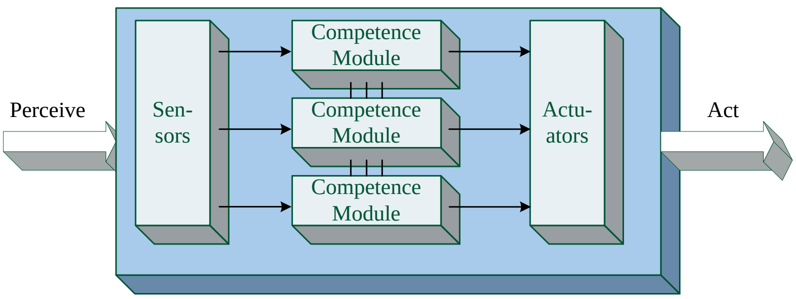

Figure 1.9: Reactive agent architecture (cp. [Rao and Georgeff, 1991])

Reactive agents perceive their environment and immediatly react to occuring changes. This interaction is the basis for their intelligence, in contrast to the internal representations of deliberative agents [Brenner et al., 1998]. The basic architecture of a reactive agent is shown in figure 1.9. Even in complex situations the agent only needs to identify basic axioms or dependencies. These information are processed by task-specific competence modules to create reactions. Again actuators influence the environment based on the determined actions.

A representative of reactive agent architectures is the Subsumption Architecture of [Brooks, 1991]. There every behaviour is an almost independent process subsuming the behaviours of the lower behaviours (cp. figure 1.10).

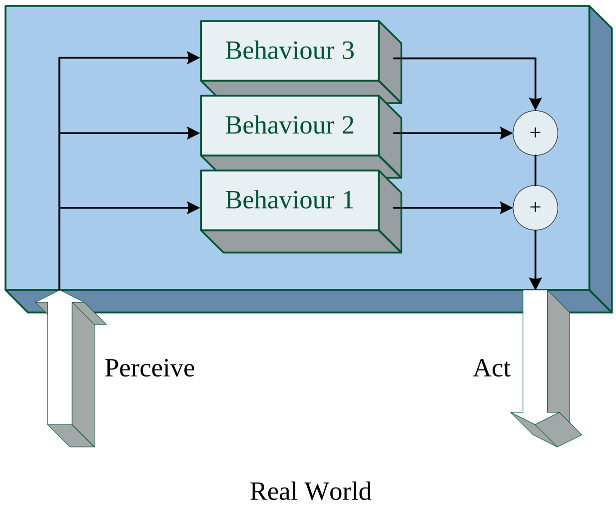

Figure 1.10: Subsumption agent architecture (cp. [Kernchen and Vornholt, 2004])

1.2.2.3 Hybrid Approaches

Hybrid architectures try to combine different architectural approaches to a complex system. The idea behind is to get all advantages but not the trade-offs of the particular approaches. Following Ferber hybrid approaches can be classified according to the capacity of agents to accomplish their tasks individually as well as to plan their actions.

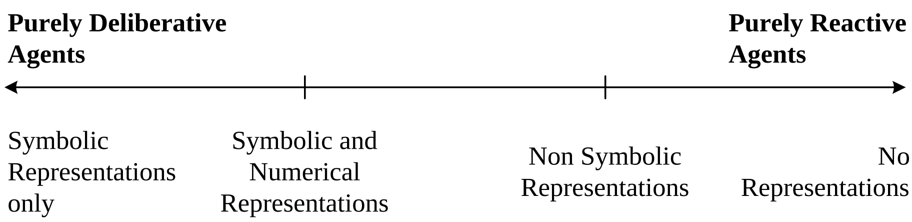

Figure 1.11: Hybrid agent architecture classification (cp. [Ferber, 1999])

Literature like [Brooks, 1991] proposes horizontal as well as vertical levels, each with own functionality, in those complex systems. An example of a hybrid architecture is shown in figure 1.12 and was developed by Müller in 1996.

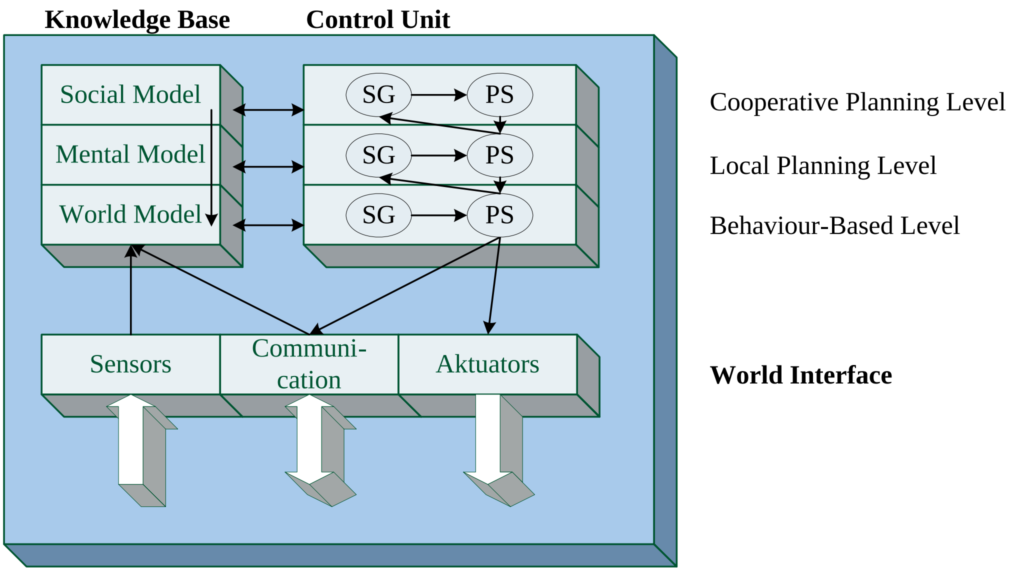

Figure 1.12: Hybrid agent architecture (cp. [Müller, 1996])

One important advantage of agent technology is its possibility to find better problem solutions due to the cooperation of many individuals. That directly leads to the concept of multi-agent systems.

1.2.3 Multi-Agent Systems

The central approach of solving a given problem with a single agent may lead to certain restrictions ([Nwana, 1996], [Sycara et al., 1996]). Multi-agent systems (MAS) are societies of a number of autonomous agents that work together to overcome them. It comprises their abilities and experiences an additional surplus value by the interaction among in individuals as this saying by Aristoteles reflects: "The whole is more than the sum of its parts." Every agent of the MAS either can pursue its own goals and only communicate for information gathering or it can provide a coordinated, partial solution for the whole problem. But always the agent has a well defined task that it is responsible and especially appropriate for.

Common areas of application are problem-solving, multi-agent simulation, the building of artificial worlds, collective robotics and program design [Ferber, 1999].

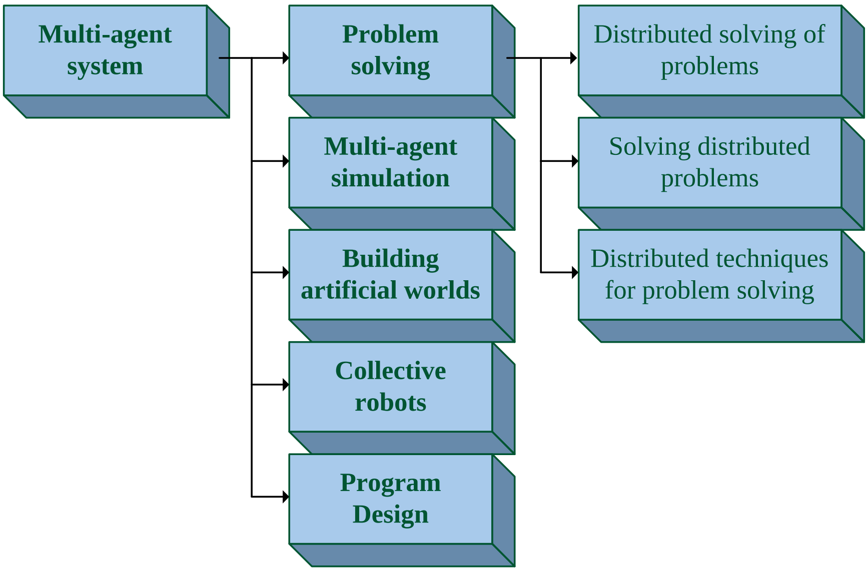

Figure 1.13: Classification of application types for multi-agent systems (cp. [Ferber, 1999])

Definition 7 *The term **multi-agent system** (or MAS) is applied to a system comprising the following elements [Ferber, 1999]:*

1. *An environment, E, that is a space which generally has a volume.*
2. *A set of objects, O. These objects are situated, that is to say, it is possibly at a given moment to associate any object with a position in E. These objects are passive, that is, they can be perceived, created, destroyed and modified by the agents.*
3. *An assembly of agents, A, which are specific objects ($A \subseteq O$), representing the active entities of the system.*
4. *An assembly of relations, R, which links objects (and thus agents) to each other.*
5. *An assembly of operations, Op, making it possible for the agents of A to perceive, produce, consume, transform and manipulate objects from O.*
6. *Operators with the task of representing the application of these operations and reaction of the world to this attempt at modifications, which we shall call the laws of the universe.*

MAS have several advantages. [Hayzelden and Bigham, 1999b] listed the following ones:

- "To address problems that are too large for a centralized single agent, for example because of resource limitations or for robustness concerns (the ability to recover from fault conditions or unexpected events);
- To enable the reduction of processing costs - it is less expensive (in hardware terms) to use a large number of inexpensive processors than a single processor with equivalent processing power;

- To allow for the interconnecting and interoperation of multiple existing legacy systems, e.g. expert systems, decision support systems, legacy network protocols;
- To improve scalability - the organizational structure of the agents can dynamically change to reflect the dynamic environment - i.e. as the network grows in size the agent organization can re-structure by agents altering their roles, beliefs, and actions that they perform;
- To provide solutions to inherently distributed problems, e.g., telecommunications control, air traffic control, and workflow management;
- To provide solutions which draw from distributed information sources; and
- To provide solutions where the expertise is distributed."

Following [Brenner et al., 1998] the most important restrictions of single agents, and thereby reasons for the creation of MAS, are:

- Enormous amount of knowledge necessary for complex problems
- Problem can be so complex, that there exists no actual technology that enables one single agent to develop a solution
- Many problems are distributed and require distributed solutions
- Often domain knowledge and other resources are distributed among different places
- Single agents can be bottlenecks in terms of processing speed, reliability, flexibility and modularity

There exists an agent-based approach being differently to creating multi-agent systems by subdividing system functionality. This layering architecture can have two occurrences: horizontal and vertical. In vertically layered agents only the lowest layer senses the environment and only the highest layer acts. Here a decomposition into subagents is unlikely. By contrast horizontally layered agents can be decomposed, because each layer has sensing and acting functionalities [Müller et al., 1995].

1.2.4 Agent Interaction

This concept is the basis for every successful society of agents. Without interaction multi-agent systems are only a set of individuals not being able to seize advantages out of the "multi" in "multi-agent systems".

Definition 8 ***Agent interaction*** *describes a set of behaviours resulting from a society of agents that need to interact to reach their goals while considering possible limited resources and skills [Ferber, 1999].*

For agents the most important aspects that design interaction are their goals and intentions, available resources and their skills. Table 1.2 lists a typology of interaction situations.

Goals	Resources	Skills	Types of situation	Category
Compatible	Sufficient	Sufficient	*Independence*	Indifference
Compatible	Sufficient	Insufficient	*Simple collaboration*	Indifference
Compatible	Insufficient	Sufficient	*Obstruction*	Cooperation
Compatible	Insufficient	Insufficient	*Coordinated collaboration*	Cooperation
Incompatible	Sufficient	Sufficient	*Pure individual competition*	Cooperation
Incompatible	Sufficient	Insufficient	*Pure collective competition*	Antagonism
Incompatible	Insufficient	Sufficient	*Collective conflicts over resources*	Antagonism
Incompatible	Insufficient	Insufficient	*Collective conflicts over resources*	Antagonism

Table 1.2: Classification of interaction situations [Ferber, 1999]

MAS reveal an organisational structure that is characterised by an assembly of classes of agents (roles allocated to the agents) and a set of abstract relationships existing between these roles (cp. [Ferber, 1999]). Five types of dimensions between organisations are visualised in figure 1.14. Again interaction is a key factor of this aspect of MAS and may result in fixed, variable oder evolutionary evolving couplings between organisational components.

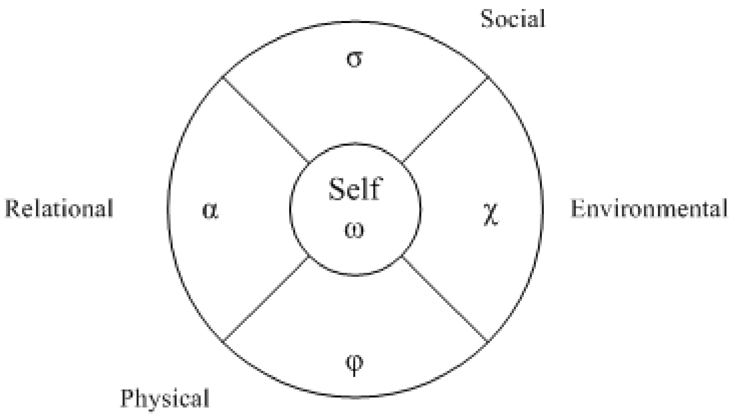

Figure 1.14: Aspects of analysing organisations (cp. [Ferber, 1999])

1. The physical dimension (ϕ) describes non-virtual existing aspects. That includes implementation, organisational architecture as well as its personal resources.
2. The social dimension (σ) is deduced from organisational theory and refers to role and place of the organisation within a meta-organisation.

3. The next dimension, the relational (α), is the most interesting one for agent interactions. It describes the exchanges the organisation might have with other on the same level including communication and coordination.
4. As agents organisations need capabilities to perceive, reason and act with the environment. The environmental dimension (χ) is linked to that purpose.
5. Everything related to the organisation itself is described in the personal dimension (ω).

Following [Brenner et al., 1998] the main aspects of agent interaction in MAS are communication and cooperation. Without these aspects no mutual solution strategies can be developed and no distributed resources can be used. Thereby the communication itself is the basis for cooperation.

1.2.4.1 Communication

Communication is the foundation for every interaction. Its intentions are information and conversation. Agent communication theory is based on the theory of communication that emerged from telecommunications research of [Shannon and Weaver, 1949]. This model consists of a sender, who encodes the message to be sent with a language and sending it via a communication medium/channel to a receiver who decodes it. The situation both, sender and receiver, are placed in is called the context of the communication (cp. figure 1.15).

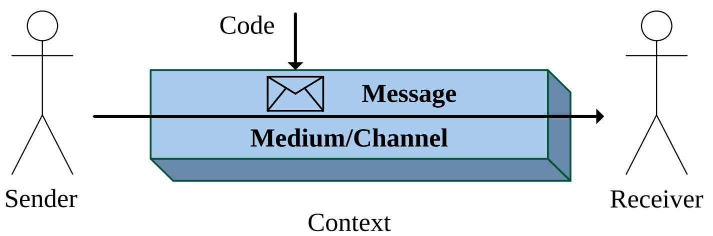

Figure 1.15: Classic model of communication theory (cp. [Ferber, 1999])

The difference between communication of objects and agents are already described in section 1.2.2 and figure 1.6. The most basic communication method of agents is a procedure call, where the message is encoded within the parameters and the answer is the return value of the procedure. But thereby only primitive communication can be established. Blackboard and message-based communication are more appropriate techniques and described below.

Blackboard Technique for Communication

Definition 9 *A* ***blackboard*** *is a shared working environment for all participating agents to share information, data and knowledge [Brenner et al., 1998].*

Its origins lay within the research are of distributed artificial intelligence, too. To communicate, an agent writes information on the blackboard - the message is ’sended’. To ’receive’ a message, agent read (potentially filtered) information from the blackboard. No direct communication between agents is established. For management and security purposes a central management component can be included, where agents need to register themselves. Multiple specialised blackboards can exist within a MAS, additionally one agent may register for more than one blackbord. Figure 1.16 visualises an extended blackboard architecture, that includes the already mentioned management component, a dispatcher for agent notification and further refined mechanisms for knowledge access (Knowledge Source Activation Record - KSAR).

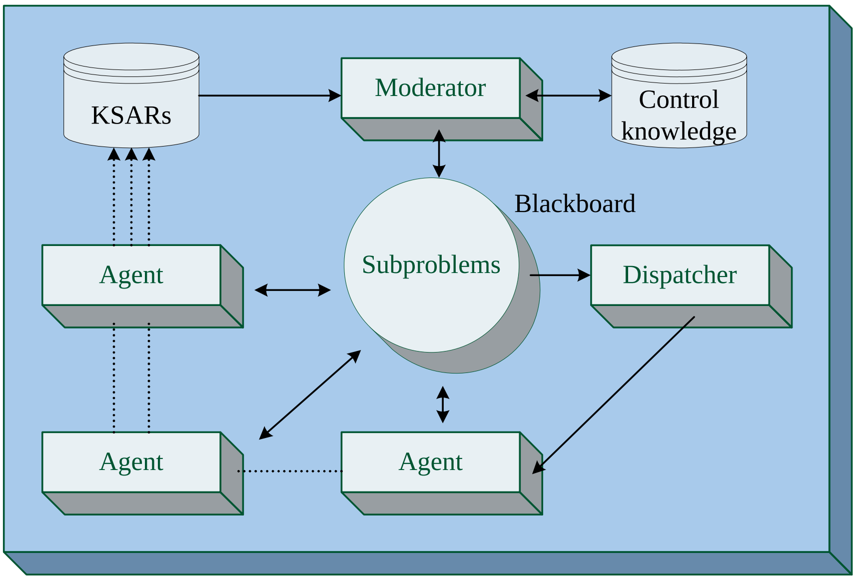

Figure 1.16: Extended blackboard structure (cp. [Brenner et al., 1998])

MAS may consist of hundreds or thousands of agents being distributed across an unreliable network; then communication based on a shared memory not always a sufficient solution for message exchange [Tanenbaum and van Steen, 2002]. Other communication approaches are needed.

Messages and Conversations for Communication Communication based on message exchange provides a flexible basis for complex scenarios [Brenner et al., 1998]. It has its foundations in speech act theory based on research of [Austin, 2005], [Searle, 1969] and [Habermas, 1984]. There exist five types of speech acts ([Searle, 1969], [Schoop, 2001]) and each has a locutionary aspect describing its physical creation, a illocutionary aspect describing the sender’s intention and a perlocutionary aspect describing the effects of the speech act at the side of the receiver [Austin, 2005].

- Assertive speech act: express facts about the world
- Directive speech act: express instructions for the receiver
- Commissive speech act: express the sender's commitment for future actions
- Expressive speech act: expressions about the sender's feelings or psychological attitudes
- Declarative speech act: the world is changed due to the speech act itself

Message-based communication follows the structure that was already presented in figure 1.15. The message structure is defined by certain Agent Communication Languages (ACLs) for a free content composition. Based on these degrees of freedom extremely complex and flexible dialogues can be defined. ACLs, conversations and some protocols as generally accepted dialogue structures are described below.

Agent Communication Languages Following [Ferber, 1999] a communication language is one of the four basic languages for agent technology implementation. The others refer to the implementation and formalisation of multi-agent systems, to the knowledge representation of agents as well as to the definition of behaviour. Figure 1.17 shows these aspects.

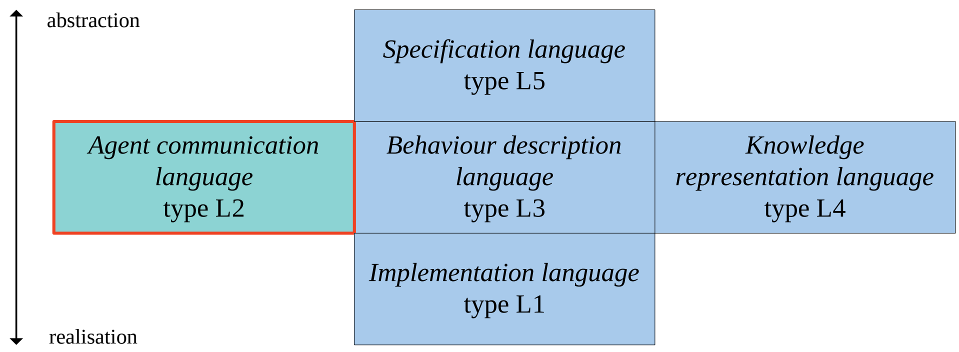

Figure 1.17: Agent communication language in the context of other implementation languages (cp. [Ferber, 1999])

Communication languages (type L2) are thereby used for data transmission and mutual requests for informations and services. Their efficient usage is the basis for all interaction types and by this for the advantages inhered in multi-agent systems. KQML is the classic referenced language. The other languages are the

- Implementation languages (type L1) which are used to program agents and agent-based systems,
- Behaviour description languages (type L3) which prescind from implementation and are necessary to describe additional details to understand the environment and the behaviour of agents,
- Knowledge representation languages (type L4) which are used to model information about the environment and to deduce assumptions about the future and the

◦ Specification languages (type L5) for the definition of a common understanding of multi-agent systems based on certain concepts as well as for the determination of requirements for modelling and implementation of those systems.

All these types of languages are connected to each other as for example a representative of L2 is used to send a message that can be interpreted by a representative of L3.

Table 1.3 comprises an overview about existing agent communication languages and is based on [Barbuceanu and Lo, 2000], [Bryce and Cremonini, 2001], [Chaib-draa et al., 2006], [Cockayne and Zyda, 1997], [Foundation for Intelligent Physical Agents (FIPA), 2002b], [Freeman et al., 1999], [Garcia et al., 2004], [Genesereth and Fikes, 1992], [Grosof and Labrou, 2000], [Haugeneder and Steiner, 1998], [Hindriks et al., 2000], [Jeon et al., 2000], [Kuwabara et al., 1995], [Labrou and Finin, 1997], [Liu and Ye, 2001], [Moore, 2000], [Papadopoulos, 2001], [Petrie, 2000], [Pitt and Mamdani, 2000], [Rossi et al., 2001] and [Skarmeas, 1999].

Agent communication language	**Language characteristic**
ACML	XML-based
Agent-0	KQML-based
AgenTalk	Descriptive language
April++	OO concurrent language
COOL	Descriptive language
DIAGAL	Descriptive language
FIPA-ACL	XML-based
FLBC	XML-based
GroupLog	Extended Horn clauses
JADL	Java-based
KIF	Descriptive language
KLAIM	Descriptive language
KQML	Descriptive language
Little-JIL	Visual language
LuCe	Prolog related
MAI^2L	Descriptive language
sACL	Command language
Telescript	Command language
TRUCE	Protocol specification
WARREN-ACL	KQML-based
3APL	Command language

Table 1.3: Common agent communication languages (revised and extended version of [Wille, 2005])

KQML (Knowledge Query Manipulation Language) [Labrou and Finin, 1997] and FIPA-ACL (Foundation for Intelligent Physical Agents - Agent Communication Language) [Foundation for Intelligent Physical Agents (FIPA), 2002b] are the two main agent languages [Chaib-draa et al., 2006]. Both are based on the already introduced speech act theory.

KQML and FIPA-ACL treat messages as environment-influencing actions and their message types are named performatives.

KQML was developed in the context of DARPA (Defense Advanced Research Projects Agency) research [Chaib-draa et al., 2006]. A corresponding message has three conceptual levels:

- **Communication level** to specify sender and receiver,
- **Message level** to specify performative, knowledge representation language and used ontology and the
- **Content level** to specify the message's content.

Some performatives of KQML are categorized in table 1.4.

Function Class	Member Performatives	Level
Query and response	ask-if, ask-all, ask-about, ask-one, tell, untell, deny, sorry	agent-pair
Cursor manipulation and result formatting	ready, next, discard, rest stream-all, stream-about, eos	agent-pair
Advertise or commit to a capability	advertise, unadvertise	agent community
KB editing	insert, uninsert, delete-one, delete-all, undelete	agent-pair
Enactment	achieve, unachieve	agent-pair
Error handling	error	agent-pair
Communication primitives other than pure asynchronous messages	broadcast, forward, standby, subscribe and monitor (like a kb alerter), pipe, break (make and dismantle a pipe), generator	either
Trading	broker-one, broker-all, recommend-one, recommend-all, recruit-one, recruit-all	agent-community
Name service	register, unregister, transport-address	agent-community

Table 1.4: Classification of KQML performatives [Vasudevan, 1998])

Notice, that a later definition of semantic for KQML messages was proposed in [Labrou and Finin, 1998]. Certain KQML and FIPA-ACL message might reveal a similar structure due to the same theoretical fundamentals, the same intentional usage as well as due to their mutual development. A KQML message has the following structure.

```
(KQML-performative
:sender   <word>
:receiver <word>
:language <word>
:ontology <word>
:content <expression> ...
)
```

KQML was not sufficient for researchers and practitioners due to several reasons. First problems were the imprecise definition of the performatives and their large, almost not handable and not-bounded number. The interaction of different MAS implementations was not always guaranteed. Additionally no protocol for message transport was specified and no semantic of the language was defined. Also some performatives for action coordination were missing. As a result interoperability, communication and message transport were not supported to a usable extent. So FIPA-ACL was developed.

FIPA-ACL is an standard that defines messages and their descriptions that are intended to be used for agent communication. It differs from KQML in the available performatives and in the defined semantics. For the second point a Semantic Language (SL) was developed to model beliefs, vague beliefs and desires of agents [Wooldridge, 2002]. SL defines feasibility conditions and rational effects for every performative. The SL-based semantic definition of the `inform`-performative is given below [Foundation for Intelligent Physical Agents (FIPA), 2002c].

$< i, inform(j, \varphi) >$
- Feasibility precondition: $B_{i\varphi} \wedge \neg B_i(Bif_{j\varphi} \vee Uif_{j\varphi})$
- Rational effect: $B_{i\varphi}$

A corresponding message contains the mandatory parameter `performative` (cp. [Foundation for Intelligent Physical Agents (FIPA), 2002c] for a list of available performatives) and several other optional parameters (cp. table 1.5).

An exemplary FIPA-ACL message has the following structure:

```
(inform
:sender agent1
:reveiver agent2
:content (price good2 150)
:language sl
:ontology hpl-auction
)
```

Parameter	Category of Parameters
`performative`	Type of communicative act
`sender`	Participant in communication
`receiver`	Participant in communication
`reply-to`	Participant in communication
`content`	Content of Message
`language`	Description of Content
`encoding`	Description of Content
`ontology`	Description of Content
`protocol`	Control of conversation
`conversation-id`	Control of conversation
`reply-with`	Control of conversation
`in-reply-to`	Control of conversation
`reply-by`	Control of conversation

Table 1.5: FIPA-ACL message parameters
[Foundation for Intelligent Physical Agents (FIPA), 2002b])

Communication between agents can result in extended message sequences, also called conversation or dialogue. [Walton and Krabbe, 1995] lists several types of conversation. They are presented in table 1.6.

Type of Dialogue	Goal of the Dialogue	Initial Situation
Persuasion	Resolution of conflict	Conflicting point of view
Negotiation	Making a deal	Conflict of interest
Deliberation	Reaching a decision	Need for action
Information-seeking	Spreading knowledge	Personal ignorance
Inquiry	Growth of knowledge	General ignorance
Eristic	Accomodation in relation-ship	Antagonism

Table 1.6: Primary types of dialogue [Walton and Krabbe, 1995])

Often occuring conversation pattern are specified for common agreement. Some chosen generally accepted and standardised protocols are the

- Contract-Net Protocol [Smith, 1980]
- Yes-No-Query Protocol [Pitt and Mamdani, 2000]
- Confirmation Protocol [Pitt and Mamdani, 2000]
- Haggle Protocol, cp. [Wille et al., 2002]
- Commitment Protocol [Pitt and Mamdani, 2000]
- FIPA Conversation Protocols, e.g. FIPA Iterated Contract Net Interaction Protocol Specification [Foundation for Intelligent Physical Agents (FIPA), 2002b] and other FIPA Standard protocols
- Request-for-Action Protocol [Winograd and Flores, 1986]
- ...

Protocols with a large number of states can become crucial for agent communication because of possible computation problems as well as due its decreased flexibility for agents [Chaib-draa et al., 2006].

1.2.4.2 Agent Cooperation

Especially in environments with a lot of cooperation between participants agent technology can map emerging requirements and patterns because of their ability to cooperate with themselves [Kargl et al., 1999]. This cooperation between entities can be the largest context of interaction [Dumke et al., 2000]. Mentionable aspects of this activity are the coordination of actions, the degree of parallelism, the sharing of resources, system robustness, the non-redundancy of actions as well as the non-persistence of conflicts. Cooperation indicators are increasing individual and group survival capacity, performance improvement and conflict resolution. Therefore a usual definition of cooperation is given as [Ferber, 1999]:

Definition 10 ***Cooperation*** *is collaboration, coordination of actions and the resolution of conflicts.*

Cooperation is mainly implemented due to several desires. That includes the reduction of communication costs that are associated with a central problem solver, the improvement of performance through parallelism, increased reactivity because of not needed consultancy of a central problem solver and the improved robustness by reduced dependencies [Hayzelden and Bigham, 1999a]. Therefore the addition of new agents should lead to an increased performance of the group and their performed actions should solve or avoid actual or potential conflicts [Ferber, 1999].

Cooperation methods are classifiable into six categories [Ferber, 1999]. Correlating problems, techniques and objectives are visualised in figure 1.18.

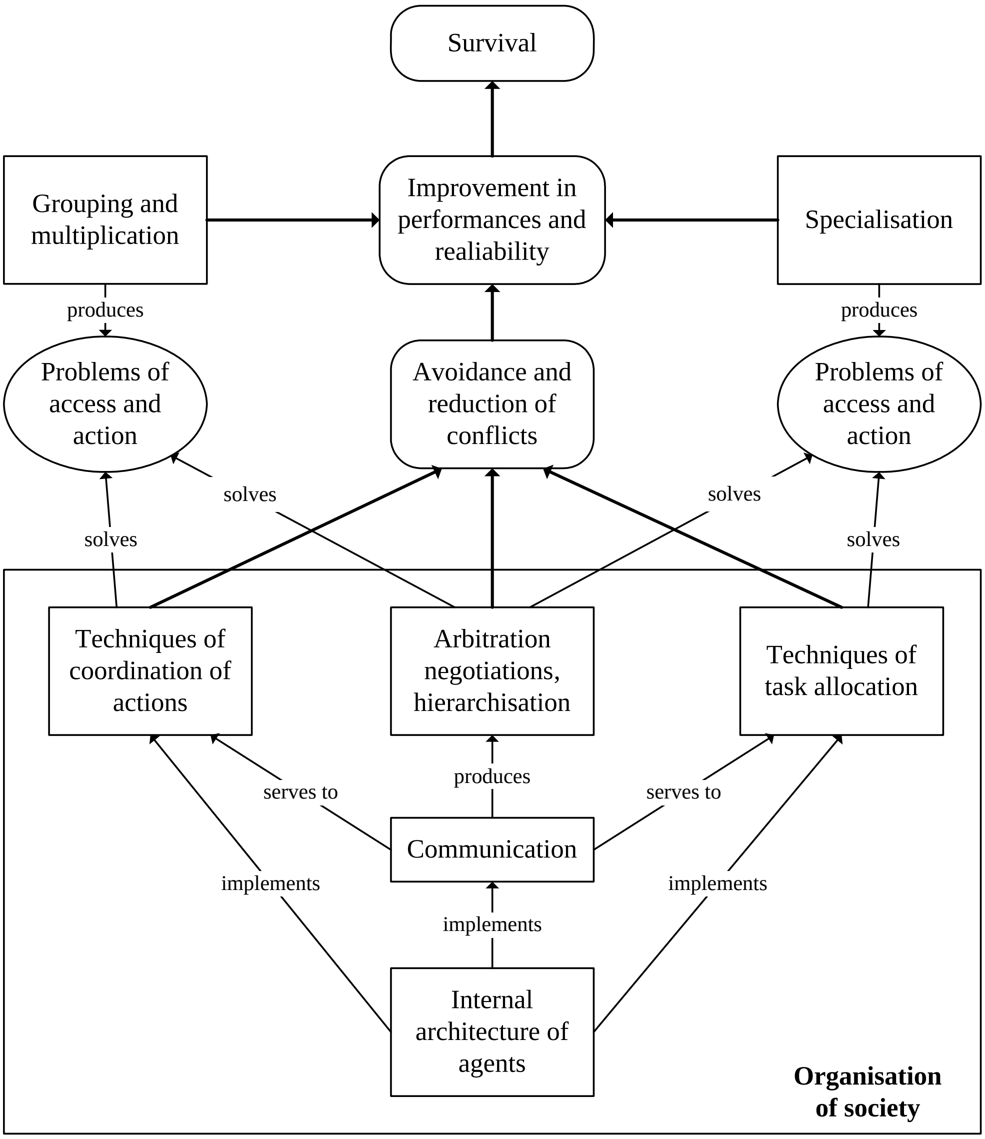

Figure 1.18: Characteristics of cooperation in agent-based organisations (cp. [Ferber, 1999])

- **Grouping and multiplication:** Grouping is a natural phenomenon that describes a more or less homogeneous unit that emerges from physical closeness or the existence of a communication network. It is the basis for specialisation and supports learning. Multiplication comprises several advantages in situations that benefit from pure quantity of individuals, resources or skills. Overall performance and reliability can be increased without increase of individual productivity.
- **Communication:** This aspect is the base of every other cooperation. It connects the individuals of the agent society either by explicit messages or signals in the environment.
- **Specialisation:** Specialisation is a process of adaptation towards specific tasks. This special performance increase has as a trade-off the decreased ability to perform other

tasks. There multiple individuals in a group needed for multiple jobs to be performed for an overall task.

- **Collaborating by sharing tasks and resources:** Collaboration is one of the intentions of communication. It requires a general goal to be achieved. To keep it, a distributed allocation of tasks, information and resources is needed [Dumke et al., 2000].
- **Coordination of actions:** Coordination in MAS is needed due to several reasons. That includes prevention from confusion, the meeting of global constraints, speciality of agents and depending sub-actions [Hayzelden and Bigham, 1999a]. Mainly the reasons evolve from the fact of a missing global view on the complete problem. They need further information and services to get their local problem solutions that are intended to subsume to the global solution. That needs to be arranged in a reasonable way. Coordination can be achieved by synchronisation, planning, reaction and regulation.
- **Conflict resolution by arbitration and negotiation:** These to approaches are used to minimize decrease of system performance due to conflicts between individual agents. Arbitrations lead to behavioural rules whose concern is to restrict conflicts and preserve the society of agents.

In the following we want to briefly define the main parts of cooperation after Ferber.

Collaboration Agents collaborate, when they are working together. Collaboration techniques are those that distribute tasks, information and resources among agents in the advancement of a common labour. Such a distribution can be centralised by coordination agents or decentralised by offering supplies and demands. Distributed approaches itself may base on the market principle or on mutual representations of the agents' capacities [Ferber, 1999].

Definition 11 ***Collaboration*** *is the collective solution of a problem or the collection processing of a task by a society of agents.*

The adressed advantages of agent collaboration like increased processing speed and robustness are 'paid' by trade-offs related to overheads in terms of team formation and collaboration, agent communication and team maintenance [Wilsker, 1996]. Some exemplary multi agent collaboration strategies are:

- Joint Intentions model of Cohen and Levesque [Cohen and Levesque, 1990], [Cohen and Levesque, 1991]
- SharedPlan model of collaboration [Grosz and Sidner, 1990]
- Planned Team Activity by Kinny [Kinny et al., 1994]
- Commitment based on agents' mental states and relationships by Castelfranchi [Castelfranchi, 1995]
- Responsibility delegation by Matsubayashi [Matsubayashi and Tokoro, 1993]
- Team formation after Tidhar [Tidhar et al., 1992]

Coordination Coordination is the next part of interaction following Ferber's widely accepted definition. Main research and definition approaches base, among others, on [Malone and Crowston, 1994], [Wegner, 1996] and [Gelernter and Carriero, 1992].

Definition 12 *Coordination is the management of interaction and dependencies between certain agents [Omicini et al., 2001].*

Coordination techniques can be classified [Nwana et al., 1997] as:

- **Organisational structuring** by defining an interaction framework with roles, communication paths and authority relationships.
- **Contracting** by using manager agents for problem decomposition and task assignment.
- **Multi-Agent planning** by a centralised or distributed planning of interaction to avoid conflicting actions.
- **Negotiation** by interaction to reach a mutually accepted agreement.

Within coordination techniques and strategies, agents may serve as coordination components [Papadopoulos, 2001]. A corresponding approach is a facilitator/mediator where the agent provides services and thereby satisfies requests of other agents. Broker agents also satisfy request, but by provding third-party services. A special look-up service (yellow pages) is provided by matchmaker agents. Repository agents managing requests for other agents follow the blackboard approach. The management and conduction of communication for other agents in a well defined area leads to a job description of a local area coordinator agent. Cooperation domain servers are agents providing facilities to access shared information and to subscribe, exchange messages.

Conflict Resolution Classically conflicts are seen as disturbances within a MAS [Tessier et al., 2001]. On a conceptual level exist resource conflicts and knowledge conflicts. The first type can occur when resource, like processing time, is involved. Knowledge conflicts arise when the agents' information differ. Contradiction between propositions is the one that is most dealt with.

Definition 13 *A **conflict** is a subset of all propositional attitude(s) (e.g. beliefs, desires, intentions, hopes, etc.) of the agent that must be reduced by removing a propositional attitude [Tessier et al., 2001].*

In other words - it is a situation with incompatible or exclusive attitudes. Appropriate approaches either try to anticipate, solve or avoid them, otherwise conflicts remain unsolved and change agents' behaviours or enrich agents' knowledge. Following [Aïmeur, 2001] the three modes for conflict resolution are

- Negotiation: as a discussion procedure to reach a common agreement between the involved parties,
- Mediation: as a negotiation with a neutral part that facilitates the solution research,
- Arbitration: as the decision of a solution by a neutral part.

Definition 14 *Thereby* ***conflict resolution*** *is the application of certain techniques for the transition from a situation with conflicting agent attitudes to a situation with less or no conflicting agent attitudes.*

1.2.5 Agent Mobility

Another major advantage of agents is their ability to migrate between environments over a network ([Jennings and Wooldridge, 1998b], [Franklin and Graesser, 1996]). It is an extension of the client/server paradigm of computing by allowing the transmission of executable programs between network nodes (cp. figure 1.19).

Definition 15 *Agent mobility is the agent's property that permits the continuation of its execution on another network node than it was started [Object Management Group (OMG), 2000].*

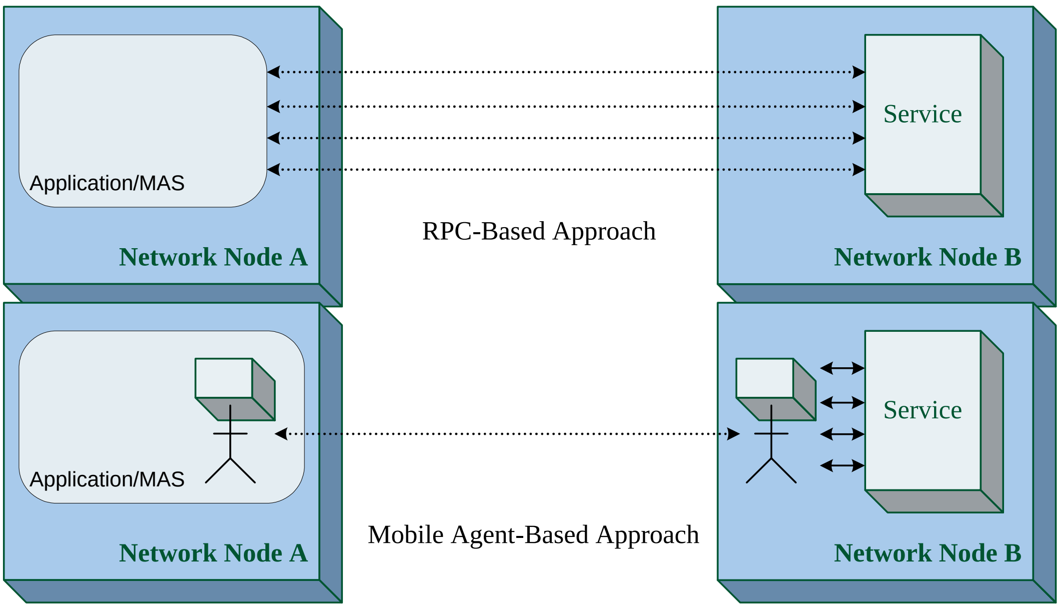

Figure 1.19: Mobile agent paradigm (cp. [Lange and Oshima, 1998])

Mobile agent usage can reduce network traffic, overcome network latency and allow asynchronous and autonomous interaction, disconnected operation (cp. figure 1.20) as well as remote searching and filtering. Furthermore they encapsulate protocols, adapt dynamically, are naturally heterogeneous and robust and fault-tolerant [Lange and Oshima, 1998].

By this bandwidth and storage requirements maybe positively impacted [DeTina and Poehlman, 2002]. Other fields of application are the access and administration of distributed information [Buraga, 2003] or the dynamic configuration of a entity network [Sadiig, 2005]. Additional useful implementations are related to

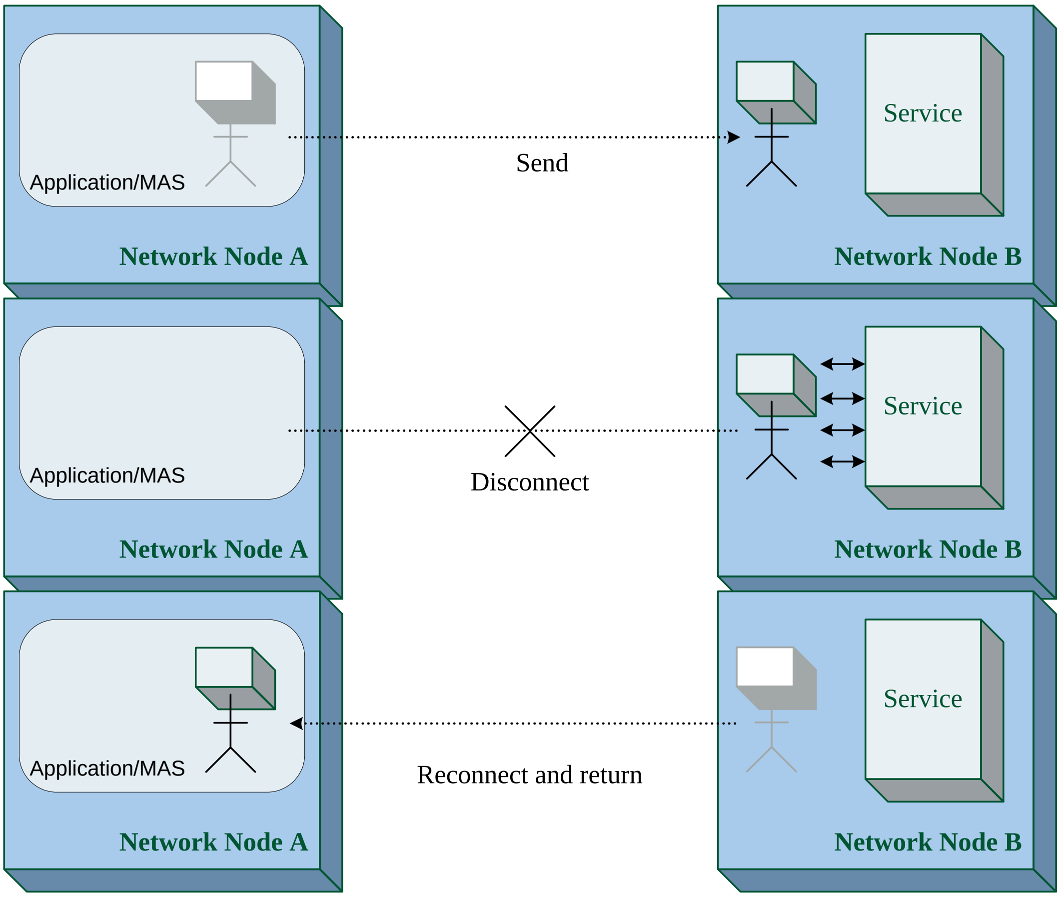

Figure 1.20: Disconnected operation (cp. [Lange and Oshima, 1998])

remote diagnostics, maintenance, control or other related services for stationary or mobile technical systems [Jain et al., 2002].

The standard for agent mobility, Mobile Agent System Interoperability Facility (MASIF), was proposed by the Object Management Group (OMG). It standardises agent management, agent transfer, agent and agent system names as well as agent system type and location syntax [Object Management Group (OMG), 2000].

Several types of agent mobility can be distinguished. A first one is related to agent's execution state. Thereby strong migration means the agent is migrated together with is execution state. It carries all stack information about with one to determine the point of task execution. Weak migration only supports the transport of predefined data (cp. figure 1.21).

Societies of agents are often logically fragmented for the semantical aggregation of single, but related agents. These cities or regions accomodate certain agents. Migrating agents from one region to another one within the same agent platform is named intra-platform migration. Its counterpart is inter-platform migration.

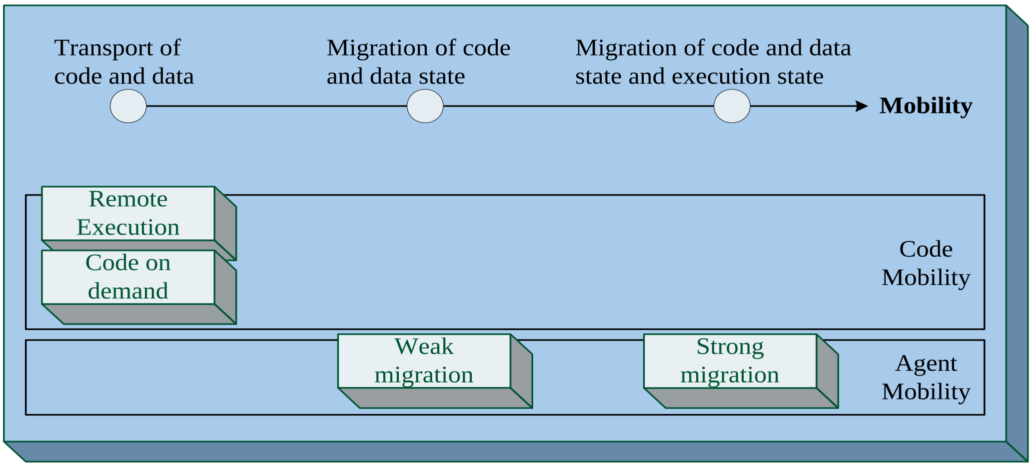

Figure 1.21: Agent mobility (cp. [Kernchen and Vornholt, 2004])

1.2.6 Chosen Agent Platforms

Common functions of an agent system are e.g. creating an agent and transferring an agent, which can include initiating an agent transfer, receiving an agent, and transferring classes. Furthermore it should provide globally unique agent names and locations, should support the concept of a region, find mobile agents and ensures a secure environment for agent operations [Object Management Group (OMG), 2000].

For these purposes certain agent tools, platforms and frameworks have been developed. The following selection of agent platform respectively agent frameworks does not asser one's claims to completness. More exhaustive lists and descriptions go beyond the scope of this work, but can be found e.g. in [AgentLink III, 2007].

1.2.6.1 JADE

JADE (Java Agent Development Environment) provides an agent platform and packages for FIPA-compliant agent development. A basic set of functionalities is given instead of a specific agent architecture. Its development was started in 1999 by Teelekom Italia Labs and the software is available as open source under the terms of the Lesser General Public License Version 2 (LGPL). JADE platform and Lightweight Extensible Agent Platform (LEAP) libraries allow to obtain a FIPA-compliant agent platform with compatibility to mobile Java environments [Telecom Italia, 2007]. Several further add-ons are developed and available for the actual version 3.5.

The JADE agent platform can be distributed across multiple network nodes that not even have the same operating system. Therefore it supports the container concept for either the logical seperation of certain agents or for their physical separation on different machines. The main container contains the primary necessary DF agent, AMS agent and the RMI registry. Additional containers can be started on the same or from remote hosts. Remote containers can be connected to the main container. JADE supports FIPA compliant ACL messages and allows agent migration and cloning.

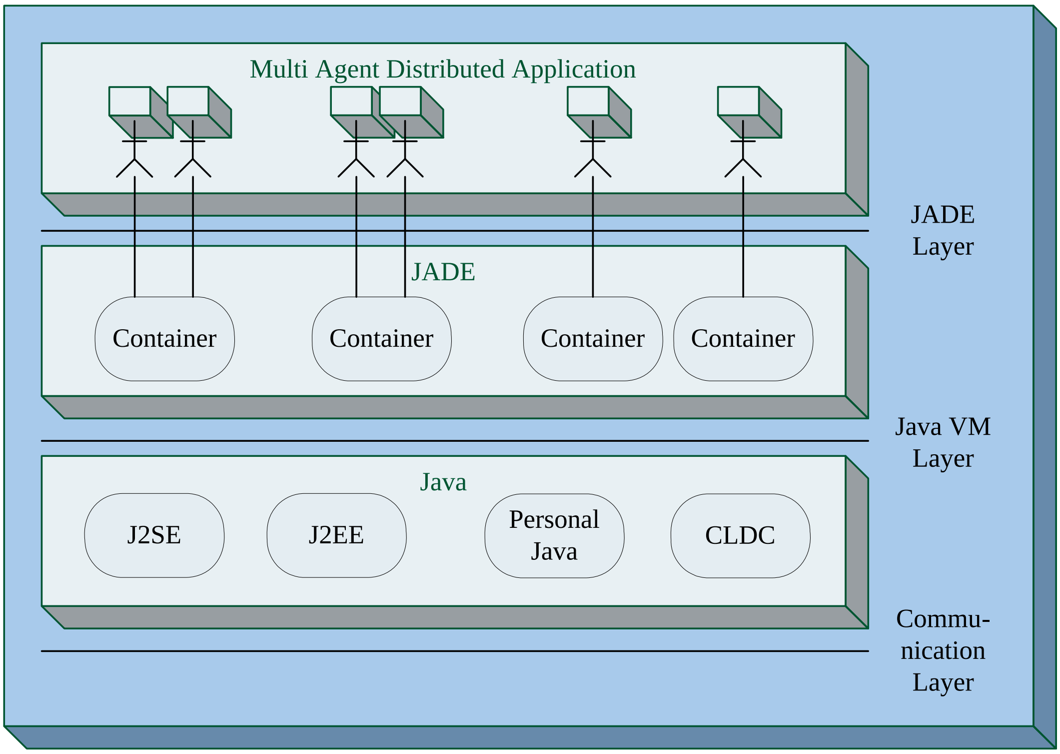

Figure 1.22: JADE architecture (cp. [Kernchen et al., 2006])

1.2.6.2 JATLite

JATLite is a development of the University of Stanford. It is intended to wrap certain functionality with agents (cp. figure 1.23).

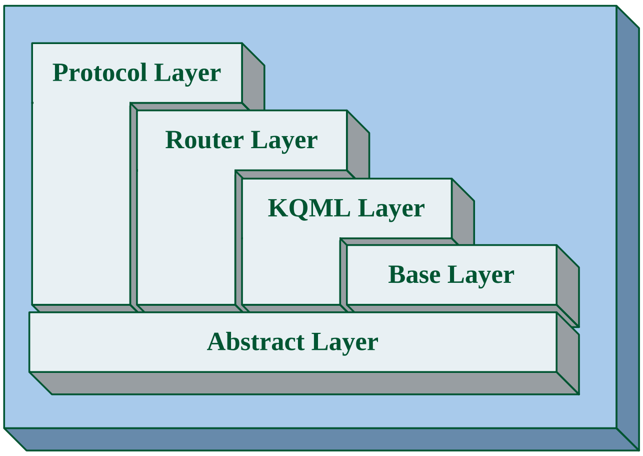

Figure 1.23: JATLite architecture (cp. [Jeon et al., 2000])

Main focus is laid on the establishment of communication. Therefore an agent message router is implemented to send KQML messages. Several templates are provided for the creation of agents with different communication capabilites. The abstract layer defines certain Java classes and supports basic communication protocols like the User Datagram Protocol (UDP). The basic layer focusses on Transmission Control Protocol/Internet Protocol (TCP/IP) network communication. Furthermore the KQML layer supports KQML messages and the File Transfer Protocol (FTP) layer is intended for messages to pass large volumes of data. The router layer provides the already described services.

1.2.6.3 MadKit

MadKit is a modular and scalable multi-agent platform written in Java and built upon the AGR (Agent/Group/Role) organizational model: agents are situated in groups and play roles. MadKit is intended to allow high heterogeneity in agent architectures and communication languages and various customizations [The MadKit Project, 2005]. Communication in MadKit is based on a peer-to-peer mechanism. Programming languages for MadKit agents may be Java, Scheme (Kawa), Jess (rule based engine), BeanShell or other script languages.

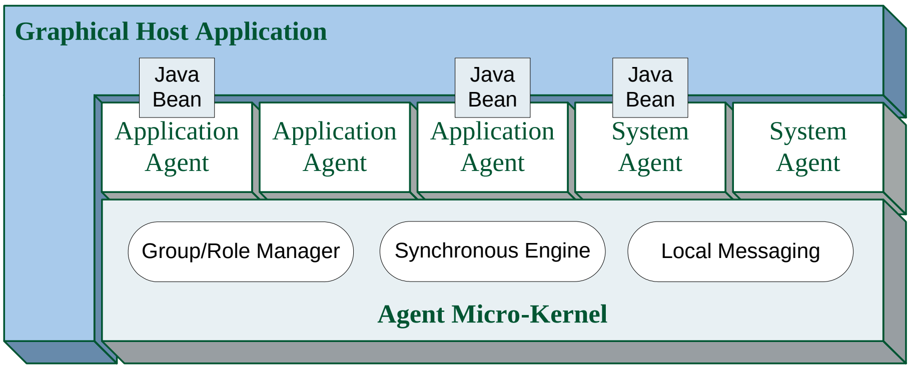

Figure 1.24: MadKit architecture (cp. [Weiss and Jakob, 2005])

The micro-kernel is the core of MadKit. It is responsible for the key facilities for the deployment of services. The micro-kernel's main tasks are:

- Control of local groups and roles
- Agent life-cycle management
- Local message passing

1.2.6.4 Aglets

Aglets are Java-based mobile agents that were developed by IBM Japan in 1996 and is currently open source, licensed under IBM Public License with the current version 2.0.2.

The provided framework of the consists of three parts: an API for the development of agents, a server API for the development of agent systems and the agent platform Tahiti ([Lange and Oshima, 1998], [IBM, 2002]). Basic Aglet functionalities are described in figure 1.25.

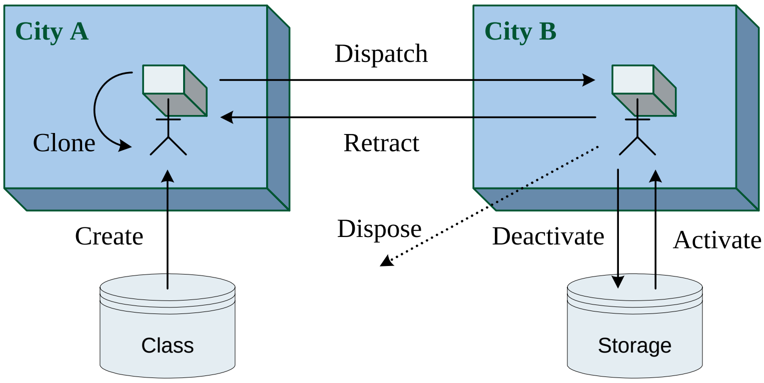

Figure 1.25: Basic Aglet functionalities (cp. [Kernchen et al., 2006])

The basic functionalities of agents within their life cycle are their creation (definition in a special context), cloning (implementation of an already existing agent during runtim), dispatching (moving an agent to a new city), retracting (transferation back to its origin), activation/deactivation (stopping and restarting the agent) and disposal (agent destruction).

2 Foundations on e-Learning

> "*Learning* is such a common human experience that few people reflect on exactly what it means to say that something has been learned. A universally accepted definition does not exist. However, many critical aspects of the concept are captured in the following statement" [Domjan, 1998].

Definition 16 ***Learning*** *is an enduring change in the mechanisms of behaviour involving specific stimuli and/or responses that result from prior experience with similar stimuli and responses [Domjan, 1998].*

Especially e-Learning is nowadays one of the most interesting of the "e-"domains available through the Internet [Anghel and Salomie, 2003]. In general it refers to a wide range of applications and processes designed to deliver instruction through computational means [Juneidi and Vouros, 2005]. It is seen as a technology-based learning alternative respectively extension to the classic classroom model [Giotopoulos et al., 2005].

E-Learning is not intended to exclude existing methods and technologies. A appropriate use might complement them [Anghel and Salomie, 2003]. Actual technical and technological progress and development lead to an increased usage of collaborative environments and distributed learning techniques. The aspects of e-Learning tend to be unique [Cerri, 2002].

It is not necessarily possible to simple apply certain technologies and pedagogical approaches to make people learn. A complete replacement is not the correct solution, too. Certain specific technologies and specific pedagogical principles are required to be adopted, developed and applied [Sadiig, 2005]. "Many learning and technology professionals believe that e-Learning will take its place when we will stop referring to it using a separate name and regard it as an integral part of a complete learning environment." [Giotopoulos et al., 2005].

E-Learning is an already established concept. First roots can be traced back to the 60ties with the PLATO and TICCIT experiences in the USA [Cerri, 2002]. The first knowledge-based tutoring application appeared in domain of artificial intelligence in early 1970s. The first applications were simple automated instruction tools. Next fundamental steps were taken in the early 1990s. Authoring systems for intelligent tutoring systems were designed and developed. Furthermore generic approaches were implemented, e.g. with the usage of task and domain ontologies [van Rosmalen et al., 2005]. The market for e-Learning products increased and became highly fragmented and less transparent. A wide array of products and concepts appeared, even more because of the internet and its flexibility for learning and delivery detached from time and place.

There were approx. 5000 global participants on the e-Learning market in the year 2000 [Hambrecht & CO, 2000]. In 2001 the german market consisted of 34% full service providers, 30% content providers, 24% technology providers and 12% service providers [Berlecon Research, 2001]. Possible types of e-Learning are shown in figure 2.1.

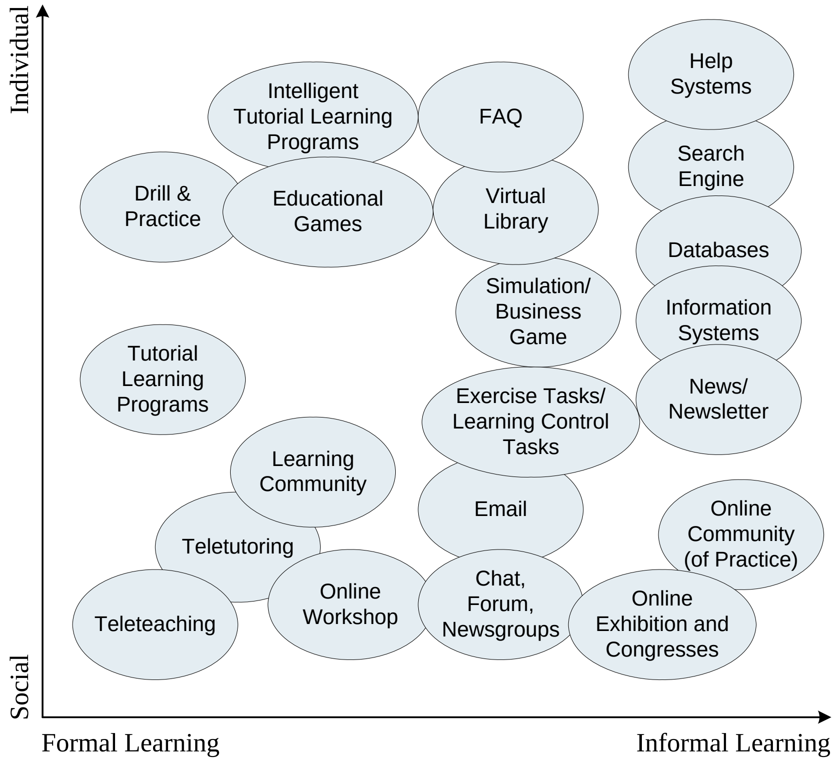

Figure 2.1: E-Learning types (cp. [MMB Institut für Medien- und Kompetenzforschung, 2004])

The actual operating range of e-Learning includes many fields of application. The most common are [Garro and Palopoli, 2002]:

- (a) Private self-improvement (e.g. for lifelong learning),
- (b) Scholar learning,
- (c) Vocational training,
- (d) Support of courses of universities and other higher educational establishments and
- (e) Business training as a component of Enterprise Knowledge Management.

General classes of vendors within the learning sector of e-commerce are technology providers, content providers and service providers. Certain full service vendors exist, too. Technology providers concentrate on learning platforms and portals, online conferencing systems, testing platforms, authoring tools and administration systems amongst others. Content providers generate and distribute differently specialised content as e.g. IT training, foreign languages, project management or individual content. Services can be e-Learning consulting, application service providing, development, adaptation or training and support.

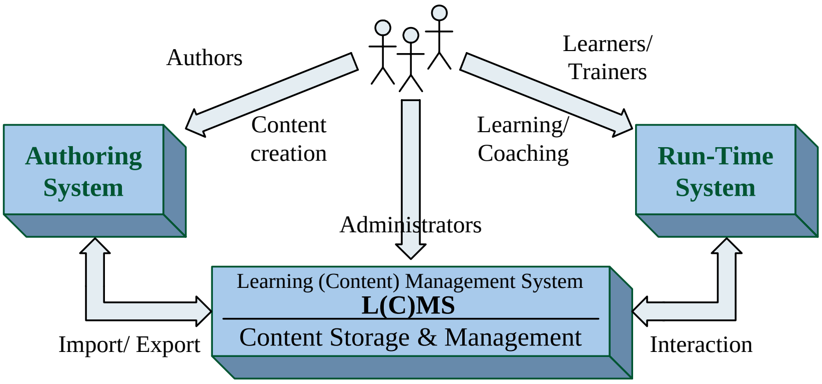

Figure 2.2: General e-Learning system and involved roles (cp. [IMS Global Learning Consortium, Inc., 2003b])

A general view on e-Learning systems, involved roles and components is visualized in figure 2.2. In a typical learning environment learners, authors, trainers and administrators are the main groups ([Pankratius et al., 2004], [Giotopoulos et al., 2005]). Sometimes these roles overlap, so trainers and authors can be the same person, especially for small e-Learning systems. The content to be presented is created by the authors using authoring systems, stored in the learning management system (LMS) and thereby made available for the learner via a run-time system. The administrator's role is the mainly the maintenance of the e-Learning system's core. He sets up, configures, updates and maintains the L(C)MS. Especially for larger applications additional roles can be identified e.g.: content expert, instructional designer, programmer, graphic artist and project manager [Giotopoulos et al., 2005]. The role of learners as content consumers is obviously clear.

2.1 Definitions and Primary Concepts about e-Learning

There exist many terms within the context of e-Learning. This section provides an overview about primary concepts of this knowledge domain.

Definition 17 ***E-Learning*** *refers to a wide range of applications and processes designed to deliver instruction through computational means [Juneidi and Vouros, 2005].*

A definition taking into account those further details is given by the American Society for Training & Development (ASTD).

Definition 18 ***E-Learning*** *refers to a wide set of applications and processes, such as Web-based learning, computer-based learning, virtual classrooms, and digital collaboration. It includes the delivery of content via Internet, intranet/extranet (LAN/WAN), audio- and video tape, satellite broadcast, interactive TV, CD-ROM, and more [American Society for Training & Development (ASTD), 2007].*

Today mainly internet and intranet-based learning is entitled e-Learning. Following [SIVECO Romania SA., 2005] “the electronic resources permit the shift of the accent from *What are we teaching?* to *How are we teaching?*”.

Contrary to that distance education (includes learning, teaching and training aspects) [UNESCO, 1987] describes a “variety of educational programs and activities... [where] the learner and teacher are physically separate but... efforts are made... to overcome this separation using a variety of media”. It is important to know the difference. E-Learning definitions focus on instruction delivery technology meanwhile distance education is described in terms of physical separation (cp. table 2.1). Based on this, e-Learning uses computational means to make distance education possible.

INSTRUCTION DELIVERY TECHNOLOGY	PHYSICAL SEPARATION yes	PHYSICAL SEPARATION no
Computational	Distance education & e-Learning	e-Learning
Other	Distance education	-

Table 2.1: Classification: distance education vs. e-Learning

Definition 19 ***Distance education*** *is an educational situation in which the instructor and students are separated by time, location, or both. Content is synchronously or asynchronously delivered to remote locations [American Society for Training & Development (ASTD), 2007].*

The independence of e-Learning in terms of spatial and temporal constraints is a primary aspect of this technology. Table 2.2 contrasts these properties with different e-Learning types defined below.

	SYNCHRONOUS (SAME TIME)	ASYNCHRONOUS (DIFFERENT TIME)
SAME PLACE	Traditional learning (classroom)	Asynchronous distance learning (Using learning centers or labs)
	Face-to-face meetings with technology insertion (Computer Assisted Instruction (CAI) using computers, videos or Web-based material in PC-labs)	Learning at own place in own time with organization’s facilities (Computer-Based Training (CBT) with CD-ROM, DVD, disks or tapes)

	SYNCHRONOUS (SAME TIME)	ASYNCHRONOUS (DIFFERENT TIME)
DIFFERENT PLACE	Real-time distance learning Live courses via high speed data links such as LANs, Satellites and the Internet (communication supported Web-Based Training (WBT), teleconferencing and Video Tele-Training (VTT))	Distributed learning Learning at own place in their own time, independent of geographic location (videotaped courses, WBT and CBT). Can incorporate aspects of the other quadrants.

Table 2.2: Time/place framework for technology supported distance learning [Belanger and Jordan, 2000]

E-Learning itself is a process containing two major phases: content development (additionally including planning, design and evaluation) and content delivery (additionally including maintenance). Its nature is iterative (cp. figure 2.3). Evaluation is recommended for continuous improvement [Giotopoulos et al., 2005].

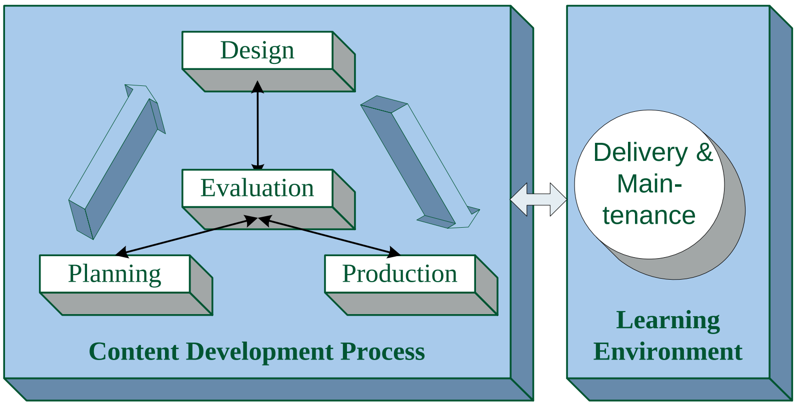

Figure 2.3: Iterative process of e-Learning (cp. [Giotopoulos et al., 2005])

2.1.1 Definitions of e-Learning Types

Nowadays in the age of the internet one primary technical device for e-Learning is the computer. Many researchers defined several types of computer-aided education systems [Soh et al., 2005b], [Baxter, 1990], [Kulik and Kulik, 1991], [Bangert-Drowns et al., 1985]. In the following only the actual, main types of e-Learning are defined.

2.1.1.1 Computer-Based Teaching

A general definition subsumes those types as computer-based teaching/training (CBT). This term is a short description of the process of instruction delivery on a computer [Belanger and Jordan, 2000]. Mainly self-motivated and/or a large number of potential learners are targeted.

Definition 20 *The terminus **Computer-based Teaching/Training (CBT)** summarises the use of computers in both instruction and management of the teaching and learning process. CAI (computer-assisted instruction) and CMI (computer-managed instruction) are included under the heading of CBT [American Society for Training & Development (ASTD), 2007].*

The most common usage of those systems is for drill and practice exercises and for tutorial instruction [Soh et al., 2005b]. Web-based or computer-based tools are used to assist regular instruction [Belanger and Jordan, 2000].

Definition 21 ***Computer-Assisted Instruction (CAI)** is the usage of a computer as a medium of instruction for tutorial, drill and practice, simulation, or games. CAI is used for both initial and remedial training, and typically does not require that a computer be connected to a network or provide links to learning resources outside of the course [American Society for Training & Development (ASTD), 2007].*

Definition 22 *Within **Computer-Managed Instruction (CMI)** the computer is used to oversee the learning process, including testing and record keeping [American Society for Training & Development (ASTD), 2007].*

2.1.1.2 Computer-Enriched Instruction

Systems having been classified as a computer-managed, operate on the basis of a model representing information about the student and provide appropriate instructional resources [Soh et al., 2005b].

Definition 23 ***Computer-Enriched Instruction (CEI)** generally supports the leaner's study by computational means. According tools support problem-solving, generate data at the student's request to illustrate relationships in models of social or physical reality, or executes programs developed by the student. [Kadiyala and Crynes, 1998].*

Computer-Enriched Instruction systems solve user requests like solving a mathematical equation, generating data, and executing programs [Soh et al., 2005b].

2.1.1.3 Web-Based Teaching

A teaching model focussed on web technologies is the web-based teaching/training (WBT). There problems occur and need to be solved as there are e.g.: who develops the course, place of course delivery, timing of course delivery, level of interaction.

Definition 24 ***Web-based Teaching/Training*** *is the delivery of educational content via a Web browser over the public Internet, a private intranet, or an extranet. Web-based training often provides links to other learning resources such as references, email, bulletin boards, and discussion groups [American Society for Training & Development (ASTD), 2007].*

2.1.1.4 Distance Education

As already stated out the classic understanding of e-elearning involves the *'distance'* aspect. Taking this into account literature distinguishes the educational aspects of learning, teaching and training. Distance learning analyzes the concept under survey from the learners point of view.

Definition 25 ***Distance teaching*** *is a family of instructional methods in which the teaching behaviours are executed apart from the learning behaviours... so that communication between the teacher and the learner must be facilitated by print, mechanical or other devices [Moore, 1973].*

On the other hand distance teaching focusses more intensively on the delivering part of knowledge respectively skill transfer in contrast to the already mentioned acquisiting part.

Definition 26 ***Distance learning*** *...should be viewed from the learners' perspective...Learning may not occur...if barriers exist...such as difficulty in using the technology or lack of instructor interaction when answering questions [Belanger and Jordan, 2000].*

If the aspect to be educated has a more practical nature than knowledge and involves skill improvement than this aspect of learning is often entitled as distance training.

Definition 27 *By its nature,* ***distance training*** *is focused on the development and performance of specific tasks or skills. Training tends to be more job or company specific and involves the the acquisition of job-related skills by employees [Belanger and Jordan, 2000].*

2.1.1.5 Virtual Education

Virtual education combines advantages of distributed education and classic classroom learning - it uses virtual learning environments. Using modern Web-based video conferencing systems students can be all over the world but learn together (with a teacher) and access the resources provided by learning groups. This type of e-Learning can be combined with other types like WBT. An appropriate technical infrastructure is needed to implement virtual education.

Definition 28 ***Virtual Education*** *uses online learning spaces where students and instructors interact to learn together [American Society for Training & Development (ASTD), 2007].*

Special realisations virtual education in virtual learning environment are virtual classrooms and virtual laboratories.

2.1.1.6 Mobile Learning

The term *mobile learning* (sometimes also referred as "ubiquitious learning") describes a kind of e-Learning with a special technical focus on content delivery via mobile devices like PDAs, pocketPCs, cellular phones, smart-phones, tabletPCs (cp. figure 2.4). Mostly it is seen as an extension of learning activities ([Kukulska-Hulme, 2002], [Waycott et al., 2002]). The appropriateness of technic, learning content and learning activities need to be taken into account for the application of this e-Learning type.

Definition 29 ***M-Learning*** *(mobile learning) is learning that takes place via such wireless devices as cell phones, personal digital assistants (PDAs), or laptop computers [American Society for Training & Development (ASTD), 2007].*

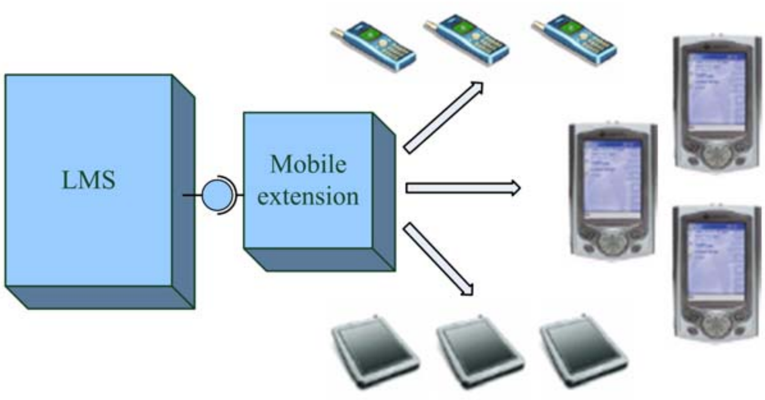

Figure 2.4: Mobile e-Learning

2.1.1.7 Blended Learning

Blended learning is a combination of e-Learning and presence courses. The main idea is to apply and use e-Learning aspects in the learning process [Giotopoulos et al., 2005]. Thereby the quality is improved by electronic and multimedia services [Claußen, 2001]. Examplified it may result in the usage of an e-Learning platform and periodically lectures, group meetings, exams, etc.

Definition 30 ***Blended Learning*** *are learning events that combine aspects of online and face-to-face instruction [American Society for Training & Development (ASTD), 2007].*

2.1.1.8 Lifelong Learning

Lifelong learning is one important catchword in the context of e-Learning. It relies to the fact that learning is not limited to schools, universities or vocational education. With the opportunities of the World Wide Web, Web2.0, mobile devices and all other recent technological developments as well as the learning requirements set by industry and society this field of application becomes more and more important for software development.

Lifelong learning is continuous education in everyday life. The corresponding idea was firstly articulated in modern times by Basil Yeaxlee [Yeaxlee, 1929].

Definition 31 ***Lifelong Learning*** *encompasses all formal, non-formal and informal learning over the entire life cycle of a human being [Kruse, 2003].*

Multidimensional changes need to be considered from a psychological point of view. Lifelong learning is influenced by biological, psychological and cultural developments: human abilities, adaptation capabilities and cognitive capabilities change over time. Cultural aspects refer to changes in roles and function.

Lifelong learning is not limited to the already mentioned aspects. Furthermore it stands e.g. for the re-entry in education or for the certification of acquired but not formally evidenced competencies.

Therefore it recombines the existing segmented education areas to a complete system. That includes preschool, school, vocational education, higher education as well as common and advanced vocational education.

There are three key features of lifelong learning [Tight, 1996]:

- Lifelong education is seen as building upon and affecting all existing educational providers, including both schools and institutions of higher education.
- It extends beyond the formal educational providers to encompass all agencies, groups and individuals involved in any kind of learning activity.
- It rests on the belief that individuals are, or can become, self-directing, and that they will see the value in engaging in lifelong education.

An approach to partly support lifelong learning was presented by Maddocks et al. [Maddocks et al., 2000]. The presented tool is aimed towards students for the development of reflective learning skills by encouraging the adoption of an ongoing model of development from school, through higher education to professional membership within the construction industry. In contrast to the approach presented in this paper it is limited in terms of domain and time.

Lifelong learning is a highly complex, rapid changing and very important aspect of everyday life for the society.

2.1.1.9 Educational Games

The main purpose of educational games is to increase learner's motivation and engagement during the learning process (e.g. [Virvou et al., 2005], [Papert, 1993], [Boyle, 1997]). A twofold decision must be made. Actual criticism of this combination of education and gaming covers the sometimes occuring lack of belief of certain persons in charge as well as the quality of existing approaches.

Definition 32 *Based on these information an* ***Educational Game*** *is a computer-based game that motivates and engages the player/learner to learn.*

The four main categories of individual motivations for that are responsible for the positive effects of educational games are challenge, fantasy, curiosity and control [Malone and Lepper, 1987].

2.1.2 E-Learning Concepts

Some of the main concepts of e-Learning are already described above, like the physical separation on page 43 or the electronic dimension of this learning type on page 39. The following explanations target further fundamental definitions of concepts within the domain of e-Learning.

2.1.2.1 Mediation

The term mediation within the context of e-Learning describes a type of content delivery. Its analysable aspects are instructor and technology mediation [Belanger and Jordan, 2000].

Instructor mediation is focused on learning experience delivered by an human teacher/trainer, etc. He preparates the courses and presents the lectures. Furthermore he chooses the content delivery technology. The main advantage is the possible interaction with the learner, e.g. to provide information, explanations, evaluation, feedback, human touch. The choice of a level of involvement has financial and teaching aspects to be considered and is figured in 2.5.

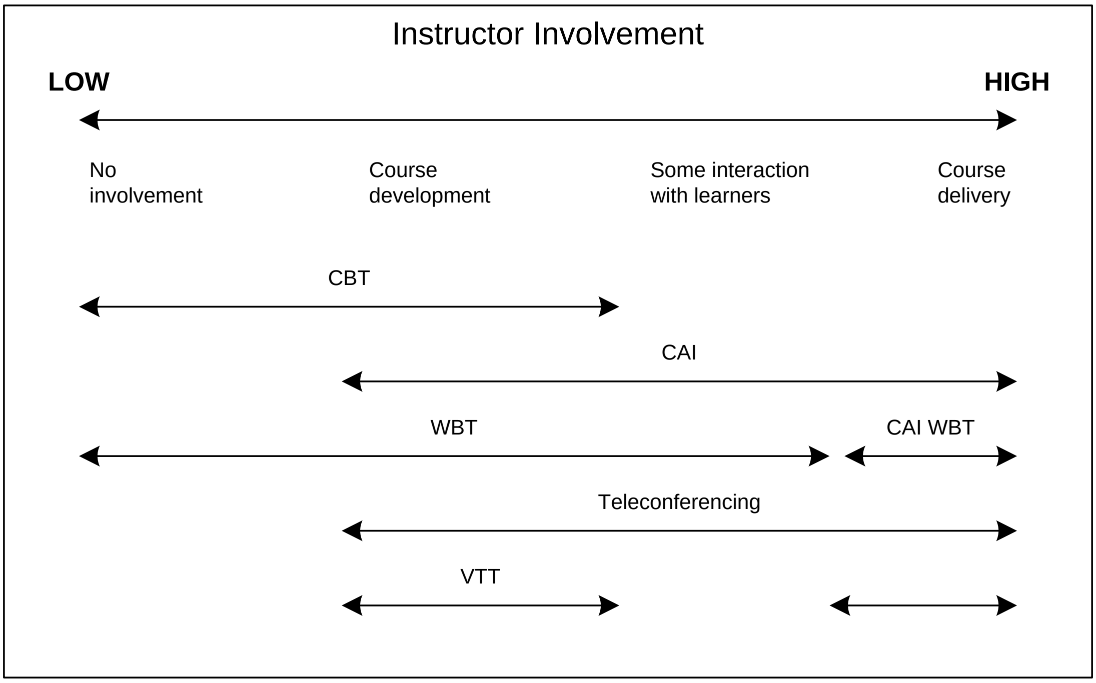

Figure 2.5: Instructor involvement in e-Learning [Belanger and Jordan, 2000]

Technology mediation uses actual advantages in information systems and web technologies to facilitate e-Learning. Some sources claim that the performance does not significantly differ between traditional and e-Learning

([Russell, 2001], [Webster and Hackley, 1997]), but brings out several additional advantages. There are several factors to be considered like participation, satisfaction with learning environment, costs, reliability of technology and quality of delivery [Belanger and Jordan, 2000]. Technical aspects for several types of e-Learning are depicted in figure 2.6.

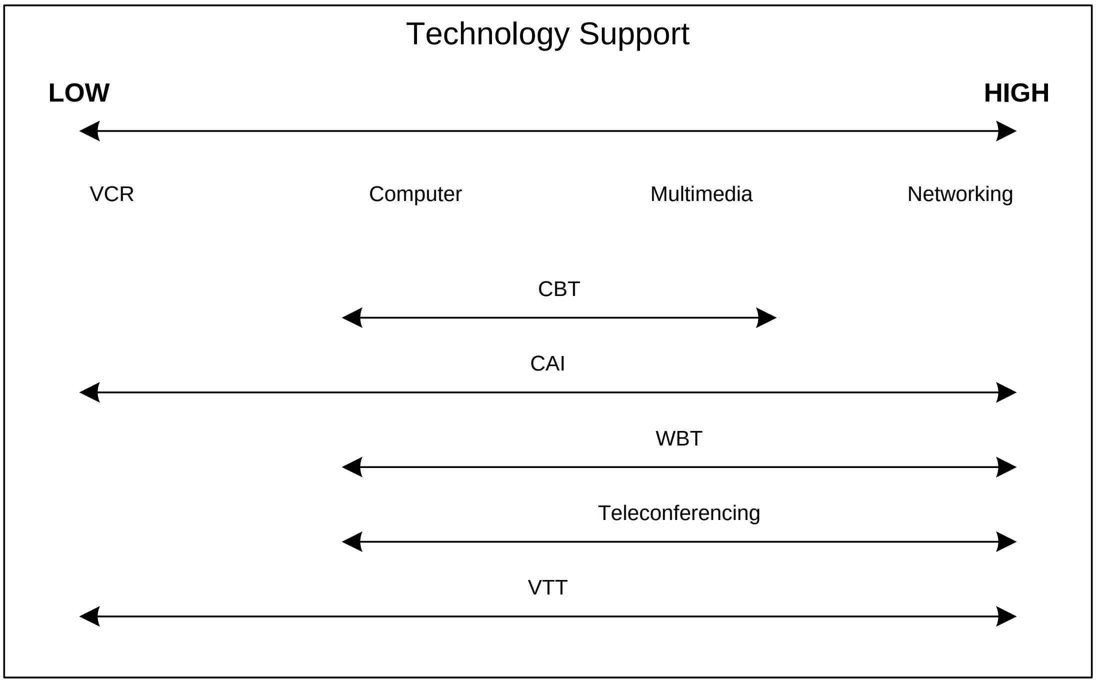

Figure 2.6: Technology support in e-Learning [Belanger and Jordan, 2000]

2.1.2.2 Learning Object

A *learning object* (LO) is an instructional component that represents a small piece of knowledge within the e-Learning domain [Garro et al., 2003]. Together with the other associated LOs it forms the entire course. It should be usable in ways, contexts and for different purposes [Mohammed and Mohan, 2005].

Definition 33 ***Learning Objects*** *are defined as a reusable, media-independent collection of information used as a modular building block for e-Learning content [American Society for Training & Development (ASTD), 2007].*

Definition 34 *Based on above definition of LO an* ***e-Learning course*** *is any composition of related LO for the purpose of teaching/providing information for group of potential users.*

Definition 35 *An* ***e-Learning curriculum*** *is a set of e-Learning courses that must be passed by students in order to make the grade defined by their study specifications.*

A common aspect to all learning objects is the needed management for storage and (re-)combination. Therefore and for their description by metadata several standards were already defined (cp. section 2.6). The most important properties for an LO are ([Wiley, 2000], [Garro et al., 2003]):

Atomicity The atomicity of an LO describes the (self)consistent nature of a piece of knowledge.

Reusability A LO is reusable if it can be shared by multiple learning paths or in multiple courses.

Repurposability This term defines the ability to extract portions of a LO and to adapt them to new contexts.

Availability No temporal or spatial restrictions make an LO available.

Granularity Granularity is the functional size of an ressource.

Interoperability A LO is interoperable if it can be exchanged, reused and shared independent from its developer and its developer's organisation.

The LOs described above typify a relative static nature. That represents a bottleneck for the general usage of LOs due to the needed manual re-purpose by specialists [Mohammed and Mohan, 2005]. *Reusable learning objects* (RLO) are intended to be automatically re-organised for multi-purpose usage in different contexts like certain courses [Belanger and Jordan, 2000].

Definition 36 ***Reusable Learning Objects*** *(RLO) are LO that can be transferred to various infrastructures or delivery mechanisms, usually without changes [American Society for Training & Development (ASTD), 2007].*

They represent modular reusable units of study, exercise, or practice and can be "consumed" in a single session [Pankratius et al., 2004]. They are intended to be authored independently from the target platform by an authoring system and to be stored within an LMS. The main intention for breaking up entire courses into RLOs respectively the summative creation of courses with certain RLOs is the interoperability, the possibility to independently reuse them on different target systems. Futhermore they are more focused and can be developed by experts. Consistency is another advantage. The needed descriptive metadata ease the lookup and automatic course generation [Belanger and Jordan, 2000].

Modularisation can be conducted using different ways depending on certain requirements.

- Type of knowledge chunk (e.g. definition, description, assessment)
- Type of representation (e.g. xml-files, picture, text)
- Different levels, e.g. in virtual worlds (e.g. geometry, scene, procedures, guided explanations/free usage)
- Aspired knowledge processing time (e.g. 5 - 15 minutes [Belanger and Jordan, 2000])

Following [Mohammed and Mohan, 2005] the next development step can be so called *smart learning objects* (SLO).

Definition 37 ***Smart learning objects*** *are defined as: "a structured aggregation of learning resources and the associated metadata encapsulated by a set of methods that provide intelligence, self sufficiency and platform independence while facilitating pedagogy" [Mohammed and Mohan, 2005].*

Based on the 'bucket model' suggested by [Nelson, 2000] SLOs represent a object-oriented container consisting of multiple packages and access methods and should be conform to the Sharable Content Object Reference Model (SCORM) (cp. section 2.6.2). The packages itself are aggregrated by software files, image files, data sets and several other elements. They are described by metadata. The bucket model is implemented in Perl but not limited to this technology.

The learning objects described above respectively their combination to more complex course units result in different types that may occur isolated or combined [Klobas and Renzi, 2000]. Some examples are listed below and linked with several technical systems in table 2.3.

- Lectures, goal: deliver material to enhance knowledge
- Presentations
- Workshops, goal: develop skills in a particular technique
- Laboratories
- Seminars and tutorials, goal: improve or deepen understanding aspects of a particular topic
- Consultations
- Interactive experiments
- Educational games
- Documents, slides, simulations, role plays, questionnaires, pre-recorded lessons [Garro et al., 2003]

EDUCATIONAL STRATEGY	CHARACTERISTICS OF STRATEGY	CATEGORY OF WEB-BASED SOFTWARE FOR TEACHING AND LEARNING
Lecture or presentation	Teacher presents material to a class.	Readings or presentations prepared or converted to HTML format or web pages as index of downloadable material (text, tables, presentations) or audio, video material live or recorded and distributed via streaming technology.

EDUCATIONAL STRATEGY	CHARACTERISTICS OF STRATEGY	CATEGORY OF WEB-BASED SOFTWARE FOR TEACHING AND LEARNING
Workshop or laboratory	Students complete set tasks designed to develop their skills; often live or recorded demonstrations presented or prepared by an instructor are included.	Activities prepared using WWW or other technology (including multimedia technologies), made available to students from a web page.
Self-guided instruction	Students work individually (often in geographical isolation), to complete assigned readings and exercises.	Readings, references and activities, prepared using WWW technology or distributed from a web page.
Seminar or tutorial	Students, working in relatively small groups, discuss set topics, cases or reading with the instructors guidance.	Discussion or conferencing software.
Consultation	Students (individually or in small groups) meet with the instructor to obtain answers or guidance on topics.	E-mail, chat, audio and video conferencing.
Collaborative learning	Students work together; the students learn through collaboration with one another rather than from material delivered by the teacher.	Discussion or conferencing software, e-mail, chat, audio/video conferencing, specific tools for community building and collaborative work.

Table 2.3: Web-based software for teaching and learning strategies [Klobas and Renzi, 2000]

2.1.2.3 Assessments

The assessment is an aspect common to traditional classroom learning as well as to e-Learning. Either the learner's knowledge of concepts in a certain domain or the quality of his solutions steps can be assessed.

Definition 38 *An **assessment** is the process used to systematically evaluate a learner's skill or knowledge level [American Society for Training & Development (ASTD), 2007].*

Several advantages are evolving because of automated assessment within e-Learning. That includes the avoidance of subjectivity and the improved performance

[Anghel and Salomie, 2003]. Problems may arise because of the question whether a mistake was made du to a slip or due to missing knowledge, the possibillity of guessing right answers, the uncertainty in judging the quality of a solution and the uncertainty in plan recognition when analysing the learner's solution path.

Certain concepts need to be instantiated within assessments, including [Anghel and Salomie, 2003]:

- Learner entity
- Teaching authority
- Assessment or test
- Assessment type
- Question
- Question type
- Correct answer
- Assessment procedure

Several strategies for assessments are possible, like e.g. (multiple response) questions, drag and drop for extended object matching, image hot spot, code writing, . . . [Andronico et al., 2003].

2.1.3 Definitions Regarding Technical Aspects

For the preparation and accomplishment of e-Learning certain technical support and management systems are necessary. The section briefly describes the main systems.

2.1.3.1 Learning (Content) Management Systems

Learning management systems (LMS) represent the core of e-Learning systems. They comprise functionalities like learner management, user profile management, learner progress and event scheduling. Additional support is provided for interaction and collaboration among learner and tutors.

Learning content management systems (LCMS) extend LMS-functionalities by the functionalities of an content management system (CMS). Usually a database is used for content storage. An LCMS targets the improvement of content reusability and content development workflow support. The content is delivered via predefined presentation layers and interfaces ([Brandon Hall Research Group, 2006], [Pankratius et al., 2004]).

Further functionalities of L(C)MS are e.g.:

- Provision of virtual class rooms
- Provision of tools for task and test creation
- Assessment support
- Course administration
- Course planning
- Process tracking
- Content management
- Creation and distribution of electronic and non-electronic learning content

- Skill management including management and organisation of the learner's qualification level and abilities
- Electronic marketplace for further training services

Table 2.4 contrasts the main aspects of LMS and LCMS.

	LMS	**LCMS**
Target Group	Manager, teacher, administration	Content developer, didactical experts, project managers
Supporting the management of …	Learners	Content
Classes, teacher lead exercises	Mostly yes	No
Reports about learning progress	Main focus	Marginal focus
Learner collaboration	Yes	Yes
Management of learner profiles	Yes	No
Shared learner profile usage with ERP systems	Yes	No
Class scheduling	Yes	No
Competence mapping, skill-gap analysis	Yes	Sometimes yes
Content Creation	No	Yes
Organisation of reusable content	No	Yes
Assessment creation and management	Yes	Yes
Dynamic pre-tests and adaptive learning	No	Yes
Workflow tools for content creation process support	No	Yes
Content distribution	No	Yes

Table 2.4: Differences between LMS and LCMS [Hall, 2000]

2.1.3.2 Intelligent Tutoring Systems

An actual approach to capture and deal with aspects of knowledge are Intelligent Tutoring Systems (ITSs). They use techniques from artificial intelligence (AI).

Definition 39 ***Intelligent Tutoring Systems*** *are computer-based learning systems that seek to reflect new methods of teaching and learning based on one-to-one interaction with the help of techniques from AI to be able to adjust the content and delivery to students' characteristics and needs by analysing and/or anticipating theirs affective responses and behaviours [Nkambou, 2006].*

Essential features of ITSs are:

- Include detailed domain or expert model
- Include personal or student model
- Include knowledge transfer or instructional model
- Immersive person involvement vs. guided learning
- Domain specific information

2.1.3.3 Authoring Tools

The technical infrastructure as well as management support are useless without the content to be tought to the learners. For its creation authoring tools exist.

Definition 40 ***Authoring tools*** *are software applications or programs used by trainers and instructional designers to create e-Learning courseware [American Society for Training & Development (ASTD), 2007].*

They are used to develop learning object of different granularity levels. That can be text fragments, grafics, links questions, simulations, courses, video and audio files, etc.

A possible classification is the distinction into professional authoring systems, WYSIWYG-tools and rapid content development tools [Hettrich and Koroleva, 2003].

Another source [American Society for Training & Development (ASTD), 2007] differenciates into instructionally focused authoring tools, Web authoring and programming tools, template-focused authoring tools, knowledge capture systems, and text and file creation tools.

2.1.3.4 E-Learning Repositories

Actual e-Learning realisations at different organisations produce a huge amount of learning objects and courses. Their reuse and thereby provision is supported by e-Learning repositories. They learning materials and appropriate metadata are stored and centrally made available. So they can be used in organisation internal e-Learning processes or distributed/sold via brokers to other users. Technological basis are LCMS respectively CMS.

Definition 41 *We define **e-Learning Repositories** as central collections of e-Learning material with appropriate metadata that are stored for availability, exchange and reuse purposes.*

2.1.4 Definitions Regarding Didactics

Didactics is a science targeting several directions, so it is the science of organized teaching and learning, the science of education or it is the application of psychological teaching and learning theories. Additionally it is seen as the theory of education contents and the theory of controlling learning processes [Kron and Sofos, 2003].

Traditional learning paradigms are still valid for e-Learning up to a certain degree. Web technologies further developed them and sometimes turned them into new learning models that are dynamic in nature [Sadiig, 2005].

Some reason for those developments and adaptations are:

- One single approach does not effectively accomodates the variety of students' learning approaches ([Dimitrova et al., 2003b], [Angehrn et al., 2001])
- Correlation between learning behaviour and learning performance [Dimitrova et al., 2003a]
- Classic approaches are not sufficient for implicit learning [Angehrn et al., 2001]
- Missing direct supervision by teachers
- New technologies for learning, teaching, interaction, ...
- Changed self-conception of learners for interaction and learning, e.g. due to new technologies

In literature exist different definitions and classifications of learning styles. Whilst [Felder and Silverman, 1988] differenciates sensory/intuitive, visual/auditory, inductive/deductive and active/reflective, [Biggs, 1987] defines classes like surface (students doing only the things being necessary for the accessment), deep (students critical interact with the knowledge) and achieve (students using either durface or deep methods to attain the highest grade). Based on Biggs' classification [Dimitrova et al., 2003b] created a further distinction for classroom and distance learners. Classroom learner are the Ideal Learner, the Struggler, the Reflector, the Shallow Learner and the Social Learner. Traditional Learner, the Achieving, the Interactive Learner, and the Struggler are distance learner types.

Definition 42 *We want to define a* ***Learning Theory*** *as an approach to analyse and describe how people learn.*

The three main learning theories are briefly described below.

- Behaviourism is based on changes in behaviour that are observable. A new behavioural pattern is repeated until it becomes automatic [Phillips and Soltis, 1991]. The main researchers of the theoretical foundations are Ivan Pavlov, Edward Thorndike, John Watson and B.F. Skinner.
- Constructivist model is based on thought that everybody constructs his own perspective of the world. This view is influences by individual experiences and schema. The learner should be prepared to solve problems in ambiguous situations [Brooks and Brooks, 1999]. Key theorist in this field is Vygotsky.
- Cognitivism is based on the thought process behind the behaviour. Changed behaviours are observed. These changes are used to indicate what is happening inside the mind of the learner [Ormrod, 2004]. Main researchers regarding cognitivist

foundations of learning are David Ausubel, Edgar Dale, George Miller, Allan Paivo and Joseph Novak.

Definition 43 *A* ***Learning objective*** *is a statement establishing a measurable behavioral outcome, used as an advanced organizer to indicate how the learner's acquisition of skills and knowledge is being measured [American Society for Training & Development (ASTD), 2007].*

The best known approach in this field is Bloom's taxonomy of educational objectives (cp. figure 2.7).

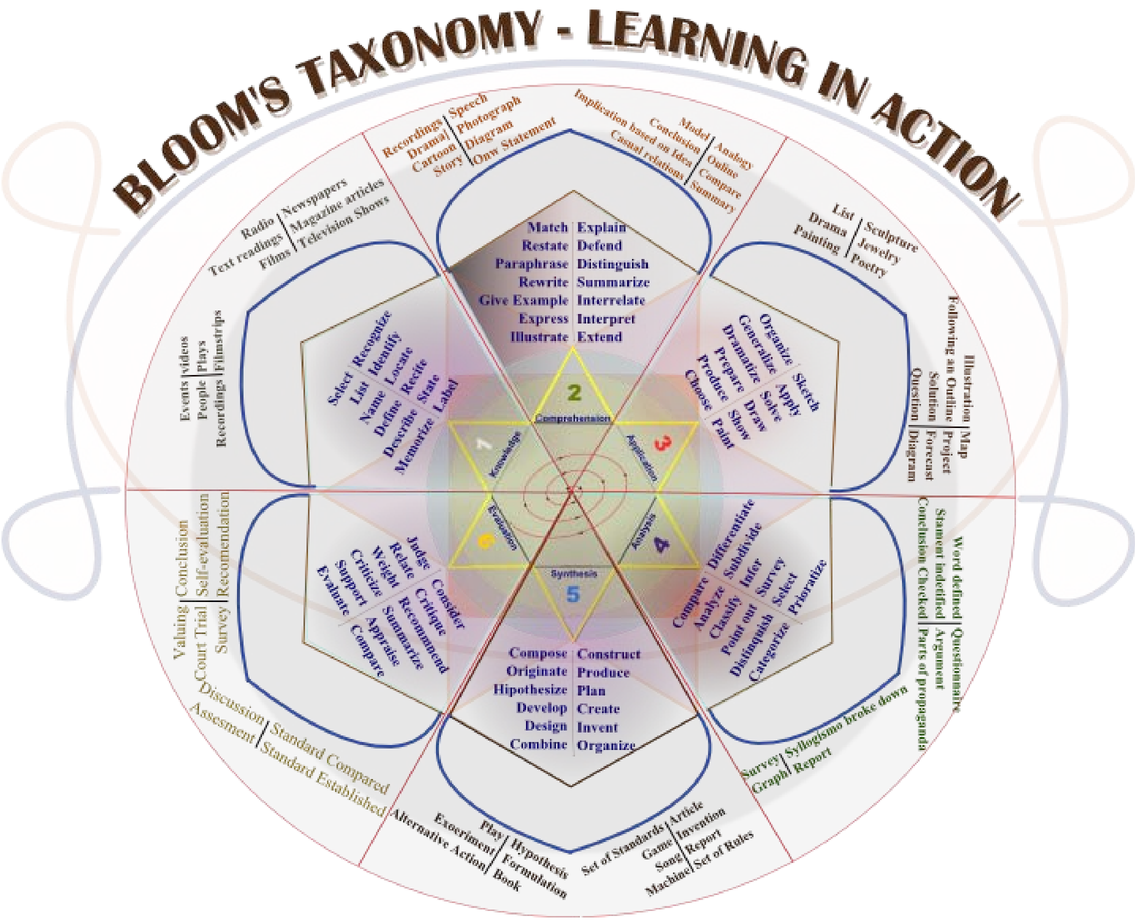

Figure 2.7: Bloom's Wheel of Bloom's vers and matching assessment types (graphic by John M. Kennedy T.)

The taxonomy focusses on the affective, psychomotor and cognitive domain.

The affective domain is about interests, emotions, perceptions, tone, aspirations, degree of acceptance or rejection of institutional content [Belanger and Jordan, 2000]. The objectives range from simple attention to more complex aspects of characters and conscience [Bloom et al., 1964]. Learning is based on the affective involvement of the learner.

- Receiving: on this low level the learner is aware of the learning content and willing to receive the stimuli. It is the basic requirement of learning.
- Responding: in this phase the learner is able to create own points of view and obtains satisfaction due to the fact that was able to learn.
- Valuing: here the learner is willing to accept a value and to judge about the learning content/problem/experience.
- Organisation: the priorisation and organisation of relationships between values is a more complex level.
- Characterisation: describes the generalisation and classification of real world situations and judging and acting according to the learned values.

The psycho-motor learning objective domain is about muscular or motor skills for the manipulation of objects or other physical activities [Belanger and Jordan, 2000]. Furthermore it is related to speech, physical education, trades, operation of machinery, typing capabilities, etc. Therefore often simulations are used e.g. flight simulators, operation of machinery simulations, Virtual Reality [Mencke, 2007], ...

The cognitive learning objective domain consists of six categories, each with subcategories ([Bloom, 1956], [Belanger and Jordan, 2000]). Each category is based on the ones before in terms of requirements and characteristics. Thereby the level of interactivity and media-richness increases from the lowest to the highest level. Media richness describes the support of communication media for contextual cues [Daft and Lengel, 1986]. The following list briefly summarises the categories [Belanger and Jordan, 2000]:

- Knowledge: is the basic level. It includes the recall of pattern, structures or settings and specific facts (e.g., terminology) or ways and means of dealing with those facts (e.g., trends, methodology, principles, theories).
- Comprehension: is lowest level of understanding and includes translation, interpretation and extrapolation.
- Application: is about the generalization/abstraction (application of principle, theories or ideas) in concrete or specific situations.
- Analysis: of the elements of a topic and the relationships between them.
- Synthesis: is about rearranging and restructuring of knowledge as well as the creativity in generating new knowledge.
- Evaluation: involves qualitative and quantitative judgements and is the highest form of the cognitive learning objective.

2.1.5 E-Learning Processes

The general e-Learning process was already described in figure 2.2. It is mainly focussing on a permanently evaluated content production as well as on the delivery of the content. These basic e-Learning processes are described below amongst others.

2.1.5.1 E-Learning Process

Often learning is seen as an own single process. One example is the five step model of Salmon [Salmon, 2004]. With an increasing amount of interactivity the author defines access and motivation, online socialisation, information exchange, knowledge construction as well development as appropriate stages. Each involves technical aspects as well as some kind of e-moderation.

2.1.5.2 Content Creation Process

The preparation and aggregation of e-Learning content still is a problem for developers. They often follow an implicit design idea thinking about content, possible resources (text, figure, tools), sequence of topics and assessments. An arising problem is the lack of an inspectable, processable learning design. There just exists a sequence of dedicate content [van Rosmalen et al., 2005].

For its process support e.g. the PELO model can be applied. It describes the analysis, design, conceptual development, technical development and test on different stages of abstraction [Müller et al., 2005].

2.1.5.3 Establishment of e-Learning

One of the first processes to be mentioned is the establishment of e-Learning. Certain aspects need to be prepared to get e-Learning working. The following list presents the most important steps for the establishment of e-Learning, if the variables for suitability of courses to be held as e-Learning imply a positive feedback.

Informal pre-establishment phase of e-Learning:

1. Survey of demand by interviewing all responsible involved persons: determination of requirements
2. Regular meetings of all responsible involved persons
3. Establishing group of experts (committees) for accepting development steps: technical vs. operational decisions

Establishment of e-Learning:

4. Get and use disseminators like trainers, education responsible persons, personal advisers and support them by communication tools for interaction with managers/decision makers and potential learners
5. Use e-Learning in seminars for managers/decision makers to evolve their understanding for this technology
6. Train potential learners for self-learning
7. Train the trainer
8. Prepare the learning center if one is needed, hardware and software
9. Organize support material in repositories

A three step model is proposed by [Mason, 1998]. The Content and Support Model is the earliest and most extensive category of online courses. Course content and tutorial support are separated. The Wrap Around Model defines courses which consist of tailor made materials (study guide, activities and discussion) that are wrapped around existing materials. The furthest developed stage is described by the Integrated Model. The course is mainly based on collaboration, uses developed learning resources and has joint assignments. The course contents are determined by the individual and group activity.Thereby the integrated model cancels the distinction between content and support; the main aspect is the establishment and usage of a learning community as the backend of the learning process.

Another well known description is the five stage model of Gilly Salmon [Salmon, 2004]. It especially focuses on technical and moderation aspects (cp. figure 2.8). The requirements regarding them are increasing from stage to stage. Access and motivation is the first stage. Here learners need to get access to the system and to be greeted and introduced by the moderator/tutor. Stage two is about online socialisation. Here the learner gets familiar with the system and its functionalities. The moderator provides support, if needed. Information giving and receiving takes place in stage three. Learner is aware of the multiple possibilities to get information and provide them, too. The tutor's role is redirected from technical support towards content support. He provides goal and learning guidance. Stage four is about knowledge construction. Here the real learning process starts. Learner and tutor collaborate to generate new knowledge. In stage five the tutor's role is limited to a background person only being available if needed. The learner is able to learn independently.

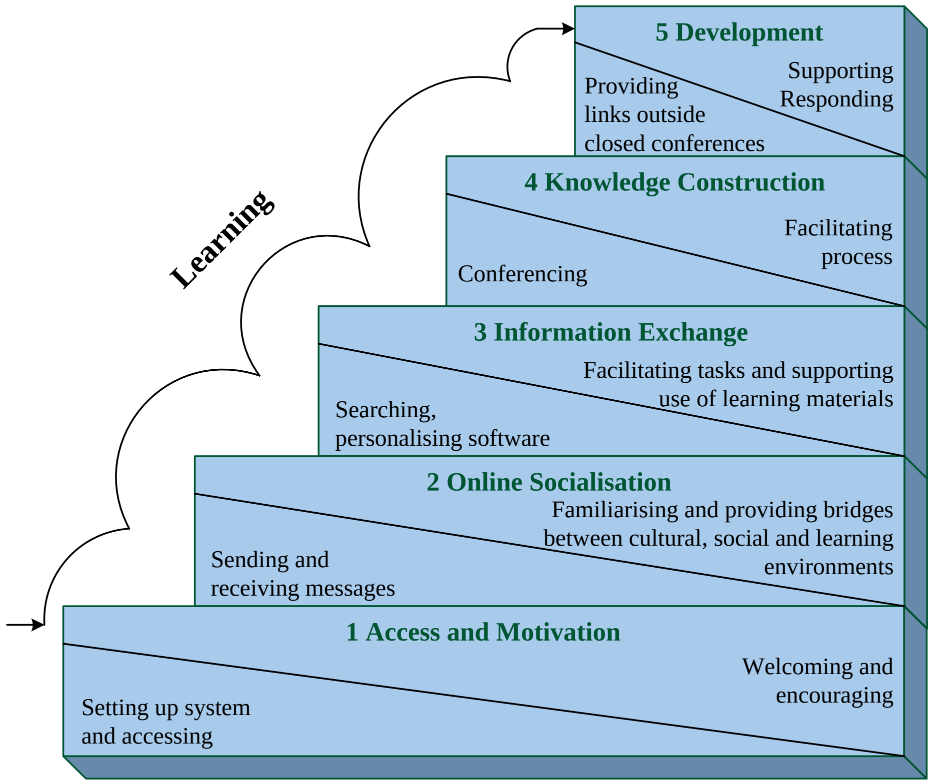

Figure 2.8: Five stage model of e-Learning establishment (cp. [Salmon, 2004])

2.1.5.4 Dissemination of e-Learning

E-Learning in general can be supported by a technical enhancement process [vom Brooke, 2005]. The authors propose several organisational, applicationrelated, method-related and technology-related steps from analysis/design to implementation/deployment for the dissemination of e-Learning.

2.1.5.5 Choosing a Learning Platform

Choosing a learning platform is an e-Learning-related process, too. [Hettrich and Koroleva, 2003] describe seven steps for it. This process is quite analogous to the choice of other software resources. Figure 2.9 visualises the corresponding steps.

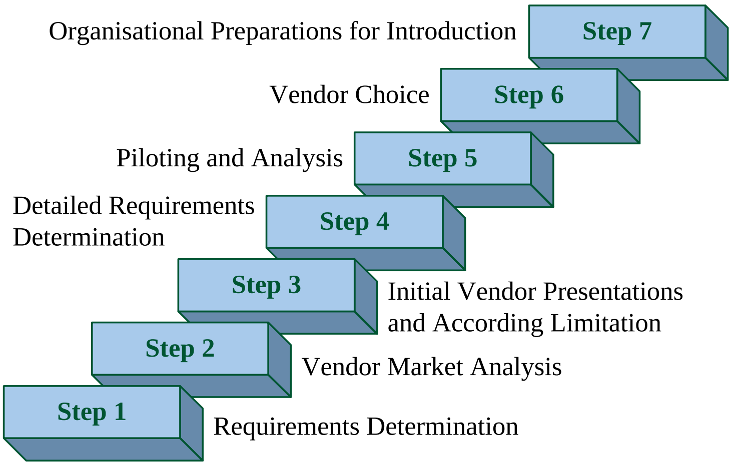

Figure 2.9: Process of choosing a learning platform (cp. [Hettrich and Koroleva, 2003])

The first step determines the fundamental requirements of the system. It is important to be sure about the intented usage. Therefore questions like: *Why is such an e-Learning platform necessary? How to evaluate the benefit of the system? What are the technical requirements? Who will operate it? Who will how use the new offers?*

The second step defines exclusion criteria and thereby limits the candidate set. Some of this criteria can be e.g.: adaptability to business processes, interfaces to existing software, profile extensibility or learning success control.

A first presentation and explanation of the remaining vendors is the third step. The following substeps are useful:

◦ Determination of participants
◦ Determination of available time for each presentation
◦ Preparation of presentation (definition of main criteria for the learning platform)
◦ Accomplishment of presentation
◦ Immediate review of the presentation

The next step is about the detailing of the requirements. The authors propose the following aspects to be important in this case: requirement introduction with information about the own organisation, common conditions for choice process, detailed functional and non-functional requirements, definitions of questions concerning the implementation, definition of expectations for adaptations and support, information about the vendors as well as detailed information about singular and recurring funding.

Step five is about the self-evaluation of the different vendors. These documents need to be carefully analysed. They are the basis for an internal prioritisation of certain functionalities. Further analysis is recommended. An example is given in [Hettrich and Koroleva, 2003]

The sixth step is about the choice for a special vendors. It can be helpful to contact certain reference customers of the vendors as well as to recapitulate the main decision criteria. All ambiguities should be eliminated and a complete contract is the result of this stage.

The last step is the preparation of the organisation for the integration of the chosen learning platform. Certain processes might be changed or adapted and an internal marketing strategy can be helpful for a successful start of the e-Learning offer.

2.1.5.6 Languages for Knowledge Transfer Process Support

Already established concepts to represent didactical expertise are Educational Modelling Languages. They shift the focus from a content-oriented design to process orientation [Gruber, 1993]. Chosen examples are listed below.

Educational Modelling Language (EML) The intended usage of the educational modelling language (EML) is to describe a learning design for automated processing [van Rosmalen et al., 2005]. It defines the learning process including activities (of students and staff) and resources/services. The Educational Modelling Language [Koper, 2001] is the basis for the IMS Learning Design Specification ([IMS Global Learning Consortium, Inc., 2003d], [Koper and Olivier, 2004]). Its major implementation is an XML-based language and was developed to codify units of study, as e.g. courses, course substructures or study programs. Therefore it provides structures for the content, roles, relations, interactions and activities of learners and students.

Learning Object Markup Language (LOML) The Learning Object Markup Language (LOML) was developed to define the structure of tutorials [Wu, 2002]. Its elements are

- **Title:** of the learning object
- **Definition:** of the core concept, the learning object is focused
- **Description:** of the core concept
- **Example:** about the core concept
- **Application:** simulation or demonstration to explain the core concept
- **Conclusion:** about the core concept
- **Exercise:** to improve the transfer of knowledge and skills
- **Test:** to evaluate the result of learning

Learning Material Markup Language (LMML) The Learning Material Markup Language (LMML) was developed for the structuring of the content of learning objects [Süss, 2000]. It is a meta-language using inheritance hierarchies to create discipline-specific markup languages, e.g. for computer science, music, finance.

PALO PALO is a language to describe and design learning scenarios ([Rodríguez-Artacho et al., 1999], [Rodríguez-Artacho and Maíllo, 2004]). A corresponding reference framework provides five layers: management, sequencing, structure, activity and content, each identifying a group of related components of a learning resource. Different strategies can be created by defining special Document Type Definitions (DTD's).

Tutorial Markup Language (TML) The Tutorial Markup Language is limited to specific learning scenarios as e.g. for questioning and problem-solving. It is an ISO SGML language for the creation of HTML-based learning materials in a platform neutral manner. Thereby it separates delivery mechanism and content representation [Netquest, 1998].

Instructional Material Description Language (IMDL) The Instructional Material Description Language is targeted towards instructional design and thereby limited to this special pedagogical design. It can be used to describe content, structure, assessments, user models and metadata in this context [Gaede, 2000].

Essen Learning Model The Essen Learning Model is a development model to support the creation of computer-supported learning environments ([Pawlowski, 2000], [Pawlowski, 2001]). Therefore it focuses on project management, quality assurance, process integration, curriculum development and learning sequence development. Another important aspect is the support for the specification of didactical models.

2.1.6 Advantages and Possible Drawbacks of e-Learning

In e-Learning the three fundamental assumptions of classic learning: same content, same time and same place are not valid anymore. Already the independence from time and place is primarily claimed to be value-adding [Cerri, 2002]. The too general argument that e-Learning has a positive impact on learning and teaching [Oblinger and Rush, 1998] can be refined and the general advantages of e-Learning like cost and time effectiveness [Garro and Palopoli, 2002] can be further distinguished. New points of view recognize much more potentials like the diversification of learning paths and general business competitive advantage [Garro et al., 2003]. The following three lists summarize various possible general advantages and classify them in terms of learner, instructor and organisation. A sub-classification is done in terms of substantial (○), abstract (⋆) and learning process orientation (+).

Advantages for learners [Belanger and Jordan, 2000]:

- ○ Increased access to learning and/or training
- ○ Increased access to richer, more diverse learning resources [Sheppard et al., 1998]
- ○ Increased choice of institution
- ○ Better marketability ([Kaipa, 1998], [Klimecki and Lassleben, 1999], [Nonaka and Takeuchi, 1995], [Garro et al., 2003], [Garro and Palopoli, 2002], [Angehrn et al., 2001])
- ○ Improves learner productivity
- ○ Better learning results because of possible re-connection of delivered knowledge and the learner's current activities [Angehrn et al., 2001]
- ○ Writing experience [Hoole and Hoole, 2000]
- ○ Increased performance
- ○ Increased promotion potential [Whalen and Hackley, 1998]
- ○ Increased compensation
- ○ Inexpensive communication tools
- ○ Immediate feedback, rapid response time
- ○ Ease of use
- ○ Access to remote experts
- ○ Free software
- ○ Increased mastery of material because of multi-sensory input ([Hall, 1997], [Ivers and Barron, 1998])
- ○ Opportunity for online self-testing and self-help
- ○ Opportunity for self-paced remediation
- ⋆ Wider cross-cultural interaction [Tetiwat and Igbaria, 2000]
- ⋆ Temporal and geographical independence ([Garro and Palopoli, 2002], [Sheppard et al., 1998])
- ⋆ Increased flexibility
- ⋆ Lifelong learning becomes more acceptable and possible [Porter, 1997]
- ⋆ Richer, more diverse learning resources and alternate points-of-view [Sheppard et al., 1998],
- ⋆ Learning (not examine) may include learning through making mistakes without negative consequences
- ⋆ Increased motivation to learn ([McArdle, 1999], [Mantyla and Gividen, 1997])
- ⋆ Optimization of acquisition of needed competencies [Garro and Palopoli, 2002]
- ⋆ Integration of (university) community, this ameliorates main disadvantage, the learning in isolation ([Hoole and Hoole, 2000], [Sheppard et al., 1998])
- ⋆ Students develop more positive attitudes towards computers [Kulik, 1994]
- ⋆ Increased access to alternate points-of-view [Sheppard et al., 1998]
- \+ Multiple modes of learning possible [Shi et al., 2000]
- \+ Different learning paths possible ([Kaipa, 1998], [Klimecki and Lassleben, 1999], [Nonaka and Takeuchi, 1995], [Garro et al., 2003], [Garro and Palopoli, 2002])
- \+ Increased learner centeredness
- \+ Modularity
- \+ Increased interaction with instructor
- \+ Increased interaction with other learners [Sheppard et al., 1998]
- \+ New forms of teaching make students spend more time in working on that subject,

comparing to the other subjects [Dvorak and Buchanan, 2002]
+ Up-to-date courses[Dvorak and Buchanan, 2002]

Advantages for instructors [Belanger and Jordan, 2000]:
○ Inexpensive communication tools
○ Improved instructor productivity
○ Platform independence
○ Links to extra resources
○ Reusability
○ Future growth
○ Opportunities for documenting, cataloguing and re-using curriculum materials and student work [Sheppard et al., 1998]
⋆ Temporal and geographical independence [Garro and Palopoli, 2002]
⋆ Everything is digital
⋆ Not transmitter, but facilitator or supporter [Tetiwat and Igbaria, 2000]
+ Increased interaction with other learners
+ Increased participation
+ Teaching flexibility
+ Individual attention to learners possible
+ Ensures instructional consistency
+ Ability to monitor and track learners' progress in an unobtrusive way [Tetiwat and Igbaria, 2000]
+ Opportunity to provide feedback, encouragement and rewards to learners using multiple communication means
+ Broader time frame to deliver courses

Advantages for organisations [Belanger and Jordan, 2000]:
○ E-Learning in business: reduce process costs, accelerate processes
○ Remain competitive as an institution [Sheppard et al., 1998]
○ Increased number of learners
○ Increased variety of learners, possibilities of reaching new/different student groups [Sheppard et al., 1998]
○ Competitive advantage
○ Decreased (operational) costs [Sheppard et al., 1998]
○ Ease of use
○ Platform independence
○ Future growth
○ Use of existing infrastructure
○ Less classroom requirements
○ Reduces turnover
○ Shorter training time
○ Reducing employee time away from the job, reducing travel expenses and shortening the amount of time students spend for learning [Giotopoulos et al., 2005]
○ More creative, autonomous and flexible employees with extended competencies for interaction and lifelong learning [Angehrn et al., 2001]
○ Compression achieved, shorter learning time compared to traditional courses (25% to

35%)
⋆ Temporal and geographical independence
⋆ New opportunities for cross-university interaction by both students and faculty [Sheppard et al., 1998]
⋆ Increased employee satisfaction
⋆ Helps to minimize the skill shortage problem [Garro and Palopoli, 2003]
⋆ Establishing or improvement of a corporate culture
⋆ New opportunities for cross-organisation interaction by both learners and organisation [Sheppard et al., 1998]
+ Capability to help enriching, sharing and circulating organisation knowledge, e-Learning as important part of Enterprise Knowledge Management ([Garro and Palopoli, 2003], [Garro et al., 2003], [O'Leary, 1998], [Soliman et al., 1999], [Garro and Palopoli, 2002])
+ Improve process quality: learning as an integrated part of work to improve the work itself
+ Increased flexibility and dynamics [Garro et al., 2003]
+ Course standardization
+ Centralized result tracking
+ Ease of update
+ Opportunities for documenting, cataloguing and re-using curriculum materials and student work [Sheppard et al., 1998]
+ More scheduling flexibility

E-Learning itself provides not only advantages, but sometimes deficiencies, too. Especially inappropriate usage of technical and didactic concepts lead to avoidable problems. A careful design considering individual and organisational capabilities and conceptions is always indispensible. Otherwise deficiencies for learners, instructors and organisations like the following may arise in certain types of e-Learning (specified in brackets if reasonable).

Possible drawbacks for learners [Belanger and Jordan, 2000]:
◦ Lack of interaction (CBT)
◦ Lack of instructor (CBT)
◦ No control of learning environment (CBT)
◦ Access to computer required (CBT)
◦ Limited interaction between learners (CAI)
◦ Reliance on internet service provider (WBT)
◦ Security and privacy (WBT)
◦ Viruses (WBT)
◦ Reliance on electronic communication (WBT)
◦ Possible low speed connections (WBT)
◦ Computer access required (WBT)
◦ Network access costs (WBT)
◦ Quality of material (WBT)
◦ Increased overall costs (WBT)
◦ "Lost on the Web" (WBT)

- Bandwidth required (TC)
- Audio limitations (TC)
- Video limitations (TC)
- No offline work (TC)
- Scheduling (VTT)
- Geographic dependence (VTT)
- Visual display limitation (VTT)
- Effort to learn to use the technology
- Danger of individual isolation
- Presentation of e-Learning content is often more influenced by technicial means instead by didactic ones
- Less automatical adaption of course material according an user profile [Buraga, 2003]
- Expensive for third world countries, infrastructure needed (internet connections, desktop pc's, software) [Hoole and Hoole, 2000]

Possible drawbacks for instructors [Belanger and Jordan, 2000]:

- Increased coordination (CAI, WBT, VTT)
- Reliance on internet service provider (WBT)
- Security and privacy (WBT)
- Viruses (WBT)
- Reliance on electronic communication (WBT)
- Digital material required (WBT)
- Dependence on course builder (WBT)
- Copyright issues (WBT)
- Authentication (WBT)
- Bandwidth required (TC)
- Audio limitations (TC)
- Video limitations (TC)
- Scheduling (VTT)
- Difficult participation of learners (VTT)
- Dependence on support personnel (VTT)
- Sometimes time-consuming operational nature of online courses [Jafari, 2002]
- Danger to become jobless
- Expensive for third world countries, infrastructure needed (internet connections, desktop pc's, software) [Hoole and Hoole, 2000]

Possible drawbacks for organisations [Belanger and Jordan, 2000]:

- Platform dependence (CBT, CAI)
- Costly revisions (CBT)
- No control of results (CBT)
- Development costs (CAI)
- Reliance on internet service provider (WBT)
- Security and privacy (WBT, TC)
- High speed connections required (WBT)
- Instructor training required (WBT)
- Lack of standards (WBT)

- ○ Support infrastructure (WBT)
- ○ Implementation and overall costs (CBT, WBT, TC)
- ○ Training required (VTT)
- ○ Implementation costs (VTT)
- ○ Production personnel required (VTT)
- ○ Expensive for third world countries, infrastructure needed (internet connections, desktop pc's, software) [Hoole and Hoole, 2000]
- ○ Sometimes not prepared to certify the knowledge and skills of learners independently from the way they have acquired them [Cerri, 2002]

Other general limitations are possible when the applied e-Learning system does not exploit the possiblities of this technology, but only reflects the classic lecture style [Angehrn et al., 2001]. Problems may also arise when these systems are used as pure content delivery mechanisms with no social interaction possibilities [Giotopoulos et al., 2005].

Tabel 2.5 summarises some properties for certain types of e-Learning following [Belanger and Jordan, 2000].

	CBT	CAI	WBT	TC(LARGE)	TC(DESKTOP)	VTT
EASE OF USE	H	M - H	M	H	M	M
EASE OF REVISIONS	L	M	H	H	M	M
IMPLEMENTATION COSTS	H	H	M - H	very H	M - H	H
OPERATIONAL COSTS	M	M	L	H	M	H
GEOGRAPHIC INDEPENDENCE	H	M	H	L	H	L
SYNCHRONICITY	A	A/S	A/S	S	S	S
INTERACTIVITY						
Learner - Instructor	L	M	M	H	H	M
Learner - learner	L	M	M	H	M	M
Learner - Content	H	H	M	L	M	L

Table 2.5: Summary of chosen properties for certain types of e-Learning (H: High, M: Medium, L: Low, A: Asynchronous, S: Synchronous) [Belanger and Jordan, 2000]

2.2 Establishment of e-Learning

Certain aspects need to be prepared to get e-Learning working in its application areas. e-Learning is suitable for courses if the following question can be positively answered and the variables listed below imply positive feedback: Is e-Learning useful for the targeted group of learners within their organisation? Negative factors like disturbance, (cultural-based) aversion of learners against e-Learning, etc. may emerge. Some other variables that need to be taken into consideration are the following [Belanger and Jordan, 2000] and the ones presented in table 2.6.

- **Learner throughput** e-Learning supports the study of more students; a better Return on Investment (ROI) can be achieved.
- **Physical risk** e-Learning can minimize or even avoid physical risk for learners, e.g. for the handling of chemical experiments, biohazards or dangerous machinery [Mencke, 2007].
- **Hands-on work/activities** e-Learning can not support every kind of learning experiences so far, e.g. cooking, medical courses or haptic, olfactory respectively flavour experiences.
- **Use of specialized tools or equipment** e-Learning may be suitable in situations when needed external equipment can be simulated or remotely accessed.
- **Group training for functional teams** e-Learning is not suitable so far for group-based psychomotor training and group-based interpersonal training, because of missing possibilities for real group settings.
- **Desired course complexity** Several aspect are needed to be taken into account to achieve respectively apply an intended complexity of the course. That includes the available technical infrastructure, the level of engagement that is required during learning to achieve learning retention, the complexity of the topic, the intended level of learning objectives that shaould be achieved as well as the degree of required simulation.
- **Situations where physical presence of learners/instructors is required**

Following [MMB Institut für Medien- und Kompetenzforschung, 2004] the seven main barriers of e-Learning are the needed high levels of self-learn-competence and self-motivation, the limited social exchange and the limited direct feedback, missing regulations for learning at the workplace, the intransparent e-Learning market, the missing approval of qualifications by e-Learning courses, the missing clarity of the additional value of e-Learning and the inadequate internal marketing for e-Learning.

VARIABLE	CBT	WBT	VTT	TC	CBT/WBT HYBRID
Length of instruction more than 80 hrs	3	3	2	1	3
Class size	3	2	Limited	Limited	2

VARIABLE	CBT	WBT	VTT	TC	CBT/WBT HYBRID
Wide geographic dispersion of learners	3	3	2	2	3
Remediation / Learning to mastery	3	3	1	1	3
Group problem solving	0	2	1	3	2
Real-time instructor feedback / instructor guided discussions / group discussions	0	2	2	3	2
Capture learner performance data	0	3	0	0	3
Automated course management information systems	0	3	0	0	3
Level of complexity	3	3	2	3	3
Temporal independence	0	2	2	3	2

Table 2.6: Summary of variables to consider (3=fully meets criteria in functionality, 2=some restrictions in functionality, 1=possible but may not be effective, 0=no functionality for this requirement (does not apply))[Belanger and Jordan, 2000]

[Belanger and Jordan, 2000] lists three types of e-Learning employment, namely technology insertion, combined delivery and total conversion (cp. figure 2.10).

For *technology insertion* communication and collaboration tools are integrated into the course to support traditional classroom activities. The expected advantages are an enriched learning environment, a direct transfer of learning in environment, and increased acceptance of technologies and facilitated collaboration.

The *combined delivery* via classroom and e-Learning enhanced courses often can be primarily aspired to enrich the learning environment, to directly transfer learning in the environment, to increase the acceptance of technologies, to facilitate collaboration and to shorter the overall course length.

The *total conversion* aims to replace classroom learning with e-Learning. The intended advantages are to enrich the learning environment, to directly transfer learning in the environment, to increase the acceptance of technologies, to shorter overall course length, to increase training opportunities, to facilitate sharing of instructional material and resources, to wider the access to expertise and to reduce travel and lodging costs. Total conversion is not suitable for psychomotor and affective learning objectives.

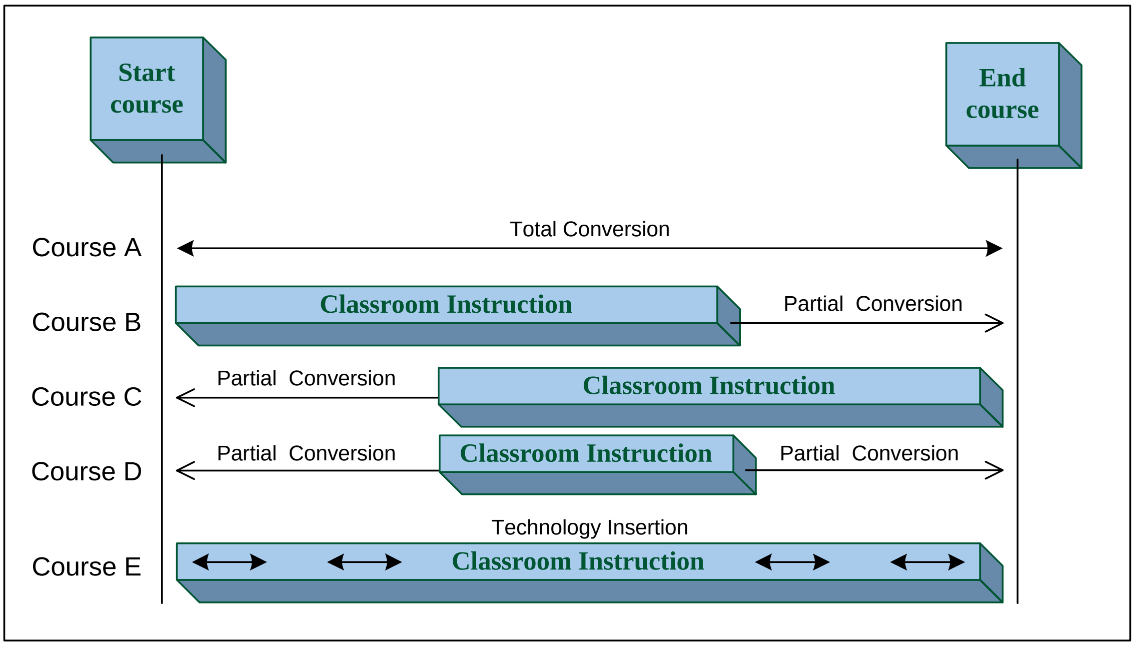

Figure 2.10: Ways to employ distant learning technologies [Belanger and Jordan, 2000]

Table 2.7 opposes learning objectives and assessment type to determine the technology implementation type.

	TOTAL CONVERSION	COMBINED DELIVERY	TECHNOLOGY INSERTION
LEARNING OBJECTIVES	cognitive, software, problem solving	cognitive, software, problem solving, affective, psychomotor	cognitive, software, problem solving, affective, psychomotor
ASSESSMENT TYPES	periodic, certification	continuous, periodic, certification	continuous, periodic, certification

Table 2.7: Learning objectives and assessment type to determine technology implementation type [Belanger and Jordan, 2000]

2.3 Interaction in e-Learning

Following [Brown and Duguid, 2000] learning is “a remarkably social process. Social groups provide the resources for their members to learn.” There are several social reasons for interactivity. It decreases isolation of the participants and increases the flexibility to adapt new conditions. Furthermore it involves more human senses into learning and increases the variety of learning experiences (multi-cultural environments, communication capabilities, …). Nonetheless interaction sometimes is a fundamental requirement for certain courses [Belanger and Jordan, 2000].

Common properties of interactivity within e-Learning are the interactive properties of the used media, the degree of engagement between learner and instructional content and the properties and technologies for communication of all involved parties [Belanger and Jordan, 2000].

An interaction pattern to guide a Web-based course preparation is presented in table 2.8.

Students working alone	Communicating with the professor (and teaching assistants)	Communicating with other students	Communicating with other people outside the course

Table 2.8: Communications pattern to guide Web-based course preparation [Aggarwal, 2000]

Table 2.9 provides an overview about possible interaction schemes of web site access for different purposes.

	INSIDE CLASSROOM WEB USAGE	OUTSIDE CLASSROOM WEB USAGE
COURSE-SPECIFIC INFORMATION	web-presented course material can be used during class	students can learn at their own pace
PUBLIC INFORMATION	virtual field trips to public websites	web access to public websites in personal non-linear way

Table 2.9: Type of Web support, type of information and place of Web usage [Aggarwal and Bento, 2000]

The level of learner interaction is a major impact on achievable learning objectives. [Belanger and Jordan, 2000] opposed learner-courseware interactivity and associated learning objectives (cp. table 2.10). Level 1-2 thereby represents low technology requirements, E-mail and a standard web browser are sufficient to present e.g. text- and graphic-based content. For level 2-3 additional benefits like tailored instruction, increased engagement and decreased instructional time can be gained by interactive texts and graphics and alternative navigation options like table of content (TOC), index, hyperlinks, search engines. Level 4 describes the most advanced stage with interactive multimedia like interactive text, video, sound and animation.

STUDENT INTERACTIVITY WITH COURSEWARE	LEARNING OBJECTIVES
Level 1: Passive ◦ Learner interaction limited to advancing the presentation	**Cognitive** ◦ Learning *facts* ◦ Learning *rules* **Psychomotor** ◦ *Perception* of normal/abnormal/emergency condition cues associated with performance of a procedure
Level 2: Limited Participation ◦ Provides drill and practice ◦ Provides feedback on learner responses ◦ Can emulate simple psychomotor performance ◦ Can emulate simple equipment operation in response to learner action ◦ Computer evaluation of learner's cognitive performance	**Cognitive** ◦ Learning *facts* ◦ Learning *rules* ◦ Learning step by step *procedures* **Psychomotor** ◦ *Perception* of normal/abnormal/emergency condition cues associated with performance of a procedure ◦ *Readiness* to take part particular actions ◦ *Guided response* in learning a complex physical skill **Affective** ◦ *Receiving* normal/abnormal/emergency condition cues associated with performance of a procedure ◦ *Responding* to cues

STUDENT INTERACTIVITY WITH COURSEWARE	LEARNING OBJECTIVES
Level 3: Complex Participation ◦ Capable of complex branching paths based on student selection and responses ◦ Can present or emulate complex procedures with explanations of equipment operation ◦ Learner can participate in emulation of psychomotor performance and extensive branching capability ◦ Capable of real-time simulation of performance in the operational setting ◦ Computer evaluation of learner procedural performance includes time and error scores	**Cognitive** ◦ Learning step by step *procedures* ◦ Learning to group and *discriminate* similar and dissimilar items ◦ Learning to synthesize knowledge for *problem-solving* **Psychomotor** ◦ *Perception* of normal/abnormal/emergency condition cues associated with performance of a procedure ◦ *Readiness* to take part particular actions ◦ *Guided response* in learning a complex physical skill ◦ Learning *mechanism* of performing complex physical skills ◦ Learning *adaptation* to modify complex physical skills to accommodate a new situation ◦ Learning *origination* to create new complex physical skills to accommodate a new situation ◦ Learning to make *continuous movement*; compensate based on feedback
Level 3: continued	**Affective** ◦ *Receiving* normal/abnormal/emergency condition cues associated with performance of a procedure ◦ *Responding* to cues ◦ *Valuing* worth of quality of normal, abnormal and emergency cues association with performance of an operational procedure ◦ Developing *competence* to make decisions using prioritised strategies and tactics in response to normal, abnormal and emergency condition cues associated with performance of an operational procedure ◦ Learning *innovation* to make decisions

STUDENT INTERACTIVITY WITH COURSEWARE	LEARNING OBJECTIVES
Level 4: Real-time Participation ◦ Capable for real-time simulation of performance in the operational setting ◦ Computer evaluation of learner performance and intellectual skills ◦ Computer evaluation of learner procedural performance includes capability to generate time and error scores ◦ Employs state-of-the-art technology for simulation and communication	**Cognitive** ◦ Learning to group and *discriminate* similar and dissimilar items ◦ Learning to synthesize knowledge for *problem-solving* **Psychomotor** ◦ Learning *mechanism* of performing complex physical skills

Table 2.10: Learner-courseware interactivity and associated learning objectives [Belanger and Jordan, 2000]

2.3.1 Synchronicity

Definition 44 ***Synchronicity*** *in the actual domain is defined as the timing of interaction or communication [Belanger and Jordan, 2000].*

The classical types of interaction-oriented synchronicity are synchronous and asynchronous. The first one describes real-time interaction, where immediate and simultanuous feedback is possible. Common media types are video, audio, graphics and text. Expected advantages are e.g. a more effective learning by trial and error, experimentation and the interchange of ideas. Certain tools and techniques are needed, that are often more expensive than an asynchronous support [Belanger and Jordan, 2000].

In contrast asynchronous interaction includes is not real-time. Corresponding tools can be applied when appropriate. Standard techniques like eMail, fax and newsgroups or learning via videotapes, CDs, etc. belong to this category [Belanger and Jordan, 2000].

2.3.2 Communication

Communication is one major part of interactivity. Thereby it is identified as "the process of engagement between two communicators in which each causes change and reactions in the other" ([Tannenbaum, 1998], [Williams et al., 1988]). For e-Learning it is necessary for learners in their respective environments to fulfil the requirements

	ASYNCHRONOUS	SYNCHRONOUS
PASSIVE	Learners receive information. They take their curse at their preferred time. E.g.: non-interactive Computer Based Training (CBT)	Learners receive information. Course is scheduled. E.g.: downlinked videoconferencing course without communication capabilities.
PARTICIPATION	Learners make responses to simple instructional cues. They take their course at their preferred time. E.g.: interactive CBT	Learners make responses to simple instructional cues. Course is scheduled. E.g.: video teletraining course with student audio participation.
REAL-TIME PARTICIPATION		Learners involved in life-like set of complex cues and responses. Course is scheduled. E.g.: desktop videoconferencing course.

Table 2.11: Interactivity and synchronicity in distance learning [Belanger and Jordan, 2000]

[Belanger and Jordan, 2000]. Communication thereby is based on several one-way linear communication acts [Shannon, 1948]. The message to be sent from the sender via the transmitter is transported to the destination's receiver over some medium (cp. figure 2.11).

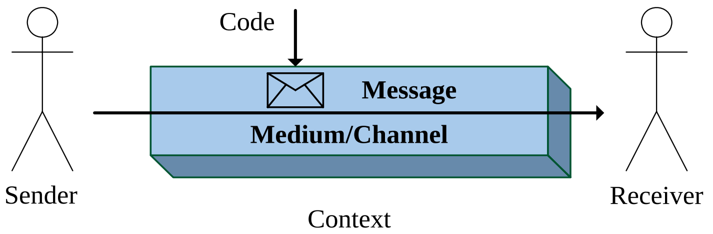

Figure 2.11: Classic model of communication theory (cp. [Ferber, 1999])

The degree of effectiveness (communication fidelity) of this transmission is affected by communication skills, attitudes, knowledge level and sociocultural position of the human sender [Berlo, 1960]. Time, place and richness of communication is dictated by the nature of the goal, task and participants and activities that are involved in completion. Communication for interaction can be analysed at different dimensions

[Belanger and Jordan, 2000]. Each learner differently uses and benefits from those communication types, depending on his individual learning style. The *interaction between learner and instructor* can be separated in terms of time and place. It is performed with asnychronous or synchronous communication. One key aspect of this communication dimension is the integration of feedback-loops to ensure comprehension or get information about achievements [Williams et al., 1988].

Communication between learners is important, too. It is assumed as a positive tool for learning (shared ideas, nonlinear concept development, exposition of different cultures or ways of thinking, . . .). Sometimes this interaction is necessary for certain types of learning, e.g. for cooperative and constructivist learning and for learning objectives that require synthesis and evaluation. In general the comprehension of the content to be learned, the critical thinking and the time of information storage is improved by team-oriented discussions and multiple points of view ([Dimitrova et al., 2003b], [Cramer, 1994]). The computer-mediated communication for collaborative learning is one preferred learning style in e-Learning [Dimitrova et al., 2003b]. Communication is efficient, if there exist defined and accepted standards for availability and acceptance of roles, the team member eliminate comprehensive problems through communication, the main communication type is synchronous and the communicating partner give precedence to content and types of communication [Haywood, 1998].

Chosen disadvantegeous characteristics of collaborative learning are listed below:

- Less quantitative productivity
- Diskussions with reduced restraints
- Learning is experienced as being more impersonal
- Social norms seem to be less binding

The *interaction between learner and content* is the degree of intellectual, emotional and physical engagement of the learner to the content [Belanger and Jordan, 2000]. There are needed special preparations of content for different purposes as for example navigation, searches and decision trees.

There exist different usable communication applications for the e-Learning domain. That includes, but is not limited to the examples within the list below and in table 2.12.

- Electronic mail [Klobas and Renzi, 2000]
  - Asynchronous
  - Possibility for attachments and to insert HTML
- Distribution lists
  - Asynchronous
  - Centralised receiving of emails and distribution to a list of addresses
  - Subscription mechanisms (early establishment of a Web community) and archives of emails
  - List: public, private, moderated, unmoderated
- Conferencing systems (forums, discussion databases, wikis)
  - Asynchronous
  - Tree structure of messages, grouping of messages in so called threads
  - Parallel discussions possible

- Chat
  - Synchronous
  - Often structured in rooms or direct point-to-point (group) chat
  - Can be part of community software
  - Sometimes extended by graphical avatars, “emotional” sound, graphical so-called smilies, voice/video transmission
- Audio and video tools
  - Asynchronous/synchronous
  - Streaming of video or audio
  - Video or audio on demand
  - IP phoning
  - Team speak server
- Integrated tools
  - Meta-chat tools integrating numerous chat clients
  - Integration of video and audio in chats

FAMILY COMMUNICATION TOOLS	TIMING OF COMMUNICATION	RICHNESS OF COMMUNICATION
E-mail	asynchronous	low: text only, but some can be enriched to moderate with attachments and HTML enhancements including hot links
Distribution lists	asynchronous	low: text only, but some can be enriched with clickable links to web sites and other objects
Forum, blogs and conferencing	asynchronous	low: mainly oriented on text, but can be enriched to moderate with attachments and HTML enhancements including clickable links
Chat	synchronous	moderately low: text, but presence enhanced by synchronous timing
Desktop video and audio	asynchronous, synchronous	moderate to high, depending on extent to which hardware and network support vocal intonation and physical gesture; richness lower when used asynchronously because immediacy of response is lost.
Integrated tools	asynchronous and/or synchronous	varies, according to tools included

Table 2.12: Software and services for communication [Klobas and Renzi, 2000]

Collaboration among learners is a key factor for learning in groups and directly bases on communication. Appropriate collaboration tools are described in table 2.13.

FAMILY OF COLLABORATION TOOLS	COLLABORATION TOOLS AND COLLABORATION FEATURES
Community building	homepage for community links page for community homepage for individual user links page for individual user community e-mail distribution who is online public and private chat (text) newsletter production and distribution individual, sharable calendars
Computer-supported collaborative work (CSCW)	workspace for work group or group of learners ability to populate workspace with documents and other objects, including URLs integration of user's existing e-mail service for individual and group distribution of e-mail
Learning environments	templates for course materials tools for development of course materials integration of administration with course content course material repositories

Table 2.13: Web-based collaboration tools [Klobas and Renzi, 2000]

2.4 Learner Centeredness

Learner centeredness is one key factor in e-Learning. Its degree affects the degree of the learners' education, because their individual learning style, their preferentially perceived type of information, their operation on perceived information in different ways, their achieved understanding at different rates and their preferences vary and therefore they should be in the center of the learning process (cp. figure 2.12) for effective learning ([Race and Brown, 1995], [Soloway, 1998]).

Definition 45 ***Learner centeredness*** *can be defined as the degree of of control the learner has over his or her learning experience [Belanger and Jordan, 2000].*

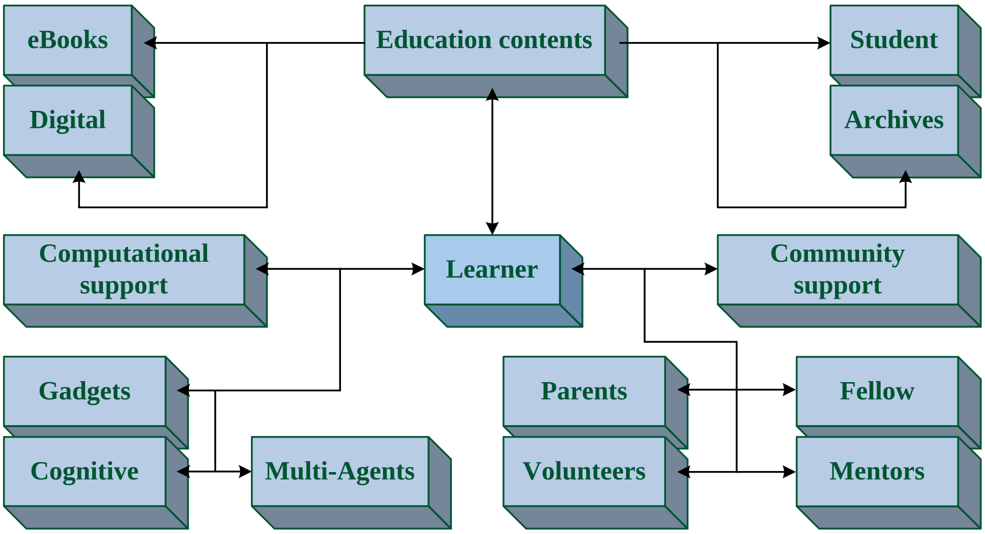

Figure 2.12: The learner in the center of a modern e-Learning system (cp. [Sadiig, 2005])

There are different conclusions for e-Learning that arrive from all those aspects of learner individuality. The most important ones are:

- Flexible learning environments [Dimitrova et al., 2003b]
- Provision of rich information in redundant formats [Dimitrova et al., 2003b]
- Learners must have control over their learning path [Race and Brown, 1995]
- Support to learning communities where participants complete assignments independently or in a group [Dimitrova et al., 2003b]
- Provision of interaction mechanisms [Dimitrova et al., 2003b]

There exist several strategies to implement those conclusions. An appropriate learning theory can support learner centeredness, as for example Cognitive Information Processing, Constructivism or Socioculturalism (cp. section 2.1.4). Furthermore it is necessary to encourage the learner. They often need motivational or appropriate technical support that they want to learn [Race and Brown, 1995].

The following sections briefly describe the most important requirements arising from the e-Learning key factor 'learner centeredness'.

2.4.1 User Models

One actual major aspect is the collection of data characterising certain users to provide a substantial basis for system adaptivity [Kabassi and Virvou, 2003]. In e-Learning such a learner profile collects data e.g. about learning credentials (student grades and performance in certain courses, ...), learning preferences, learning style and learning habits [Jafari, 2002]. Such adaptivity may for example result in individual suggestions for provided learning packages, for special courses or certain learning paths; best suited for the personal needs and preferences. Therefore a user model can be defined as:

Definition 46 *A **User Model** is a knowledge source that contains a set of beliefs about an individual on various aspects, and these beliefs can be decoupled from the rest of the system [Kobsa and Wahlster, 1998].*

Definition 47 *"**User modeling** is the process of building data structures and inference mechanisms that allow an application to assess certain properties of its user and tailor the interaction accordingly" [Giotopoulos et al., 2005].*

There many human characteristics that evoke such differences and individuality. [Belanger and Jordan, 2000] listed a few:

- "Humans receive information via sensory input and/or physical interactions."
- "Humans are not reliable receivers of information."
- "Humans are diverse and unpredictable receivers of information."
- "Humans are nomadic – they learn at different places and learn different over time."
- "Humans are self-aware and can give advice on themselves."
- "A single human can play several roles; several humans can play a single role."
- "Several learning experiences may be occurring simultaneously."

Other reasons are e.g. ethnicity, gender, religion, disability, language, culture, communities, prior domain knowledge, pre-determined learning style, individual approach to learning, personal motivation, expectations, social contexts of education, and learner's personal life style ([Dimitrova et al., 2003b], [Wild and Quinn, 1998], [Soloway, 1998]).

Self identified four major goals of user models: prediction and planning; diagnosis and remediation; negotiation and collaboration; interaction and communication [Self, 1994]. Following Eklund and Zeilinger [Eklund and Zeiliger, 1996] the main tasks of a user model are:

- Identification of the current and relevant goals of the user.
- Saving and actualisation of the user's knowledge about the system and its usage possibilities.
- Saving and actualisation of the user's background knowledge.
- Analysis of the user's experience that can be useful for knowledge transfer.
- Saving and actualisation of the user's preferences and interests.

Several distinct information can be stored, including user data, usage data and environment data. User data are e.g. goals, tasks, background, experience, preferences combined with their progress; cognitive states such as knowledge, preferences and goals, non-cognitive states like emotions and personality traits. Usage data can be data from interaction with a system by monitoring, behaviour patterns, etc. They can be used as basis for e.g. decisions about future lectures. Environment data may include the position in time and space, socio-political aspects, the state of external resources and technological information ([Cannataro and Pugliese, 2004], [Kernchen, 2005]).

Cannataro and Pugliese describe a classification of user models [Cannataro and Pugliese, 2004].

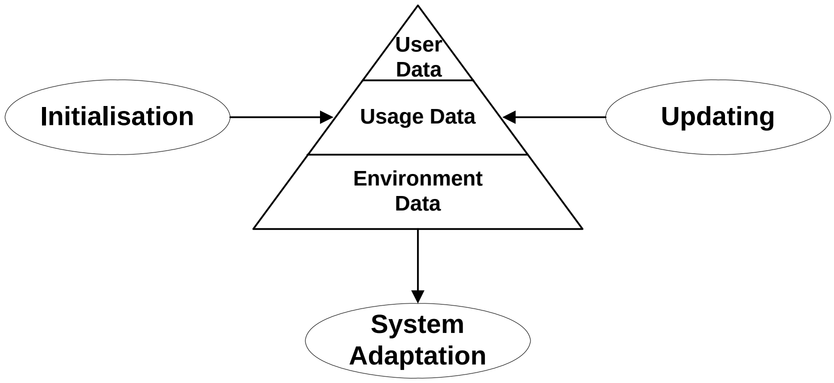

Figure 2.13: The three processes involved with a user model (according to [de Vrieze and van Bommel, 2004])

- **Overlay models:** depict relevant aspects of the user by quantitative or qualitative metrics and compare them with a domain model.
- **Stereotype models:** can be differentiated into pure, multiple and mixed stereotype models. Pure stereotypes models attribute the user to one group meanwhile multiple stereotypes allow affiliations to several groups. Mixed stereotypes use attributes for the description of affiliations.

Practical implementations often use a mixture of both models. They start with a stereotype model and with growing data they segue into an overlay model.

Data about the user can be gathered by implicit and explicit methods. Mostly implicit approaches are used, because users are not inclined to answer too many questions except they see an explicit advantage. Initialisation may be an exception. A user model can be implemented e.g. via Bayesian belief networks or decision tree models. The first possibility follows a propabilistic approach and aims to automatically build a user model using learner history data [Ueno, 2005]. They are useful to model and process uncertainty involved in student modelling, but are still limited in the number of variables ([Ueno, 2001], [Ueno, 2005], [Giotopoulos et al., 2005]). Decision trees are an approach to overcome this limitations.

2.4.1.1 IEEE Personal and Private Information Project

The IEEE Personal and Private Information Project (PAPI) was developed with a special focus on the user's learning performance [IEEE LTSC, 2002b]. That results in the depictable categories. Within this model personal information and preferences (object types used by the learner), performance, security-related aspects, a portfolio and relations to other people can be modeled. A differenciated presentation is possible for a role-based access. So a tutor can access different information than the learner or ther institution. Reusability in different systems was another goal of this standard. IEEE PAPI was once a standard developed by IEEE LTSC, but was submitted to ISO IEC/JTC1/SC36 WG 3 for further development.

2.4.1.2 IMS Learner Information Package (LIP)

IMS Learner Information Package (IMS LIP) is a management-focused approach to create user models [IMS Global Learning Consortium, Inc., 2001]. Main goals are the recording and management of learning-process-related events, goals and capabilities, learner support as well as the highlighting of learning advantages to the learner. IMS LIP is oriented towards interoperability between user models and Web-based learning systems. A special Learner Information Server is the backbone of this standard, it manages information about the users as well as the rights for its usage. The categories of IMS LIP are:

- Access properties of the user,
- Learning activities,
- Relations among categories,
- User membership in special groups,
- Competences (knowledge, capabilities, etc.),
- Interests and goals,
- Identificators (necessary biographic and demographic data),
- Certificates, qualifications and licenses (about acquired knowledge),
- Security keys for system access and
- Summaries about achievements.

2.4.2 Adaptation Techniques

Definition 48 *Content adaptation is defined by the W3C as the process of selection, generation or modification of resources within a given transmission context. Based on the given request one or more fragments are created (cp. [World Wide Web Consortium (W3C), 2005]).*

Adaptation can be performed active or passive. A certain autonomy based on intentions and complex goals is necessary for active adaption meanwhile passive adaptation is based on special learning and inference algorithms [Dumke et al., 2003].

Within e-Learning several adaptable aspects exist. Type and pecularity are determined by the system's functionalities. Classic adaptation comprises three technologies:

- Adaptive navigation support,
- Adaptive presentation and
- Adaptive content provision.

Based on the graph structure of e-Learning content adaptive navigation support describes adjustments of edges, meanwhile adaptive content provision targets the adjustment on node level [Dolog et al., 2003]. Adaptive presentation adjusts the presentation of the chosen node resources according to specific requirements or preferences of the user.

2.4.2.1 Adaptive Navigation Support

Navigation within complex content structure can cause certain problems like excessive demands in depth and broadth of available resources ("Lost in Hyperspace"). This is mainly because of the rigid navigation for multiple, complex user requirements. Techniques of adaptive navigation support try to adapt to this individuality of goals, knowledge and other user characteristics with adjustments of navigation options. The intended improvements are user guidance within the linked resources, the improvement of orientation as well as the provision of a personal view towards the available set of resources [Brusilovsky et al., 1998].

Global support is provided for information search using connetions between the resources with minimal effort. That can be achieved with the presentation of chosen and sorted links.

Local support can be necessary, if a next navigation step needs to be chosen by the learner. Based on user model and actual position within the resources, possible navigation targets can be prioritised suggested. Another possiblity is direct forwarding.

Support relative to the user's position within the content can be provided by methods of **local orientation**. Therefore additional semantically related information are used or navigation options are reduced to minimise the learner's cognitive effort. Again adaptations based on user model data can be performed. By this e.g. an adaptation to the knowledge level of the learner can be achieved.

Methods of the **global support of orientation** approach describe the resource set structure and the absolute position of the learner. Techniques are navigation maps, position markers or guided help. Local or global maps describe the possible navigation structure and position markers are intended for unique resource identification within the the whole resource set independent from the exsting navigation structures. Guided help was developed for the stepwise introducation of the of resource set to the learner.

A **management of personal viewpoints** is useful if only a small subset of the resources are needed by the learner. According to the actual goal and user model the view to the available resources are chosen and adaptively presented.

For all the methods appropriate techniques have been developed for their exclusive or combined implementation [Brusilovsky and Nejdl, 2004]. That e.g. can be:

- Direct forwarding,
- Sorting,
- Predefined set of links,
- Limitation of the navigation space (deleting, hiding, masking),
- Typing of links,
- Extension of link presentation,
- Additional information,
- Adaptive lokal and global navigation maps and
- Link generation (similiarity-based, interest-based).

Direct forwarding directly redirects the learner to the next appropriate learning resource. The rating and classification of the next candidates depends on the data of the user model. That e.g. can be the actual knowledge level, learner goals or his preferred learning object media type. Forwarding can be realised using static or dynamic links. Static links forward the learner by the graphical presentation of the link to the next resource. Dynamic links are generated on demand.

Adaptive sorting is intended to reduce the learner's navigation effort. The relevance of links is determined by criteria of the user model. This technique must be carefully implemented. It is advantageous, if new generated links need to be presented. Problems may occur with static structures, e.g. table of contents, because the replication of a special navigation path is not possible under certain circumstances.

The **limitation of navigation space** can be achieved by hiding, deleting or deactivating links actually being inappropriate according to the learner's user model. A reverse usage of this technique is link activation during knowledge increase of the learner. Task hierarchies are possible implementation approaches for this technique [Brusilovsky et al., 1998].

A typing of links was proposed in [Chiaramella, 1997]. That can result in different presentations of the links, maybe based on the resource type. Thereby navigation effort minimisation is targeted.

The most common technique is extension of the links presentation by additional texts, colours or objects etc. Thereby learning results are improved and navigation effort is minimised (cp. [Brusilovsky and Pesin, 1998] and [Brusilovsky and Weber, 2001]). Possible link text adaptations are changing font colours, font size ot font type. [Brusilovsky and Weber, 2001] describe a traffic-light metaphor to indicate appropriate or inappropriate learning resources.

Based on the user model and the actual learning resource **additional information** can presented with new navigation structures to make them available to the learner.

Global and local navigation maps can be static as well as dynamic. Static adaptations are about the application of the techniques described above meanwhile dynamic approaches change the structure of the maps itself.

Systems preselecting a subset of resources are often implementing **adaptive link generation**. Therefore three approaches exist: (a) the generation of new links and their permanent inclusion into a set of existing links, (b) generation of links for a similiarity-based navigation and (c) the dynamic extension of existing links.

2.4.2.2 Adaptive Presentation

Adaptive presentation may result in changed navigation link presentation as described in 2.4.2.1, the presentation of adaptivily changed or chosen content as described in 2.4.2.3 or in adapted changes of the presented resources' layout.

Again the user model as well as the learning resources are basis for this adaptation type. Several techniques can be distinguished.

Sorting of resource fragments can change the sequence of learning resource presentation based on learner preferences. So for example a learning system can introduce or end a learning sequence with a summary.

Adaptive presentation due to different media types for information provision can be necessary if alternative media type cause the change within the layout. under certain cirumstances a textual represenation needs more space than a diagram about the same topic.

Actual technical progress and different user requirements and preferences result in different clients for information presentation. For example a mobile device has limited hardware resources for the storage and presentation of content. because of this an **adaptive resource provision with different quality** is needed.

The capacity of transmission channels is a limitation factor that cause **adaptive resource provision due to different transmission contexts**. That may result in changes of resource itself or in the adaptation of the transmission process. For example [Laakko and Hiltunen, 2005] describes a rule-based adaption of resources using a proxy.

A next approach is mainly usable within the Web or other multicultural environment. Here the heterogeneity of potential users is very high to justify an **adaptive resource presentation due to different languages**.

Changed colours or adapted font sizes or types can be caused by learner preferences for a pleasant resource presentation.

2.4.2.3 Adaptive Content Provision

Content can be adapted either on the side of the provider, the consumer or in between as a kind of proxy-based implementation. Basis for this adaptation are the requirements determined by the attributes of the client [Laakko and Hiltunen, 2005]. That can be performed on different levels [Dolog et al., 2003] and depends on information about the learners. Again a user model is needed to model and collect these data.

Appropriate methods for adaptive content provision are e.g:

- **Additional explanations:** allow the hiding/presenting of additional resources. It is intended to present only those information to the user that are appropriate.
- **Fundamental explanations:** need to be understood before more complex concepts can be learned.
- **Comparative explanations:** provide a better understanding due to the study of similiar concepts.
- **Explanation variants:** of different concepts can be created and presented according to the learner's preferences.
- **Sorting of information fragments:** places the most relevant resources at the beginning of the learning sequence.

2.5 Media in e-Learning

Another factor is the media and its relative richness; certain properties support certain kinds of communication ([Daft and Lengel, 1986], [Walther, 1992], [Walther, 1995]).

There exist several media types being directed towards the human senses as there are sight, hearing, taste, smell, touch, temperature and balance [Kernchen, 2005]. The actual most distributed information description types are targeting the visual and the auditive sense. Examples are:

◦ Text, grafics and pictures, objects,
◦ Animations, audio data (speech, sound) and movies and worlds.

Thereby the first four are discrete and the other are continious information types [Dumke et al., 2003].

The intensity of learning depends on the number of involved senses as well as on the nature of the learning object. Matrix 2.14 gives an idea about this relationship; thereby the number 1 represents the lowest learning intensity. In general the efficiency of information transmission and thereby of learning differs according to the different media types and the different information itself. Media type and learning strategy must fit. Furthermore the preferences and capabilities of the learner as well as the media usage intense is important.

	Report (1)	**Picture (2)**	**Model (3)**	**Real object (4)**
Listening (1)	1	-	-	4
Look at (2)	-	4	6	8
Observe (3)	-	-	9	12
Concrete action (4)	-	-	12	16

Table 2.14: Learning intensity and learning medium

As described above often the combination of media is proposed for better learning results. That refers to the media, the coding and the targeted sense. There single und combined approaches can be differentiated: mono medial (book, PC, . . .) or multimedial (PC + video, . . .), single coded (only text, . . .) or combined coded (text with pictures, . . .) as well as mono modally (only visual, . . .) or multi modally (audio-visual) realisations are possible.

The combination of different media and targeted senses has advantages and disadvantages. Advantageous is the reduction of congestion, because information are distributed to different sensory channels. Disadvantages may accur due to bad coordination, if there are for example inconsistencies within the different medial representations.

2.6 Standards and Specifications in e-Learning

E-Learning is valuable usable as a part of a well-planned and properly supported educational training and learning environment [Giotopoulos et al., 2005]. It is considered as an important technology push attitude [Cerri, 2002]. Standards are needed to guarantee agreements between certain producing and consuming parties, otherwise all solutions are ad hoc and proprietary and rapidly become unsupportable [Wilson et al., 2004b].

A major step towards this quality is the definition and application of appropriate standards. Very important is the definition of metadata for the efficient and effective description of the considered aspects. There, for example additional information, is needed to classify learning objects (documents, slides, simulations, role plays, questionnaires, pre-recorded lessons, classroom lessons, ...) and their relationships with respect to their objectives, topic, used media, ... [Garro et al., 2003].

The main goals of standards in e-Learning are:

- Interoperability
- Manageability
- Accessibility
- Durability
- Re-usability
- Affordability
- Adaptability

The missing existence of an overall standard is caused by the broad range of wanted standardised areas within the domain of e-Learning. Nevertheless certain approaches exist and the main ones are sketched below. Other more exhaustive analysises and descriptions can be found e.g. in [CEN Workshop Agreement CWA 14040, 2000] or [e-Learning Centre, 2007]. In e-Learning the main categories of standards are:

- **Metadata:** as the provision of additional data labeling existing data like learning content and catalogues for indexing, storage, search and retrieval of learning objects.
- **Content packaging:** as the basis of interoperability, the possible usage of e-Learning courses in different systems. That includes learning objects, information about their assembly and sometimes rules for delivery.
- **Learner profiles:** are essential for adaptability to put the user into the focus. Corresponding data need to be exchanged across multiple systems especially for lifelong learning (cp. sections 2.4.1.1 and 2.4.1.2).

The actual main organisations for e-Learning standardisation are the Institute of Electrical and Electronics Engineers (IEEE), Advances Distributed Learning (ADL), IMS Global Learning Consortium and the Aviation Industry CBT Committee (AICC). IEEE is an international organisation that develops technical standards for certain domains. The Learning Technology Standards Comittee (LTSC) as a sub-organisation was responsible for the development of the Learning Objects Metadata Standard (LOM). ADL is originated in the U.S. and is mostly government-sponsored. Its most important standard is the Sharable Content Objecct Reference Model (SCORM). IMS is an international consortium mainly focussing on metadata usage for content packaging. AICC as a last international organisation creates guidelines, mainly for the aviation industry. Its most known standard is a guideline for computer managed instruction.

2.6.1 Learning Objects Metadata (LOM)

The Learning Objects Metadata Standard was developed by the IEEE LTSC. Its goal is “to facilitate search, evaluation, acquisition, and use of learning objects, for instance by learners or instructors or automated software processes” [IEEE LTSC, 2003]. LOM defines nine categories of metadata.

- **General:** for the definition of common information like title, used languages, keywords, descriptions, level of aggregation.
- **LifeCycle:** for the description of the history, state, version and list of contributors for the LO.
- **Meta-Metadata:** contains metadata about the metadata, because changes can be made not only by the LO author.
- **Technical:** describes technical aspects like format, size or installation requirements of the LO.
- **Educational:** for information about the recommended age of the learner, semantical density, degree of interactivity, etc.
- **Rights:** includes information about licences, costs, copyright, terms of use, etc.
- **Relation:** to defines relations between LOs.
- **Annotation:** for special remarks about the LO.
- **Classification:** for the classification of the LO with a taxonomic path or keywords.

2.6.2 Sharable Content Object Reference Model (SCORM)

The Sharable Content Object Reference Model (SCORM) is a development of the Advanced Distributed Learning Initiative (ADL). This reference model is the basis to achieve following requirements for all SCORM-based learning environments [Advanced Distributed Learning (ADL), 2006b].

- **Accessibility:** is to locate and access learning objects and to distribute them among certain locations.
- **Adaptability:** is to make changes in instruction in order to meet individual or organisational requirements.
- **Affordability:** is about time and cost effectiveness.
- **Durability:** is about independence from technology evolution.
- **Interoperability:** needs to be achieved for using content in different systems on different locations.
- **Reusability:** is about the usage of content in different applications and contexts.

SCORM is developed to create resuable learning content within given technical regulation guidelines for computer-based and Web-based learning. Therefore the initiative cooperates with the Alliance of Remote Instructional Authoring & Distribution Networks for Europe (ARIADNE), AICC, IEEE LTSC and IMS. The reference model is separated into three parts, each describing another aspect: the Content Aggregation Model (CAM), the Run-Time Environment (RTE) as well as Sequencing and Navigation (SN). The actual version is the third edition.

The CAM book describes the consistent labeling, packaging, stroing, exchange and discovery of learning objects. Therefore it focuses on SCORM Content Model components (Assets, Sharable Content Objects (SCOs), activities, content organisations and content aggregations), SCORM Content Packages (with and without sequencing information) and metadata. SCORM Content Packages are bundled learning content and needed metadata. That can be an entire course, a module or a collection of related

LOs. It can also include information for the LMS about how to process content and metadata. Those metadate are derived from IEEE LOM 1484.12, the content structure is derived from AICC, the content packaging and sequencing information from IMS [Advanced Distributed Learning (ADL), 2006a]. Figure 2.14 shows the conceptual content package.

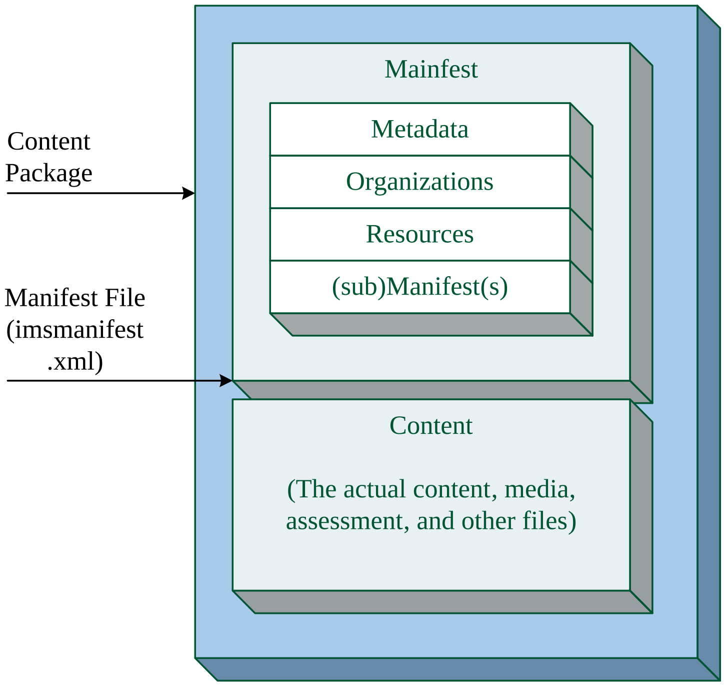

Figure 2.14: SCORM conceptual concept package (cp. [Advanced Distributed Learning (ADL), 2006b])

The RTE book is developed to ensure interoperability of content across different LMS [Advanced Distributed Learning (ADL), 2006c]. Therefore it describes common ways to lauch content, to make content communicate with a LMS and to exchange predefined data elements between content and LMS during content execution. SCORM RTE bases on the IEEE Data Model 1484.11.2 and IEEE API 1484.11.1, SCORM RTE specific technologies include the Data Model, the SCORM API, API Instance, Launch, Session Methods, Data Transfer Methods, Support Methods and Temporal Methods.

The SN book defines how learning activities can be consistently sequenced for the representation of the intended behaviour of a learning experience [Advanced Distributed Learning (ADL), 2006d]. Based on an Activity Tree and the learner's actions the branching and flow of learning activities is described (cp. figure 2.15). The learning activities itself can be identified by the triggering and processing of learner-initiated and system-initiated events. The SN book is about the binding of the sequencing rules of the CAM book and the processes and behaviours of those rules. Basic techniques are adopted from IMS.

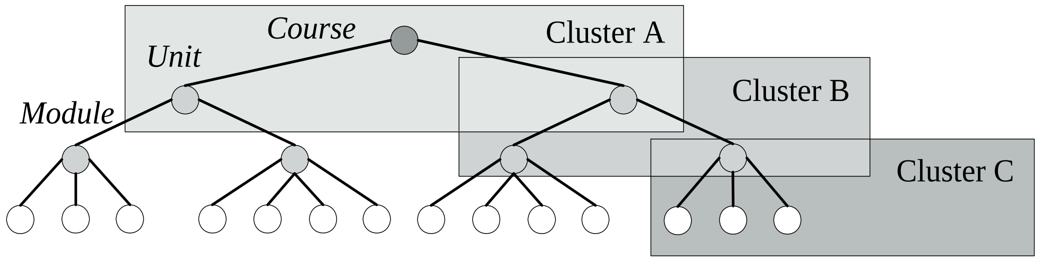

Figure 2.15: Conceptual activity tree and clusters (cp. [Advanced Distributed Learning (ADL), 2006b])

2.6.3 IMS

The IMS Global Learning Consortium, Inc. develops a number of specifications for distributed learning. That targets synchronous and asynchronous online as well as offline settings. Numerous draft or final specifications were released, most of them are public accessible. Some of them are major parts of SCORM.

The most common and important ones are:

- **IMS Learning Design:** "The IMS Learning Design specification supports the use of a wide range of pedagogies in online learning. Rather than attempting to capture the specifics of many pedagogies, it does this by providing a generic and flexible language. This language is designed to enable many different pedagogies to be expressed. The approach has the advantage over alternatives in that only one set of learning design and runtime tools then need to be implemented in order to support the desired wide range of pedagogies. The language was originally developed at the Open University of the Netherlands (OUNL), after extensive examination and comparison of a wide range of pedagogical approaches and their associated learning activities, and several iterations of the developing language to obtain a good balance between generality and pedagogic expressiveness" [IMS Global Learning Consortium, Inc., 2003d].
- **IMS QTI:** "The IMS Question & Test Interoperability (QTI) specification describes a data model for the representation of question (assessmentItem) and test (assessmentTest) data and their corresponding results reports. Therefore, the specification enables the exchange of this item, test and results data between authoring tools, item banks, test constructional tools, learning systems and assessment delivery systems. The data model is described abstractly, using [UML] to facilitate binding to a wide range of data-modelling tools and programming languages, however, for interchange between systems a binding is provided to the industry standard eXtensible Markup Language [XML] and use of this binding is strongly recommended. The IMS QTI specification has been designed to support both interoperability and innovation through the provision of well-defined extension points. These extension points can be used to wrap specialized or proprietary data in ways that allows it to be used alongside items that can be represented directly. " [IMS Global Learning Consortium, Inc., 2006].

- **IMS Content Packaging:** "The IMS Content Packaging Specification provides the functionality to describe and package learning materials, such as an individual course or a collection of courses, into interoperable, distributable packages. Content Packaging addresses the description, structure, and location of online learning materials and the definition of some particular content types" [IMS Global Learning Consortium, Inc., 2007].
- **IMS LIP:** "Learner Information is a collection of information about a Learner (individual or group learners) or a Producer of learning content (creators, providers or vendors). The IMS Learner Information Package (IMS LIP) specification addresses the interoperability of internet-based Learner Information systems with other systems that support the Internet learning environment. The intent of the specification is to define a set of packages that can be used to import data into and extract data from an IMS compliant Learner Information server. A Learner Information server may exchange data with Learner Delivery systems or with other Learner Information servers. It is the responsibility of the Learner Information server to allow the owner of the learner information to define what part of the learner information can be shared with other systems. The core structures of the IMS LIP are based upon: accessibilities; activities; affiliations; competencies; goals; identifications; interests; qualifications, certifications and licences; relationship; security keys; and transcripts" [IMS Global Learning Consortium, Inc., 2001].
- **IMS Simple Sequencing:** "The IMS Simple Sequencing Specification defines a method for representing the intended behavior of an authored learning experience such that any learning technology system (LTS) can sequence discrete learning activities in a consistent way. The specification defines the required behaviors and functionality that conforming systems must implement. It incorporates rules that describe the branching or flow of instruction through content according to the outcomes of a learner's interactions with content" [IMS Global Learning Consortium, Inc., 2003c].

2.7 E-Learning Frameworks and Architectures

The already introduced basic architecture for e-Learning (cp. page 2) may result in certain peculiarities, based on the different requirements and technical possibilities. This section aims to provide an overview about architectural aspects of the most important approaches. Other approaches can be found in [Open Knowledge Initiative, 2003], [Schools Interoperability Framework (SIF) Association, 2007], [IMS Global Learning Consortium, Inc., 2003a], [Wilson et al., 2004a] and [MOBIlearn Project Consortium, 2005].

2.7.1 IEEE Learning Technology Systems Architecture (LTSA)

IEEE LTSA is an architecture with abstract components [IEEE LTSC, 2002a]. Concrete e-Learning system implementations can be mapped to it. It is intended to be pedagogically neutral, content-neutral, culturally neutral and platform/technology-neutral [IMS Global Learning Consortium, Inc., 2003a]. The architecture is shown in figure 2.16.

Many extensions are proposed in literature, e.g. by the addition of a knowledge transfer process [Voskamp and Hambach, 2001], the extended integration of a course designer [Corbière and Choquet, 2004], the addition of an ontology [Choe and Kim, 2005] or a service-based extension [Canales et al., 2007]. Other resources are e.g. [Phorncharoen and Chittayasothorn, 2005].

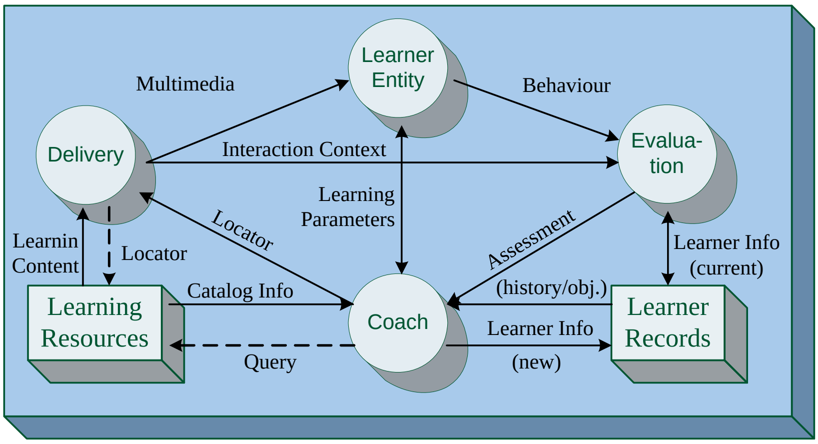

Figure 2.16: IEEE Learning Technology Systems Architecture (cp. [IMS Global Learning Consortium, Inc., 2003a])

- The main processes are:
  - **Learner entity:** is a learner or group of learners.
  - **Evaluation:** produces new learner information and assessment.
  - **Coach:** produces locators that describe delivery instructions to support learning experiences.
  - **Delivery:** produces multimedia and interaction context with delivery instructions and learning content.
- The main stores are:
  - **Learner records:** is a storage for learner-related information.
  - **Learning resources:** is a storage for learning content.
- The main flows are:
  - **Behaviour:** is the learner's behaviour observed by the system.
  - **Assessment:** is the actual learner's learning performance.
  - **Learner info:** are information about the learner.
  - **Query:** is a seek for available learning resources.
  - **Catalog info:** is an answer to a query.
  - **Locator:** is an identifier for delivery instructions and learning content, respectively.
  - **Learning content:** is this what the learner is intended to learn.
  - **Multimedia:** is the delivered media containing the learning content.

- **Interaction context:** is the contextual information associated with the delivery and the multimedia.
- **Learning parameters:** are reasons for the adoption of the learning process.

2.7.2 ADL Sharable Content Object Reference Model

ADL's objective with SCORM is twofold. They develop a model that references a set of interrelated technical specifications and guidelines and they try to knit together several different groups and thereby opinions [IMS Global Learning Consortium, Inc., 2003a]. The model bases on the work of IMS, the AICC, ARIADNE and the IEEEE LTSC. Following specifications are integrated: IEEE LOM, IEEE Data Model for Content Object Communication, IEEE ECMEScript Application Programming Interface for Content to Runtime Service Communication, IEEE Extensible Markup Language Schema Binding for Learning Object Metadata Data Model, IMS Content Packaging and IMS Simple Sequencing.

The basic structure of the model is shown in figure 2.17.

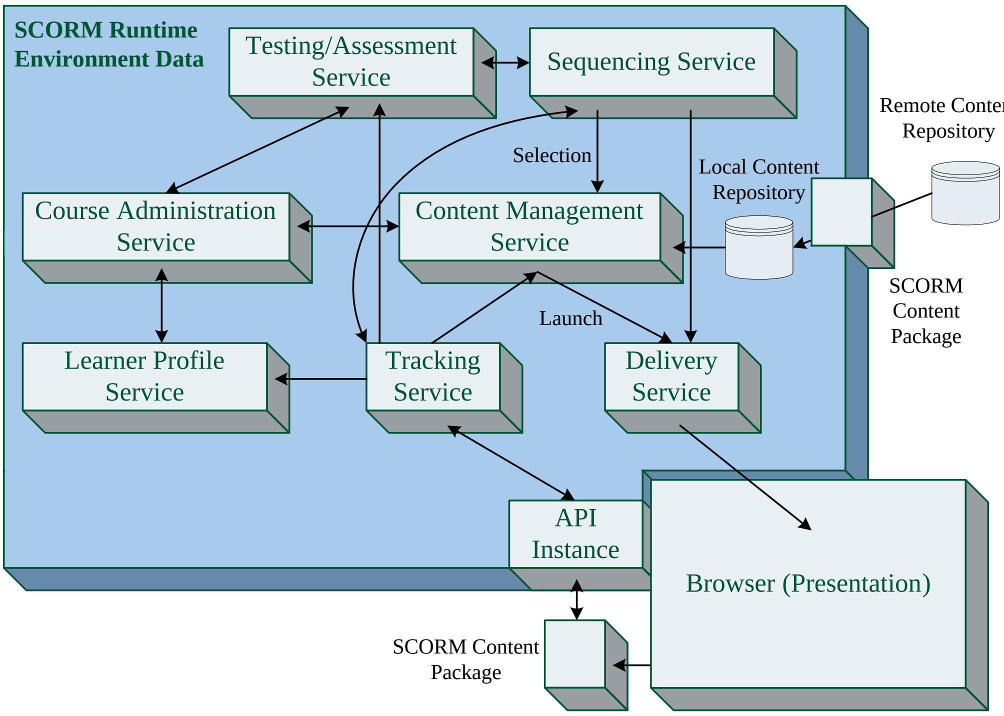

Figure 2.17: SCORM for LMS functionality (cp. [Advanced Distributed Learning (ADL), 2006b])

2.7.3 IMS Abstract Framework

The IMS Abstract Framework was developed by the IMS Global Learning Consortium, Inc. to define the context of their specifications. The other goals have been to support the migration from old to new specifications and to demonstrate the relationship between IMS and non-IMS specifications [IMS Global Learning Consortium, Inc., 2003a].

It bases on the analysis of several other approaches and summarises their basic principles. Within the framework several interfaces are identified, that are or may be specified by the IMS with appropriate specifications. IMS sees its Abstract Framework as a starting point for the definition of concrete e-Learning systems' architectures. The targeted range of applicants of e-Learning systems includes amongst others: higher education, community colleges, further education, schools and corporate training.

The underlying principles are:

- **Interoperability:** is for the exchange of information between systems.
- **Service-oriented:** means information exchange in terms of services supplied by the systems' collaboration.
- **Component-based:** realisations result in a set of services can be recombined to form particular services.
- **Layering:** is achieved by the definition of a set of services. They use services of lower layers and provide services for higher layers.
- **Behaviours and data models:** define a service. Only behaviours change data.
- **Multiple bindings:** means that the information model is defined using established syntax and semantics to allow automatic data model mapping to certain bindings.
- **Adoption:** is preferred. New requirements will only result in new specifications, if needed. Otherwise existing ones will be altered.

The Abstract Framework was developed as a layered model (figure 2.18). The Application Layer consists of tools, agents, system that present application services through a user interface to the user. The Application Services Layer is a set of services providing necessary functionality for learning. Other available services are part of the Common Services Layer. They can be used by application services as well as other common services. Transaction and communication between them is provided by services of the Infrastructure Layer. All services can be accessed by their Service Access Point (SAP).

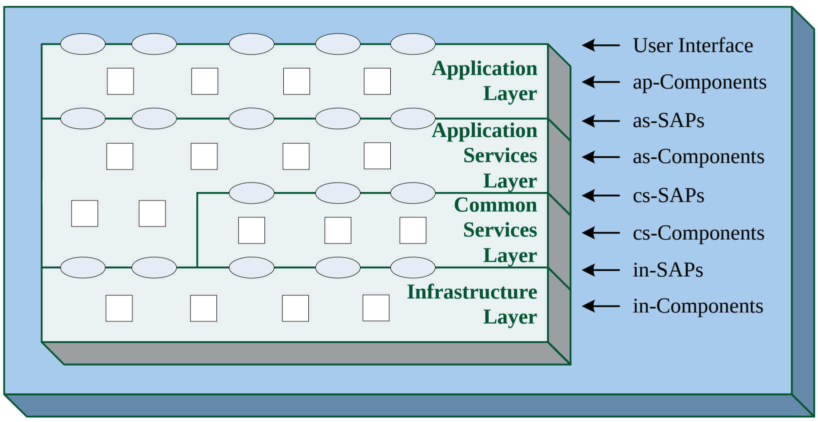

Figure 2.18: Layered model of the IMS Abstract Framework (cp. [IMS Global Learning Consortium, Inc., 2003a])

2.7.4 SUN Microsystems e-Learning Framework

The e-Learning Framework of SUN Microsystems has a four tier architecture [SUN Microsystems, Inc., 2003]. From top there are the presentation tier, the common services tier, the e-Learning services tier and the resource tier.

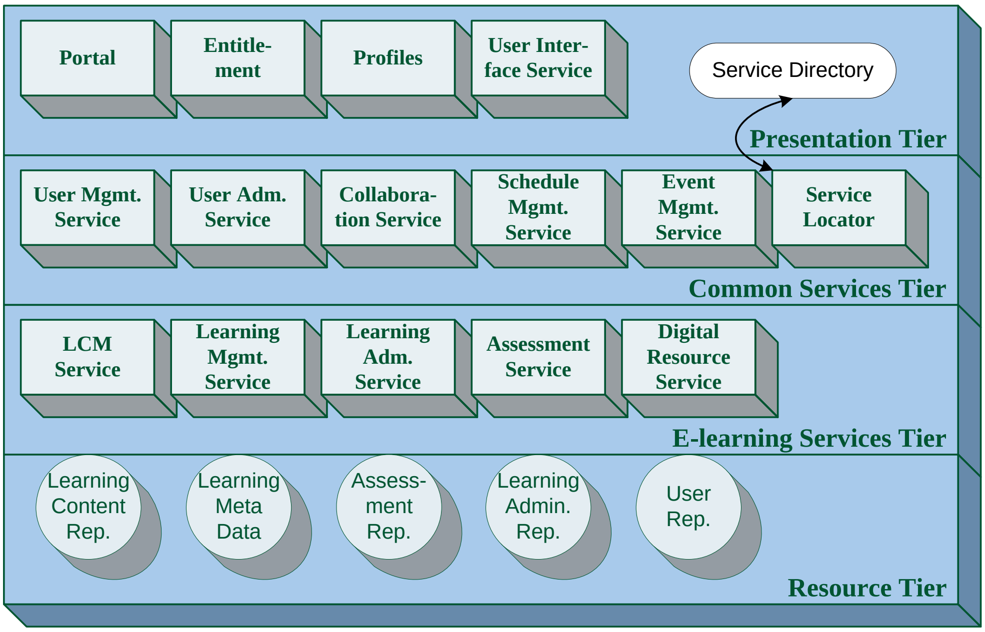

Figure 2.19: Distributed services-based e-Learning architecture (cp. [SUN Microsystems, Inc., 2003])

The presentation tier allows the interaction of the user with the application logic. Its suggested parts are the portal as an entry point for the user and an aggregation for the provided services as well as the entitlement for authentication and authorisation. The other parts are the user profile and the user interface aggregating graphical frontend of services.

The common services tier comprises all services that do not have a direct pedagogic functionality. That refers to user management and administration services, collaboration services, an event management as well as a schedule management.

E-Learning services are e.g. learning content management services, learning management services (including learnable library, learnable delivery, offering management, cohort management), learning administration services (including student record management, data exchange, enrollment, provider management, tutor record management), a digital resource service and assessment services (including assignment management, assessment submission handling, and the assessment types: collaboration, complex and automated assessment).

The resource tier provides services like a learning content repository, learning metadata, learning assessment repository, learning administration repository and a user repository.

2.7.5 Technical Classification

Classic approaches for e-Learning architectures are mainly based on client-server respectively peer-to-peer technology. The main problems are low scalability, availability and content exchange [Pankratius et al., 2004]. In the following sections architectures from a different perspective are described. Chapter 3 detailly describes another advanced approach.

2.7.5.1 Web Service-Oriented Approach

A service-oriented approach for e-Learning provides different components via implemented Web services [Pankratius et al., 2004]. The main arguments for such a realisation are the possibilities to distribute components and contents all over the web and the abstraction of the content's storage format. In contrast to monolithic approaches different vendors can be used to compose a more complex application. Thereby an individual adaptability can be achieved. The indended client to interact with the LMS is the web browser. Figure 2.20 visualises a possible Web-Service-based architecture and in figure 2.21 certain components of a Web-Service-based LMS are depicted.

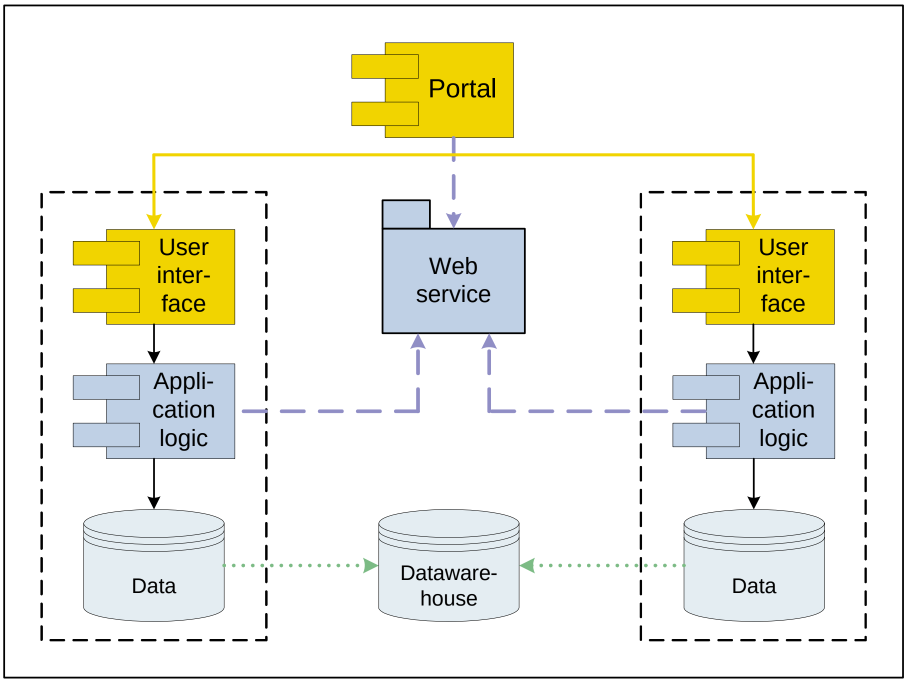

Figure 2.20: Web-service-based e-Learning (cp. [Wilson et al., 2004b])

Following [Wilson et al., 2004b] the most important expected advantages of such an approach are the reduction of the risk of investment and the possibility to define an LMS in terms of function providing services instead of static components. By the later aspect size and aggregation scalability can be achieved without the loss of standardisation efforts. Cost can be reduced due to small specialised shared services with less code size, easy development, easy maintainance, and easy porting. This advantage leads to

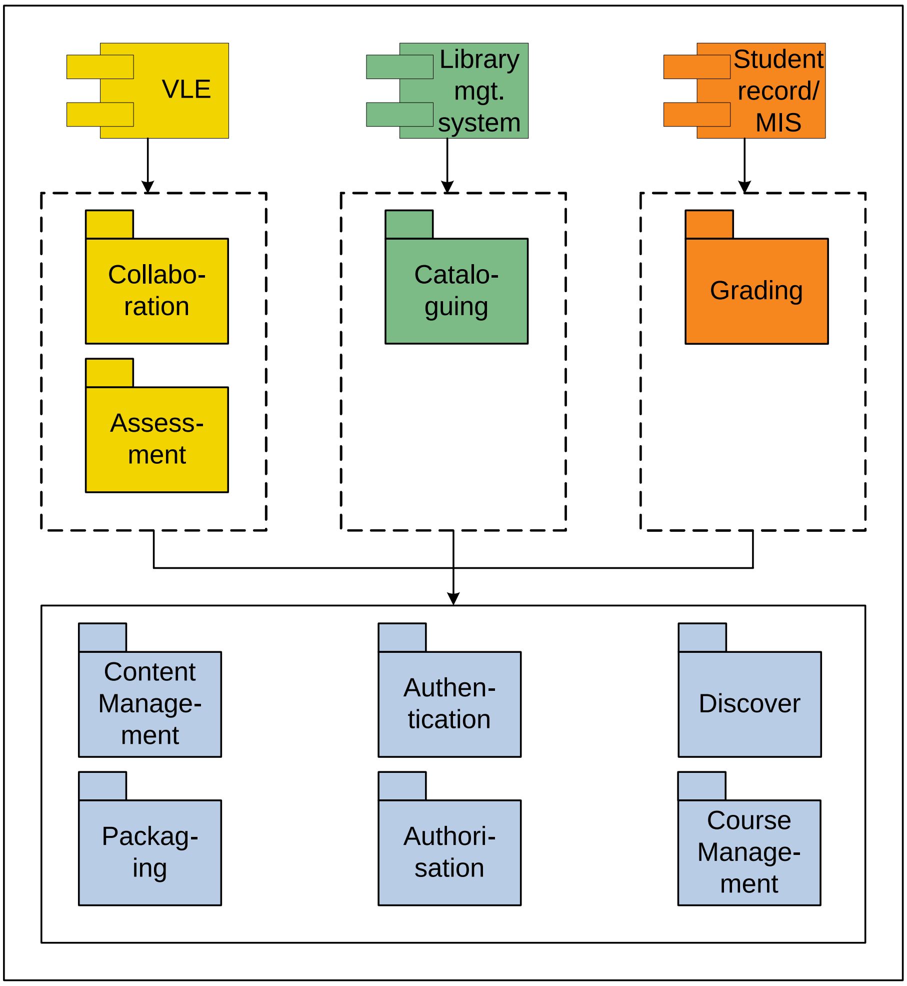

Figure 2.21: Chosen Web-service-based distributed LMS components (cp. [Wilson et al., 2004b])

an increasing specialisation and diversification of the e-Learning market; it is no longer necessary to provide complete solutions but specialised services. The last mentioned advantages are collaborative development among certain institutions and the possibility for more diverse approaches for e-Learning.

The most needed services are [Wilson et al., 2004b]:

- **Sequencing:** providing a sequence of learning objects
- **Learning flow:** management and use con learning scenarios
- **Collaboration:** support of communication and interaction
- **Activity management:** support of interaction between learning units
- **Corse/group management:** access and management of courses/groups (incl. membership management and member management)
- **Scheduling:** allocation of ressources
- **Resource management:** management of physical resources
- **Resource discovery:** finding resources
- **Content management:** publishing, retrieval, description, and organisation of information resources
- **Cataloguing:** management of descriptions for information resources
- **Packaging:** assembly of packages of information resources
- **Activity authoring:** management of learning activities
- **Resource list:** management of lists of resources
- **Archiving:** long-term preservation of documents
- **Rating/annotation:** use of secondary metadata of resources
- **Terminology:** provision of machine-readable declarations of vocabulary terms; automated mapping and classification
- **Assessment:** automated assessments
- **Grading:** support of grades against units of learning
- **Competency:** management of competency frameworks
- **Learner profile management:** management of user-related metadata
- **EPortfolio:** management and assessment of user-created artefacts
- **User preferences:** management of user-related metadata for adaptation

Needed common services are service registry, user messaging, authentication, digital rights management, logging, identifier, resolver, filing, authorization, workflow, search, harvest, alert, and metadata registry.

2.7.5.2 Peer-to-Peer Approach

Peer-to-Peer (P2P) is a networking technology to enable resource sharing. That can be data in various media types, computer resources like processing time and storage as well as shared spaces for collaboration. This networking is independent from a central server and it is not important where the resource is stored. All resources are distributed across the network of connected nodes (PCs) and thereby made available.

E-Learning independently emerges, when the intrinsic low level of collaboration turns into communities of practice and related resources are shared between the community members. The most important requirement is the learner's motivation to keep the community and thereby the learning process alive. Content must be searched, made available and rated. Potential problems are:

- Correctness of resources
- Completeness of resources
- Up-to-dateness of resources
- Security of network nodes
- Open question: actual hype or killer application

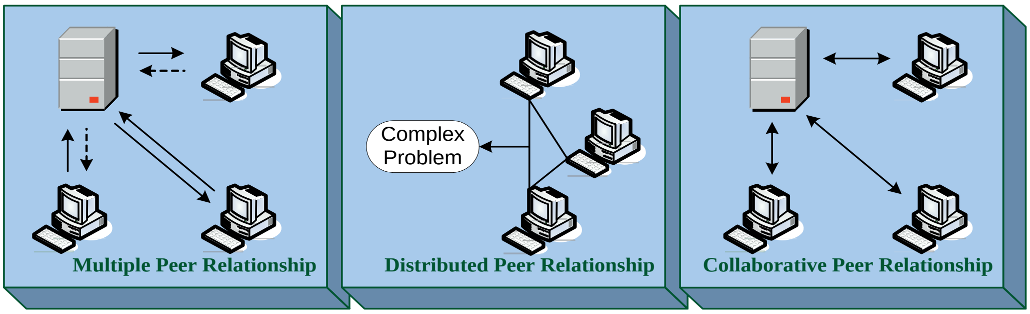

Figure 2.22: Peer-to-peer relationships

There exist three distinct computing models (cp. figure 2.22). The multiple peer relationship connects the network nodes through a central server. The distributed peer relationship directly couples network nodes to solve problems requiring massive processing capacities. The collaborative peer relationship allows the interation of distributed users through a common interface. Examples are online gaming or chats.

2.7.5.3 Grid-Based Approach

Grid-based e-Learning is proposed to be a solution for limitations of Web service, client-server or peer-to-peer e-Learning architectures in terms of scalability availability, distribution of processing power and distribution of storage [Pankratius and Vossen, 2003]. In figure 2.23 the main components for Web service-based e-Learning grid are shown.

Grid computing paradigm unifies hardware and software resources by using uniform interfaces. That does not only refer to computers and their storage and processing capabilities but to ohther remotely controllable resources (visualisation environments, electron microscopes, radio telescopes, . . .), too.

The basic types of grids are data grids, being tailored to handle huge amounts of data as well as computational grids focussing on the distribution of computation. With this technology photo-realistic visualisations or complex simulations can be part of e-Learning systems.

Grids are implemented with a middleware for the provision of the grid-related services and a certain communication infrastructure like the internet. This middleware consists of services like grid-login (user information and access rights), information services (status and type of resources), replica management, replica selection and a broker (distribution of computation and data).

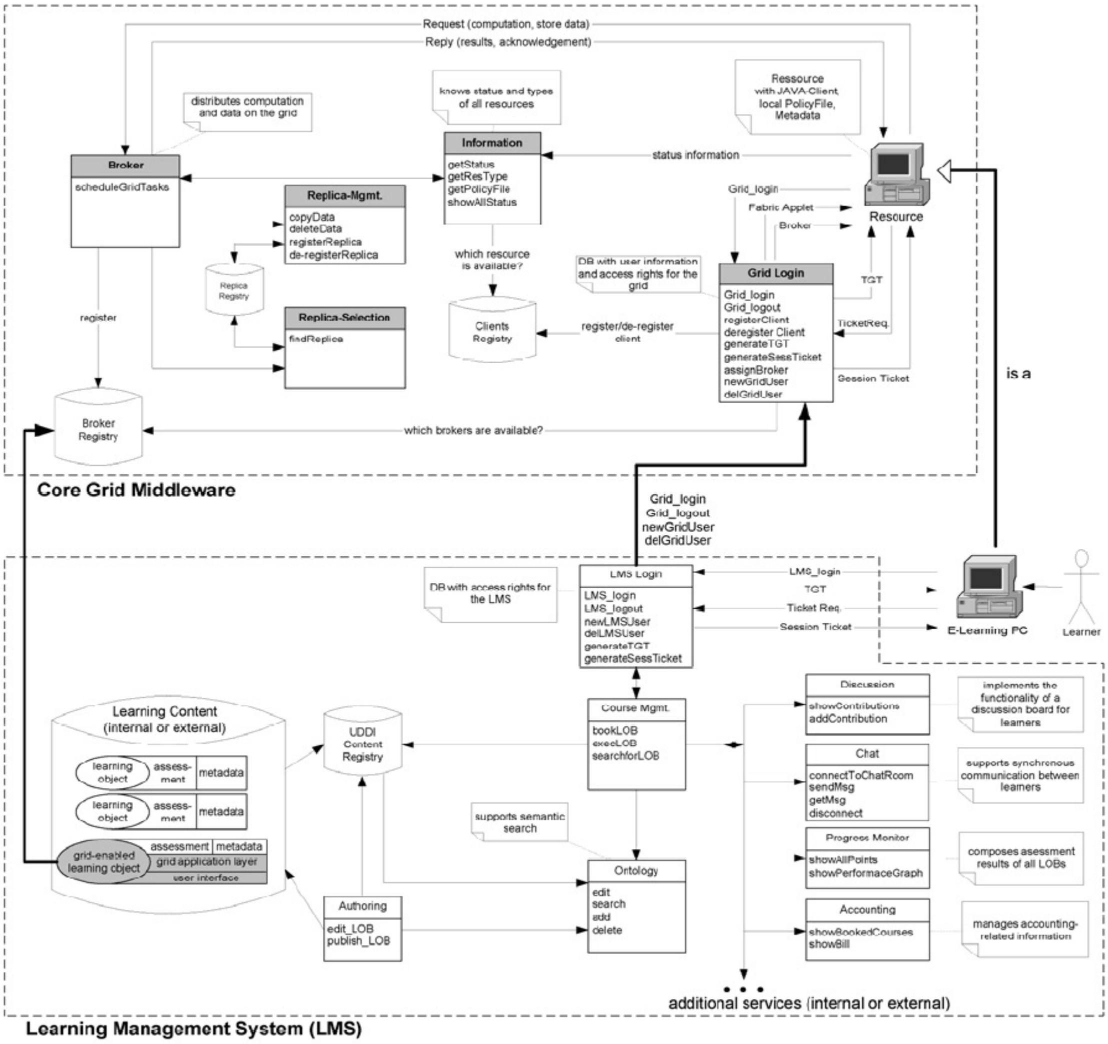

Figure 2.23: E-Learning grid architecture [Pankratius and Vossen, 2003]

2.8 E-Learning Systems

The technical and technological progress and development over the last years lead to an increased usage of collaborative environments and distributed learning technologies. Many new categories of products were developed with new capabilities or new combinations of existing technologies [Giotopoulos et al., 2005].

E-Learning systems can be studied from three possible perspectives: micro, meso and macro [Koper and Sloep, 2003].

Micro perspective: Here the functionality of the small system parts is under survey. That refers e.g. to the relationship between instructional measures or the learning processes within individuals.

Macro perspective: A macroscopic view to the e-Learning system analyses the overall functionality of the systems in relationship with the environment in which it is situated. Possible aspects are the effectiveness, the efficiency, the attractiveness, accessability and adaptability of the e-Learning system.

Meso perspective: This approach focusses on the learning of individuals in relation to the organisation of the environment in which they interact. It is the classic question of scientists and philosophers how micro activities of actors within a system relate to the behaviours of the system itself.

According to the various types and properties of e-Learning several facets of requirements of e-Learning systems can be identified in literature. Chosen important requirements are listed below arranged by their type: functional, quality, process or system-oriented. Their applicability varies as their type, intended application area and the targeted user group.

Functional requirements:

- Provide individual content[Garro and Palopoli, 2002]
- Meta-knowledge about learning objects (documents, slides, simulations, role-plays, questionaires, pre-recorded lessons, classroom lessions, ...) for their classification and use in relationships with respect to their objective, topic, used media, ... [Garro and Palopoli, 2002]
- Possibility to integrate pedagogic and content-based knowledge acquired from the classic approach of learning [Maurer and Dietinger, 1997]
- Authoring, easy creation of course content ([Maurer and Dietinger, 1997], [Claußen, 1999])
- Support of individual, but guided learning [Maurer and Dietinger, 1997]
- Possibilities to make annotations [Maurer and Dietinger, 1997]
- Synchronous and asynchronous communication tools ([Garrison, 1990], [Maurer and Dietinger, 1997])
- Integration of FAQs [Maurer and Dietinger, 1997]
- Several types of tests and exams [Maurer and Dietinger, 1997]
- System adaptability [Maurer and Dietinger, 1997]
- Adaptive presentation [Lin and Yang, 2004]
- Session control [Rahkila, 2001]
- Control of interactivity [Rahkila, 2001]
- Support for multiple simultaneous users [Rahkila, 2001]
- Handle immense set of data [Markham et al., 2003]
- Different people perceive information in a different way, advanced media is necessary [Shneiderman, 1998]
- Support of exploring the content [Markham et al., 2003]
- Interactivity and intelligent tutoring capabilities [Buraga, 2003]
- Adaptive curriculum sequencing [Lin and Yang, 2004]
- Problem solving support [Lin and Yang, 2004]

Quality requirements:

- For dynamic diversification of learning paths: small independent units of educational content (learning objects) [Garro and Palopoli, 2003]
- Use of established standards for exchange, reuse and sharing [Garro and Palopoli, 2003]
- Compliance with existing technologies [Rahkila, 2001]
- Extendability to future technologies [Rahkila, 2001]
- Maximal availability [Claußen, 1999]
- Usability criteria like fast connection and low effort to learn to work with the system [Claußen, 1999]
- Comfortable and easy to use graphical user interface ([Tetiwat and Igbaria, 2000], [Claußen, 1999])
- More carefully and more frequent update of resources and relevant subjects [Porter, 1994]

Process requirements:

- Strategic and organisational embedding in existing educational processes
- Ensured funding [Tetiwat and Igbaria, 2000]

System requirements:

- Independence from platforms and applications, e.g. WWW-based ([Claußen, 1999], [Rahkila, 2001])
- Compatibility [Claußen, 1999]
- Minimal set of assumptions about hardware and software requirements ([Buraga, 2003], [Tetiwat and Igbaria, 2000])

E-Learning systems can be classified in course-based and organisation-based [van Rosmalen et al., 2005]. The first type is course-centric in terms of specific technical support. Those systems mostly do not distinguish between tutor and author. They provide high flexibility for authors, the trade-off is the increased needed effort. The second type provide additional management components. An external content development is possible; therefore a clear role definition needs to be established.

There is a growing market for e-Learning applications due to the various already introduced advantages. Chosen systems are described below. Others are e.g. Ingenium Docent, TopClass, Lotus Learning Server or Hyperwave eLearning Suite.

WebCT (Web Course Tools) is an online LMS originally developed at the University of British Columbia but now provided by Blackboard Inc., one of the leading companies in this field. One of its key functionalities is the possibility for teachers and learners to centrally provide learning materials and information. Next to course publishing Authoring is another aspect of the platform being supported by a set of tools. Forums and an internal mailing system can be used for asynchronous communication ([Blackboard Inc., 2007b], [Claußen, 1999], [Dimitrova et al., 2003b]).

Blackboard's academic and commerce e-Learning products cover course management, content management as well as community and portal support [Blackboard Inc., 2007a]. The software is not open source, but an open architecture is provided for its extension.

Moodle (Modular Object-Oriented Dynamic Learning Environment) is an LCMS open source product. Basic feature amongst others are forums, chats, blogs, wikis, content managing, peer assessments, surveys, etc. It can be easily extended by plugins, e.g. for resource types, question types, authentification methods, enrollment methods or content filters. The actual version is 1.8 (March 2007) and on November 16th 2007 there were 35,317 registered sites, 1,492,464 courses and 15,008,441 registered users. More than 70 languages are actually supported [Moodle Project, 2007].

EduComponents is an open source development of the Otto-von-Guericke University of Magdeburg [FIN Working Group WDOK, Otto-von-Guericke University of Magdeburg, 2007]. It bases on Plone, an open source content management system. This was extended to provide e-Learning functionality. Certain modules have been developed and implemented, e.g.:

- ECLecture for the management of lecture participants and resources
- ECQuiz for the creation, accomplishment and analysis of multiple-choice-test
- ECAssignmentBox for online submission of exercise assignments
- ECAutoAssessmentBox for the automatic checking of assignment submissions
- ECReviewBox for the creation of peer-review assignments

The Distributed e-Learning Center (DeLC) aims to provide service-oriented distance e-Learning and e-Teaching [Stojanov et al., 2005]. It is part of an universitary project (University of Plovdiv, Bulgaria) which aims to develop a theoretical and conceptual base for an appropriate infrastructure for the integration of electronic services. A major focus is laid on the intended technological and architectural independence from those services.

The current version is being re-engineered to provide an agent-based application. Following advantages are expected [Stojanov et al., 2005].

- enhanced flexibility
- open environment
- intelligent interaction and interpretation of the data and contents exchanged between the different parties
- supporting context-based discovery and access to user's personal information

Agents are mainly used for the communication with the functional modules, that are implemented as Web services. On the client side they will serve as personal assistants for the learner to provide mobile services. Agents located at the server represent the services functionality and interact with the user agent (thin approach). Based on user and service profiles appropriate adaptations and arrangements are negotiated and chosen by these agents. Another approach directly connects user agents with the activation of the execution of appropriate services (thick approach).

2.9 Research Directions

Next to the already introduced and described slogans of “lifelong learning”, “ubiquitious learning”, “mobile learning” more aspects will be taken into consideration within the next years and decades. Following [Cerri, 2002] it is less a technical-driven process by providing and advertising performant solutions than a social-based recommendation process, intitiated by communities of users.

[Angehrn et al., 2001] listed three dimensions of key factors for the future success of e-Learning: the individual, organisational and process dimension. Based on their analysis the following aspects still need to be improved.

Individual dimension:

- Increased user centeredness
- Managing of user knowledge capital and competency
- Continuous assessments of knowledge states, identification of the missing gaps and weaknesses
- Evaluation of the effectiveness of the learning process
- Increased personalisation, more complete user models are needed
- Selection and adaptation of the most appropriate learning strategies

Organisational dimension:

- Learner control about their individual organisational learning
- Comparison with the learning of other members of the organisation and with the organisation’s learning objectives to define future personal learning objectives
- Socially situated e-Learning: recognition and exploitation the learners’ social networks, role models, levels of trust and influence, etc.
- Help the learner to socially situate their learning process: individual knowledge acquisition in the context of the group
- Organisational dissimination of knowledge
- Support of e-Learning communities

Process dimension:

- Monitoring, understanding and modelling (to a certain extent) of different phases of knowledge adoption
- Integrate phases of e.g. experimentation, evaluation, internalisation and application
- Support of continuous learning process: just-in-time learning, stimulation of the learner, continuous assessment, etc.
- Analysation of current and future activities to integrate learning as part of the life
- Provision of motivational support and stimulation
- Many high quality interaction strategies like story telling, stimulation, simulations, information structured in a different ways, etc.

3 Agent-Supported e-Learning

> “*Net generation* (those who learned to read after the Web) is qualitatively different in their informational behaviours and expectations; they are multi-task and expect their informational resources to be electronic and dynamic” [Marchionini, 2006].

Following the guidelines presented in the introduction, agent technology can be applicable in the domain of e-Learning. This chapter describes several existing approaches.

In the beginning we want to define agent-supported e-Learning as follows:

Definition 49 ***Agent-supported e-Learning*** *is the application of agent techniques and technologies in order to enhance the performance and the effectiveness of several aspects of e-Learning systems.*

3.1 Fields of Application for Agents in the e-Learning Domain

Literature provides several approaches for the application of agent technology for the domain of e-Learning. A “pedagogically neutral, content neutral, culturally neutral, platform neutral” [IEEE LTSC, 2002a] framework for the integration of possible architectural components is described below. It is intended to be used as an abstract representation of the functionality of certain e-Learning artefacts that is provided or supported by a set of agents [Mencke and Dumke, 2007a]. Some of the main proposed key features are e.g.:

- Adaptable architectural components with extensive (additional) agent support.
- Identification of approaches for agent-based support for e-Learning systems.
- Separation and provision of basic and specialised services for reuse and optimised system development. Implementation aspects of basic aspects are hided from the user.
- Improved focussing on key elements as e.g. pedagogical issues becomes possible.
- Exchange of application functionality between organisations and interoperability are eased.
- Extensive evaluation capabilities of users and system artefacts.

The developed framework is based on the abstract framework [IMS Global Learning Consortium, Inc., 2003a] of the IMS Global Learning Consortium, Inc. and the SUN Microsystems e-Learning Framework

[SUN Microsystems, Inc., 2003]. It is further refined by several aspects of related architectures and models as for example the Open Knowledge Initiative [Open Knowledge Initiative, 2003], the ADL Sharable Content Object Reference Model (SCORM) [Advanced Distributed Learning (ADL), 2006b], the IEEE Learning Technology Systems Architecture (LTSA) [IEEE LTSC, 2002a] and the Learning Technology System Architecture of the Carnegie Mellon University [IMS Global Learning Consortium, Inc., 2003a]. Special requirements and advantages evolve from the intended application and integration of agent-based technology. Thereby it is especially focused on adaptation, autonomy, support and flexibility.

The novel framework, visualised in figure 3.1, takes into account the diversity of users involved in learning processes in contrast to the functional models of the abstract IMS framework [IMS Global Learning Consortium, Inc., 2003a].

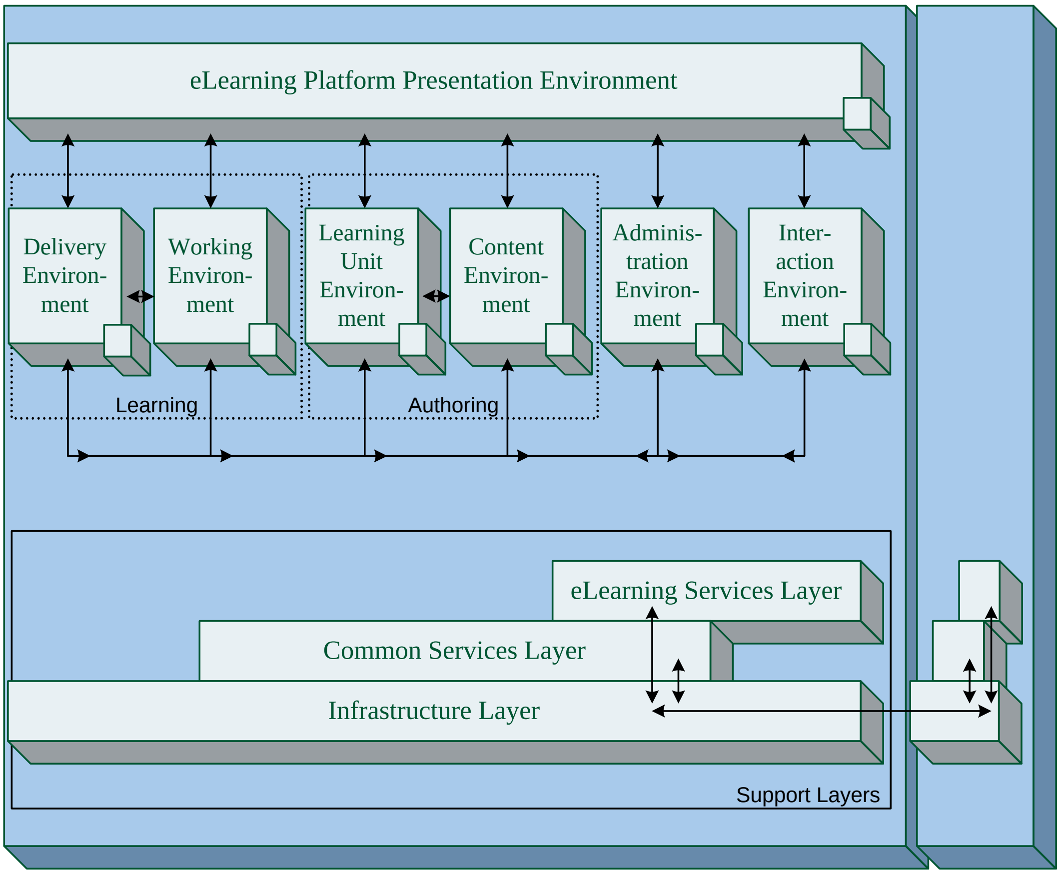

Figure 3.1: A framework for agent-supported e-Learning (cp. [Mencke and Dumke, 2007a])

Next to the main groups of learners, authors, trainers and administrators, support for content experts, instructional designers, graphic artists and project managers is needed [Giotopoulos et al., 2005]. Their requirements for an e-Learning system are grouped and depicted by several functional environments. Thereby the Presentation Environment (PE) is the basic platform for the integration and display of the other environments. It is a basic element connected to all other environments, like the Administration (AE) and

Interaction Environments (IE), too. Appropriate and specialised access to functionalities for the learner is provided by the Delivery (DE) and Working Environments (WE). Authors, trainers, content experts, instructional designers and graphic artists benefit from support of the Learning Unit Environment (LUE) and the Content Environment (CE).

To guarantee flexibility, extension and interoperability the whole framework is based on three support layers. They are differently specialised and are providing infrastructural support, common services and e-Learning services. We hereby define a service as a functionality providing entity, which can be potentially used in different environments. Meanwhile the environments are further hierarchically refined as described in the following subsections, fundamental needed and desirable services are horizontally integrated as provided by the support layers. The specific services can be ordered and used on demand. They also provide the basis for the connection and data exchange between certain implementations of the proposed framework. This abstraction of common facilities from the classic "LMS only" model was already proposed e.g. [IMS Global Learning Consortium, Inc., 2003a] and [SUN Microsystems, Inc., 2003].

In the following sections existing approaches are classified according to the described parts of the framework for agent-supported e-Learning [Mencke and Dumke, 2007a].

3.1.1 Agent Technology for e-Learning Platform Presentation

The e-Learning Platform Presentation Environment (PE) is the core of the graphical user interface (GUI) of every e-Learning system implemented following this framework. It provides personalised access for the different possible user groups. Exemplary use cases are visualised in figure 3.2. It mainly provides access to the learning, authoring and administration environments (as described in [IMS Global Learning Consortium, Inc., 2003a]), as well as to the interaction environment.

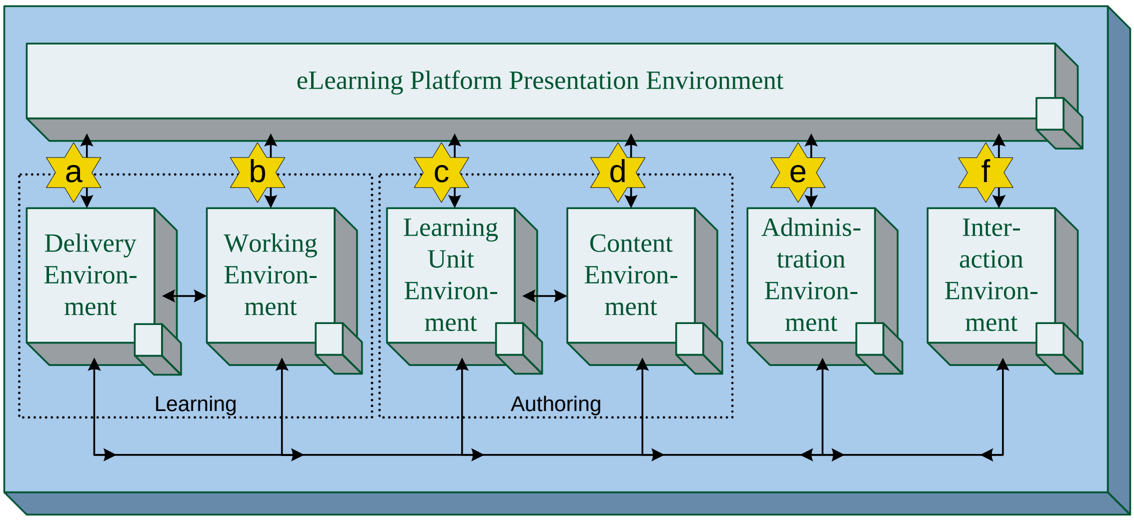

Figure 3.2: E-Learning Platform Presentation Environment (cp. [Mencke and Dumke, 2007a])

Use case a: Request and presentation of the next part of a course
Use case b: Request and presentation of personal annotations to a certain topic
Use case c: Creation and management of courses or certain course substructures
Use case d: Creation and management of learning objects (LO)
Use case e: Update of entries in a user model
Use case f: Interaction with other learners, tutors or experts

An important aspect of GUIs for e-Learning is the adaptability; the personalisation of certain aspects based on collected information or assumptions about the user. That refers to all related environments and may result in adaptive navigation support, adaptive presentation and adaptive content [Kernchen, 2005]. Adaptive navigation support is related to the guidance of users and can be established by global and local support mechanisms, by local orientation, global support for orientation and by the management of individual views. Adaptive presentation can be achieved by the sorting of resource fragments, the adaptive content presentation due to different media formats and the adaptive provision of content because of differing quality, transmission contexts and different languages. Classic approaches like changes in font size, font type and font colour can be used for adaptive presentation, too. Methods for adaptive content are e.g. basic, additional and comparing explanations, explanation variants and the sorting of information fragments [Kernchen, 2005]. Context adaptability is supported by the advantage to integrate different implementations of the proposed environments, extended with capabilities to receive and process context-sensitive information. By this mobile, ubiquitous learning becomes possible.

The different environments themselves may interact with each other. A first primary relation exists between the two learning environments. The DE and WE are closely connected, because of the high possibility of exchanging data. Functionalities provided by the WE, like media processing, can be requirements of certain tasks of the actual course presented in the DE. Similar connections are needed for the LUE and CE. The learning objects are integral part of the courses that are authored within the LUE.

Nevertheless the AE and IE will exchange data with all other environments, because each one needs to be administered and collaboration between different users is always possible, too.

3.1.2 Agent Technology for Knowledge Acquisition

The Delivery and Working Environments are grouping the functionalities of learning systems to enable the learning itself. Therefore they mainly fulfil requirements demanded by learners. The DE presents the course, its structure, course metadata, enables course catalogue browsing, realises the registration and is responsible for other all functionalities that are directly connected with the presentation of and working with learning content during the learning process.

The WE is grouping functionalities for the support of the learning process. That refers to e.g. to classic requirements known from classroom learning. Components for web search as well as for the access to certain repositories are needed to get additional information about the topic of the course. It is important for the personal learning progress to be able to make private annotations to the course content and to manage own additional information, e.g. as a list of links or in a private file system. A scheduler for collaborative work and time management and the access to office tools are needed under certain circumstances. Figure 3.3 visualises these chosen aspects for parts of the learning environments.

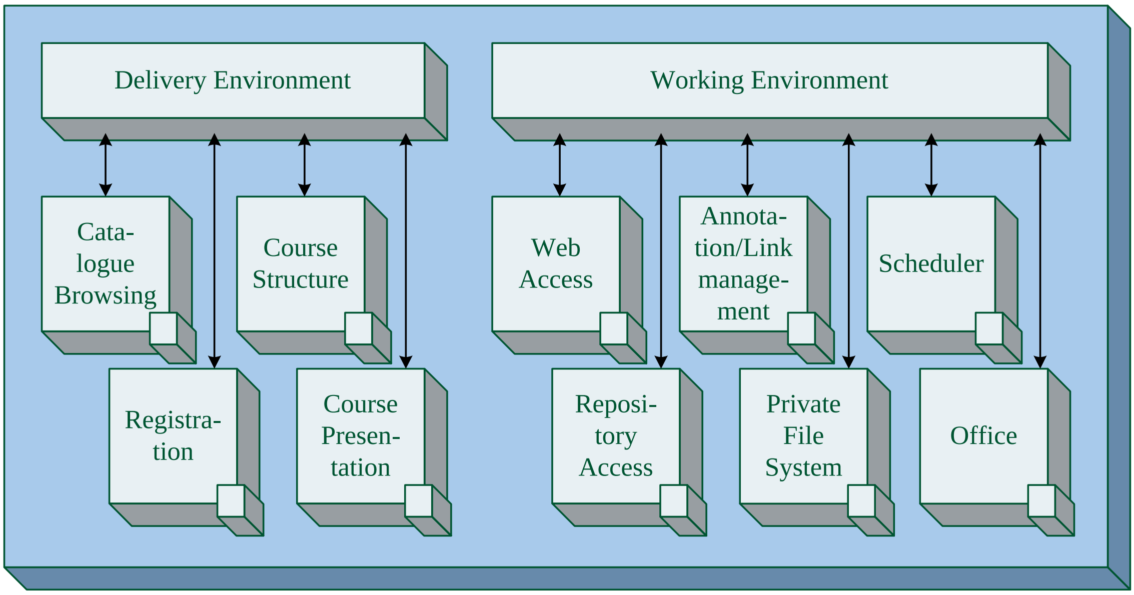

Figure 3.3: The Learning Environments (cp. [Mencke and Dumke, 2007a])

The learning environments need connections to the Administration and Interaction Environments and to the support layers. Administration for example is needed for the management of individual preferences; meanwhile interaction is fundamental for collaborative learning tasks. As for the other environments the support layers are providing access to basic information, repositories and functionalities that are needed for the functionality of the actual environment itself.

In the following, chosen approaches for the usage of agent technology within the domain of knowledge acquisition are sketched.

3.1.2.1 Agent-Mediated Online Learning

The agent-mediated online learning (AMOL) architecture targets the automisation of a online learning process [Yi et al., 2001]. Therefore the authors assumed three parties of participants: the learners, the teachers and mediating education centers (cp. figure 3.4). The difference to classic approaches is the existence of multiple education centers to provide the courses. A prototype was implemented with aglet technology (cp. section 1.2.6.4).

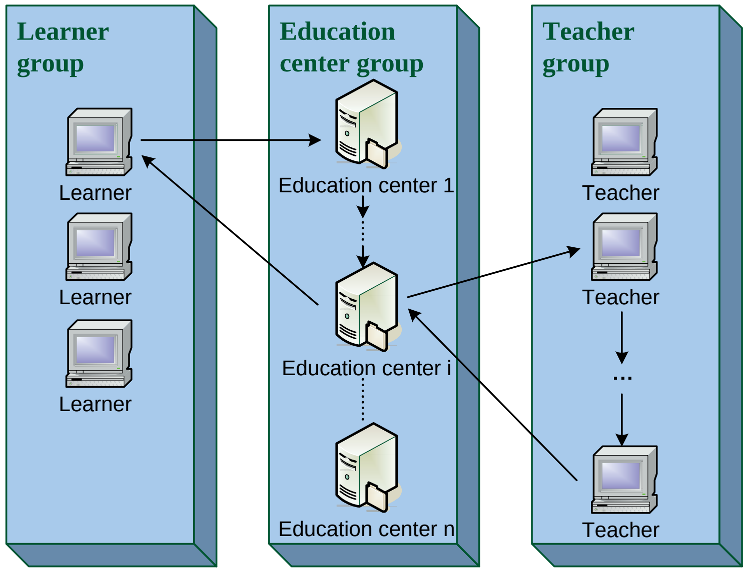

Figure 3.4: AMOL architecture (cp. [Yi et al., 2001])

The implemented agents are mobile and their types are listed below:

- **Pegagocial agent:** tutoring based on task plan and feedback (answering the learner's questions and judging his answers)
- **Searching agent:** searching for appropriate learning content based on learner request
- **Querying agent:** querying the various education centers for answers the pedagogical agent is not able to provide

3.1.2.2 Knowledge Assessment with JADE

A next architecture was described in [Anghel and Salomie, 2003]. It targets a special domain of e-Learning: the student assessment. The representativeness of this architecture is derived from its way of implementation. It is implemented by using JADE agent technology (cp. section 1.2.6.1) in an applet of a Web site. Parts of the architecture are visualised in figure 3.5.

Agent technology was chosen because of scalability issues for many users and bandwidth/latency related problems of the classic client-server model. The authors identified the following tasks for agents in their domain of interest:

- **Personal assistant agent:** for human-computer-interaction
- **Server agent:** coordination of evolving tasks (e.g. handling self-assessment requests, generating corresponding evaluation engines)
- **Evaluation agent:** evaluating the tests based on test information (questions, answer options, correct answer) and assessment process information

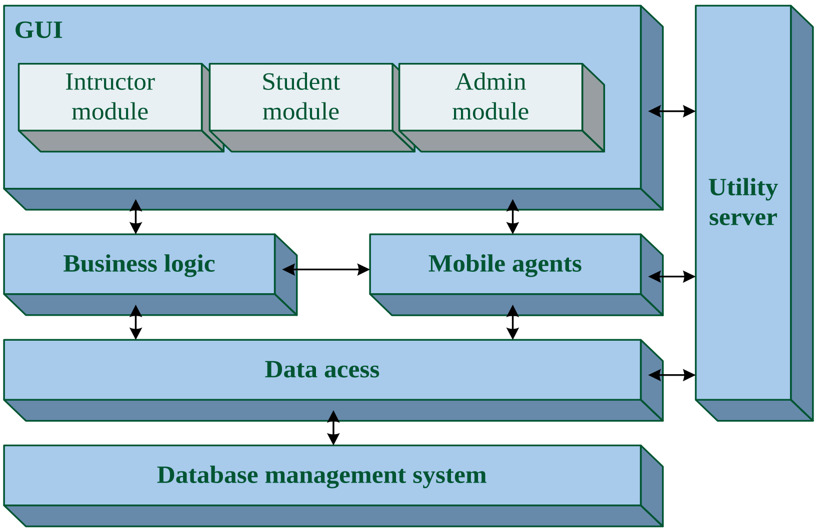

Figure 3.5: Architecture for knowledge assessment with JADE (cp. [Anghel and Salomie, 2003])

3.1.2.3 File-Store Manipulation Intelligent Learning Environment

The File-Store Manipulation Intelligent Learning Environment (F-SMILE) was published by [Virvou and Kabassi, 2002]. It is intended to teach novices the usage of a graphical user interface. Therefore it is protected and offers adaptive tutoring and help, based on the observed user actions. Used adaptation techniques are adaptive presentation and adaptive navigation support [Kabassi and Virvou, 2003].

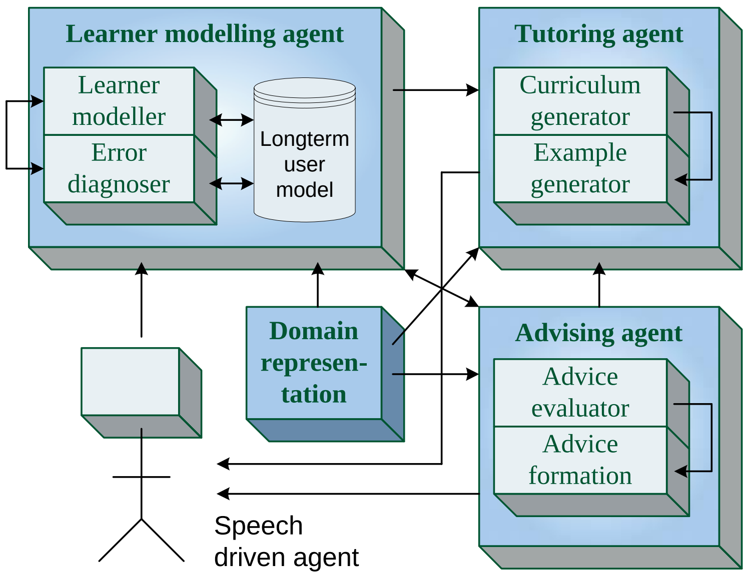

Figure 3.6: F-Smile's architecture (cp. [Virvou and Kabassi, 2002])

Four agent types are implemented (cp. figure 3.6):

- **Learner modelling agent:** observation of the learner's characteristics and identification of possible misconceptions
- **Advising agent:** simulation of a tutor's reasoning by the application of an defined formula that deals with the degree of similarity, typicality, degree of frequency, dominance to calculate the degree of certainty of the appropriatness of an given adice
- **Tutoring agent:** content, link and example adaptation based on learner information
- **Speech driven agent:** avatar for human-computer-interaction to provide entertainment and emotional function

3.1.2.4 Extended LMS "Samurai"

In [Ueno, 2005] the agent-based extension of the existing learning management system "Samurai" and an analysis of its usefulness is described. Agents are used to provide optimized instructional messages to a learner. Therefore they identified nine primary variables of the user model as informational base for adapted message delivery.

A major part of their work was the comparison of courses held with and without the agent-based extension. The main results where:

- Reduced number of students, who gave up the course
- Improved test score
- Reduced variance of test score
- Increased learning time

3.1.2.5 Web-Based e-Learning Environment Integrating Agent and Computational Intelligence

A system for web-based elearning integrating agent and computational intelligence is described in [Giotopoulos et al., 2005]. The platform frontend, the student questioner reasoning and the student model agent, are connected with Web services (figure 3.7).

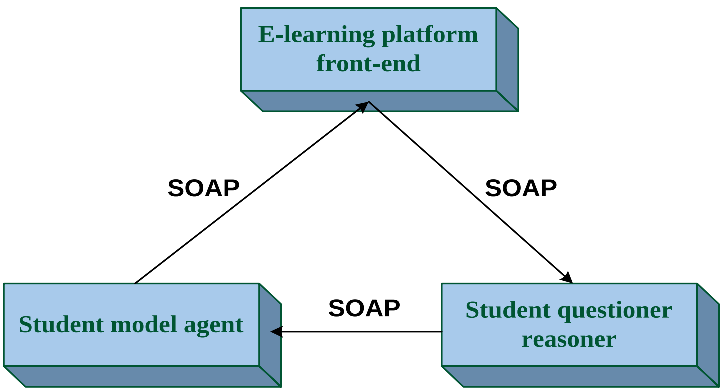

Figure 3.7: System architecture with Web-service-based interconnection (cp. [Giotopoulos et al., 2005])

The tasks of the student model agent are:

- ○ Leading of the learner through the learning process
- ○ Update of the learner model
- ○ Access to possible interesting resources

3.1.2.6 Intelligent Learning Materials Delivery Agents

The Intelligent Learning Materials Delivery Agents (ILMDA) application was designed to deliver learning material to different students taking into account the content's usage history and the student's user profile.

The agents task is to learn from the available history data and to make assumptions about the appropriatness of learning material for certain students. The ILMDA architecture is sketched in figure 3.8 [Soh et al., 2005a].

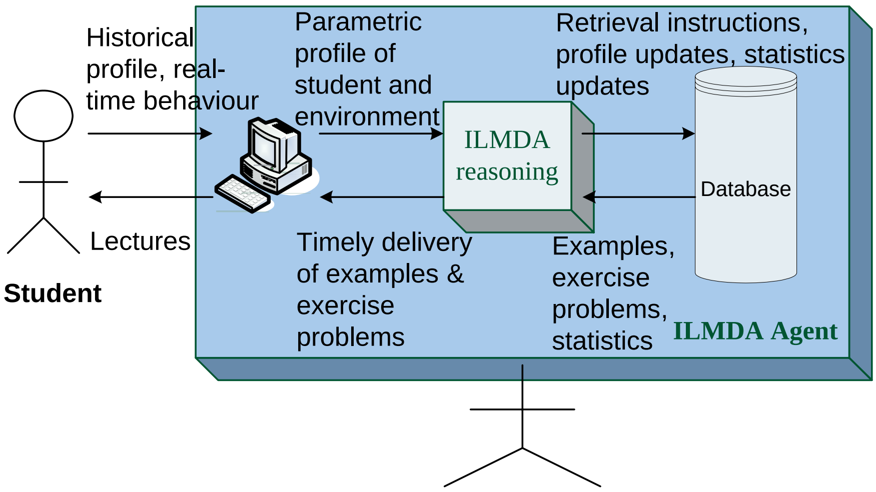

Figure 3.8: ILMDA architecture (cp. [Soh et al., 2005a])

3.1.3 Agent Technology for Authoring in e-Learning

The Learning Unit Environment and the Content Environment are focused on functionalities to support the authoring process of educational content (e.g. basic content, learning objects, assessments/tests, courses). The process' nature is iterative: the planning, design and production cycle is followed by a new iteration after an evaluation for continues improvement (cp. figure 2.3) [Giotopoulos et al., 2005].

The CE provides functionalities for the planning, design, creation, assembly and management of basic content fragments. Thereby different media types need to be taken into account. The LUE is focused on the processing of more complex content. Therefore we define a learning unit as a piece of information that is more complex than the content fragments and whose usage is targeted to education. Entire courses and course substructures like assessments or tests are learning units.

The development and authoring of strategies for course assembly is a new key element of the proposed framework. Those, e.g. didactical, strategies are needed for the high quality of assembled learning resources, because they provide expert knowledge und user guidance for this complex task [Mencke and Dumke, 2007b]. Figure 3.9 is presenting chosen aspects of the CE und LUE.

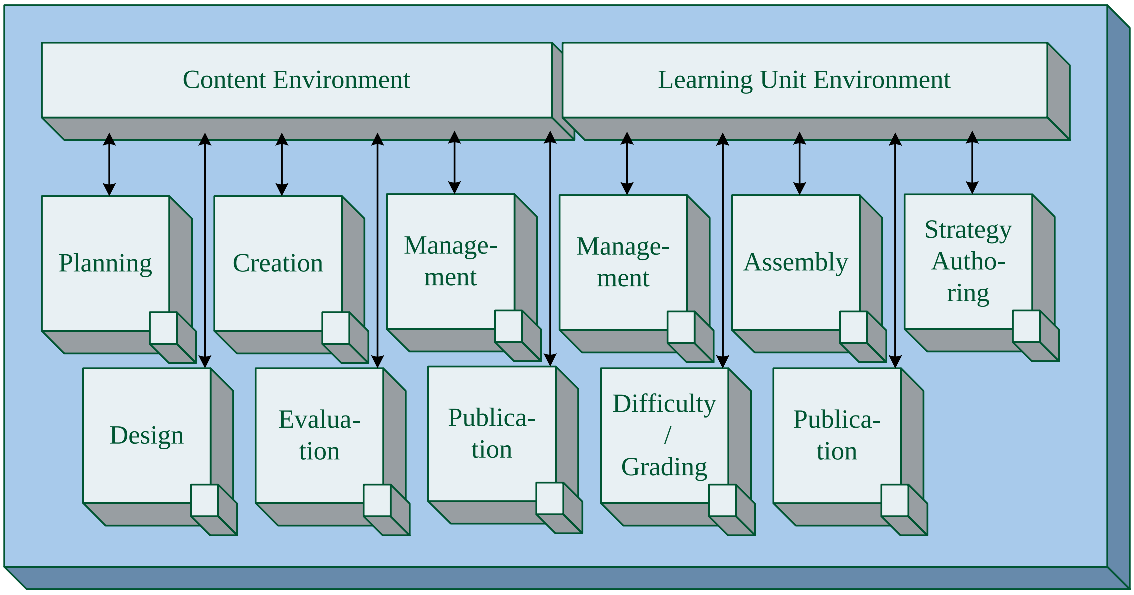

Figure 3.9: The Authoring Environments (cp. [Mencke and Dumke, 2007a])

Like the learning environments, the described authoring environments need connections to the Administration and Interaction Environments and to the support layers by the same token.

In the following, chosen approaches for the usage of agent technology within the domain of authoring in e-Learning are sketched.

3.1.3.1 ALFanet

ALFanet is a project intended to provide a framework to address the learners' need for activities and user-model-based content adaptation and tutor's need for efficiency [van Rosmalen et al., 2005]. From an e-Learning point of view the proposed architecture will be based on available standards like IMS LD (cp. section 2.6.3).

The resulting three tiers are the server layer, services layer and data layer. The server layer provides the user interface, manages application security issues and traces user interactions. The services layer is a composition of a set of application functionality and main logic providing services. Data management and storage are tasks of the data layer.

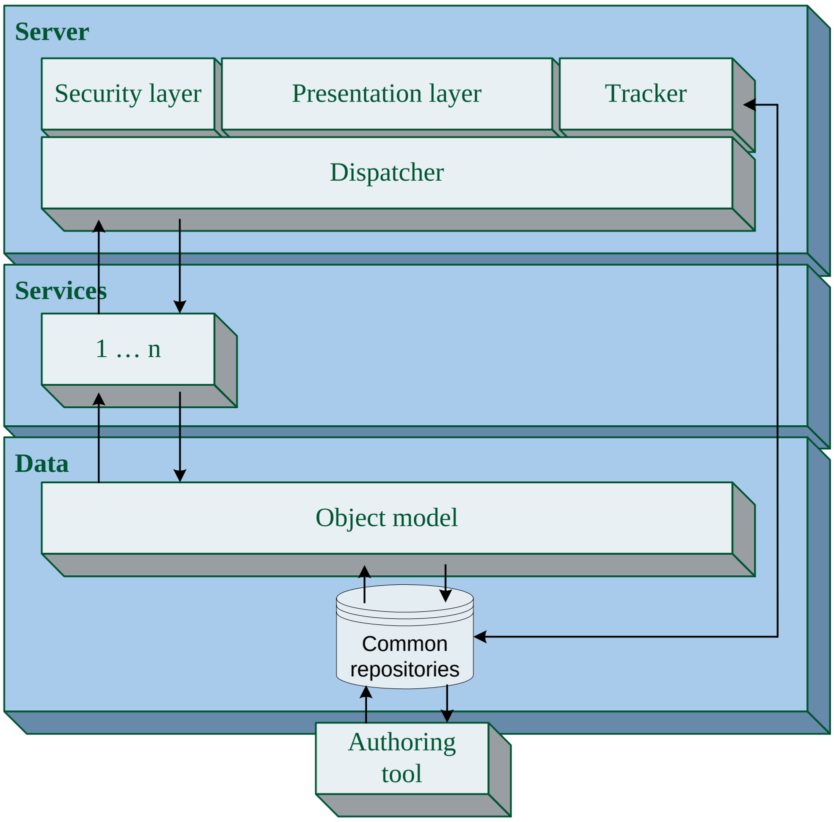

Figure 3.10: ALFanet architecture (cp. [van Rosmalen et al., 2005])

Agent technology is intended to be used for:

- Personalized guidance for learners
- Support based on an instructional model
- Support for course creators by monitoring the difference between design and actual learning process

3.1.3.2 MAS for Undergraduate Computer Science Education

A next multi-agent system in the domain of e-Learning was proposed in [Shi et al., 2000]. The authors are targeting the support of student-centered, self-paced, and highly interactive learning in undergraduate computer science education. They are following a hybrid appraoch of a problem-based and case-based learning model to support creatice problem solving and mechanical experience simulation.

From a technical point of view they prototypically implemented a Web-based GUI additionally using Java RMI, JavaSpace and JATLite (cp. section 1.2.6.2). The architecture is sketched in figure 3.11 and its main elements are several agents for certain purposes, a Web-based interface and a digital library for student profiles and course content.

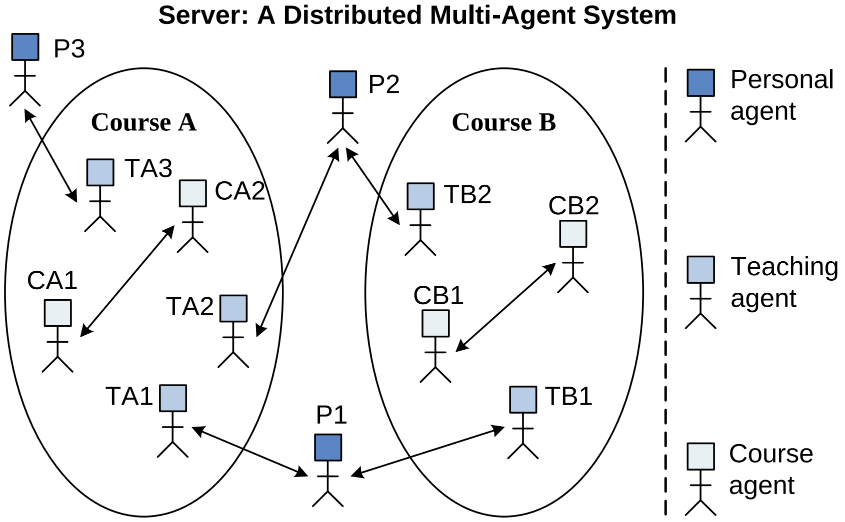

Figure 3.11: MAS for asynchronous learning (cp. [Shi et al., 2000])

The implemented agents and their assigned tasks are:

- **Course agent:** management of course materials and teaching techniques for a course
- **Teaching agent:** tutoring a course based on learning content and teaching strategy of the course agent
- **Personal student agent:** observation of the learner and management of his user profile

3.1.3.3 Knowledge Intelligent Conversational Agents

The Knowledge Intelligent Conversational Agents (K-InCA) system was designed to help people adapt new behaviours [Angehrn et al., 2001]. Therefore following methodology of human dealing with new behaviours was adopted within the implemented architecture (cp. figure 3.12).

- **Stage 1:** being unaware of new behaviours
- **Stage 2:** becoming aware of the new behaviours and the underlying concepts
- **Stage 3:** developing of interest in the new behaviours
- **Stage 4:** experimentation of how the new behaviours "work" for the human
- **Stage 5:** adoption of the new behaviours in the case of positive experience

The implemented agents have tasks of examination of user's actions, the maintaining a "behavioural profile" (reflecting the level of adoption of the desired behaviours) and the adaptive learner guidance for mentoring, motivation or stimulus. This agent-based adoption follows these steps:

- **Step 1:** observing the user's actions
- **Step 2:** activation of the diagnostic agent who updates the user model
- **Step 3:** selection a new current learning objective, solicitation of proposals from the expert agents to achieve the learning objective, proposal and selection of one or more intervention strategies
- **Step 4:** implementation of intervention

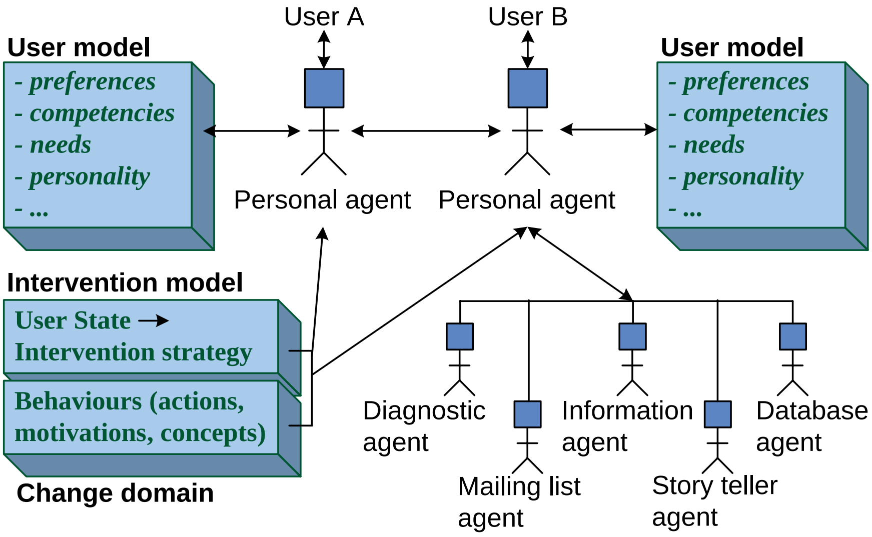

Figure 3.12: Overall K-InCA architecture (cp. [Angehrn et al., 2001])

3.1.4 Agent Technology for Interaction in e-Learning

Following Brown and Duguid in [Brown and Duguid, 2000] learning is "a remarkably social process. Social groups provide the resources for their members to learn." There are several social reasons for interactivity. It decreases isolation of the participants and increases the flexibility to adapt new conditions. Furthermore it involves more human senses into learning and increases the variety of learning experiences (multi-cultural environments, communication capabilities, etc.). Furthermore interactivity builds a sense of group identity and community. Nonetheless interaction sometimes is a fundamental requirement for certain courses [Belanger and Jordan, 2000]. Figure 3.13 is dedicated to chosen fragments of the Interaction Environment.

The proposed framework integrates multiple communication channels as technical support for human-to-human respectively human-to-computer interaction and is extended by additional support tools. An avatar is used as a human representative for e.g. personalisation, identification, anonymisation and as backup in case of absence. Another component is the grouping tool, which is intended to form groups of learners for certain collaborative learning tasks based on user model information and appropriate psychological theories.

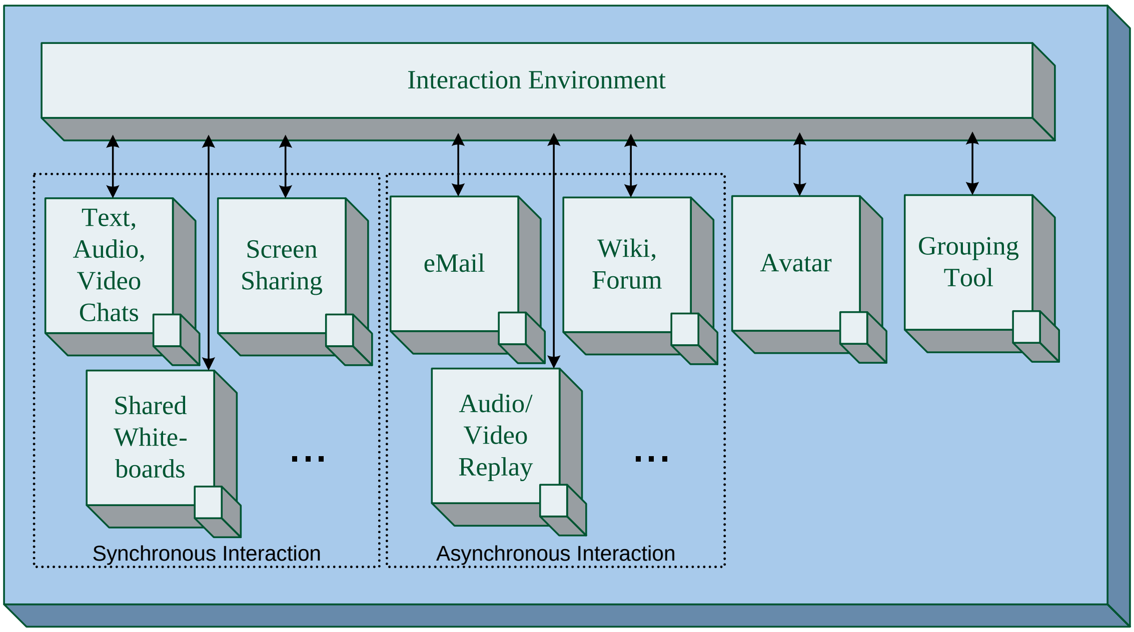

Figure 3.13: The Interaction Environment (cp. [Mencke and Dumke, 2007a])

Interaction approaches can be distinguished in synchronous and asynchronous. Synchronous tools can provide text-, audio- or video-based chat, application/screen sharing, synchronous Web browsing, shared whiteboards, etc. Asynchronous tools can span e.g. email, wikis, forums, mailing lists or audio/video replay [SUN Microsystems, Inc., 2003].

The IE technically needs close connections to all other environments, because collaborative learning and working may occur in every proposed environment.

In the following, chosen approaches for the usage of agent technology within the domain of interaction in e-Learning are sketched.

3.1.4.1 Intelligent Multiagent Infrastructure for Distributed Systems in Education

The Intelligent Multiagent Infrastructure for Distributed Systems in Education (I-MINDS) was published by [Soh et al., 2004] and it is intented to support cooperative learning among students in classic classroom teaching as well as in distance education. Therefore the application establishes an agent-federated "buddy group": a close-knit student group where its members exchange messages and help each other understand the lectures.

The implemented agent types are teacher agent (cp. figure 3.14) and the student agent:

- **Teacher agent:** assistant of the teacher to monitor the students and to adapt the class
- **Student agent:** interaction with teacher agent and other student agents to facilitate cooperative learning activities

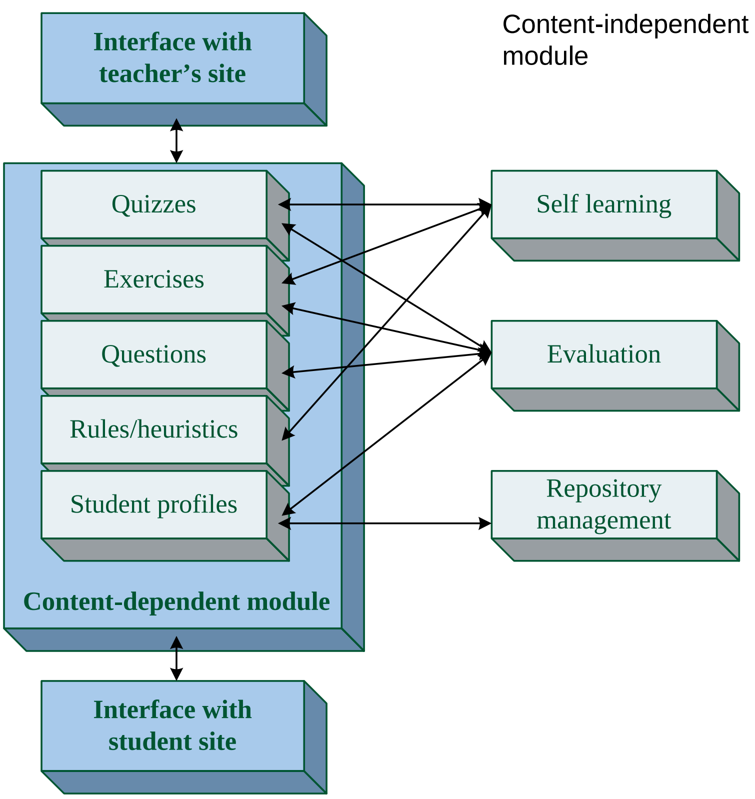

Figure 3.14: Structure of I-MINDS teacher agent (cp. [Soh et al., 2004])

3.1.4.2 Virtual Reality Game for English

The Virtual Reality Game for English (VIRGE) is an intelligent tutoring systems to teach English orthography and grammatical rules. Therefore a virtual reality game was implemented to supply the opportunity to play an 3d game [Virvou and Katsionis, 2003]. The architecture of the evolving MAS is presented in figure 3.15.

Several agent types are implemented:

- **Animated agents:** for human computer interaction
  - Virtual enemy: asking questions to learners
  - Virtual advisor: showing empathy to the learners, help for learners
  - Virtual companion: appears when the student has declined much from his usual actions or has made a repeated mistake
- **Student profile agent:** collection learner information and updating the user profile

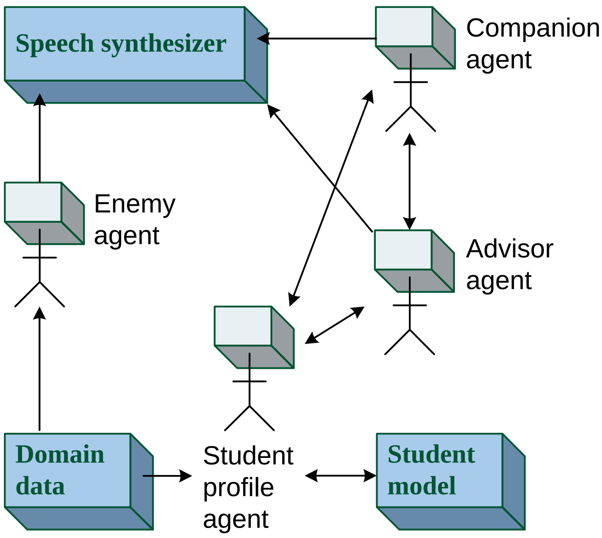

Figure 3.15: VIRGE MAS architecture (cp. [Soh et al., 2005a])

3.1.5 Agent Technology for e-Learning System Administration

The administration environment provides access for the management of all environments, system components and support layers. The possibilities are ranging from simple observation to the integration of new components or the update of existing ones. The access to components and the provided functionalities is limited by the access restriction of a particular user.

The most extensive access is possible for the administrators. All other user groups have access to their specific objects and to the adjustment capabilities of the environments where they have access to.

A very important example of needed accessibility is the manageability of the user model for the depicted learner. If it is available and manageable for individuals it gives learner control and responsibility [Kernchen and Dumke, 2007]. Thereby it supports meta-learning activities like the monitoring of learning, the setting of personal learning goals; it is the basis for planning goals and supports the reflection about and the tracing of the learning progress by the comparison of set goals. As presented in figure 3.16, the AE needs connections to all other environments.

Regarding functionalities we grouped in the user, institutional and technical area. Within the user area all aspects are pooled that are related to specific user tasks. Thereby not only learners, but all possible users have access to administration functionalities that are targeted to them, their tasks or resources. Institutional management facilities provide access to services, functionalities and resources that are related to the management of meta-activities within the specific institution as e.g. user management, course management, class management, study specification management and certification management. Management capabilities for the classic administrator role are pooled within the technical area.

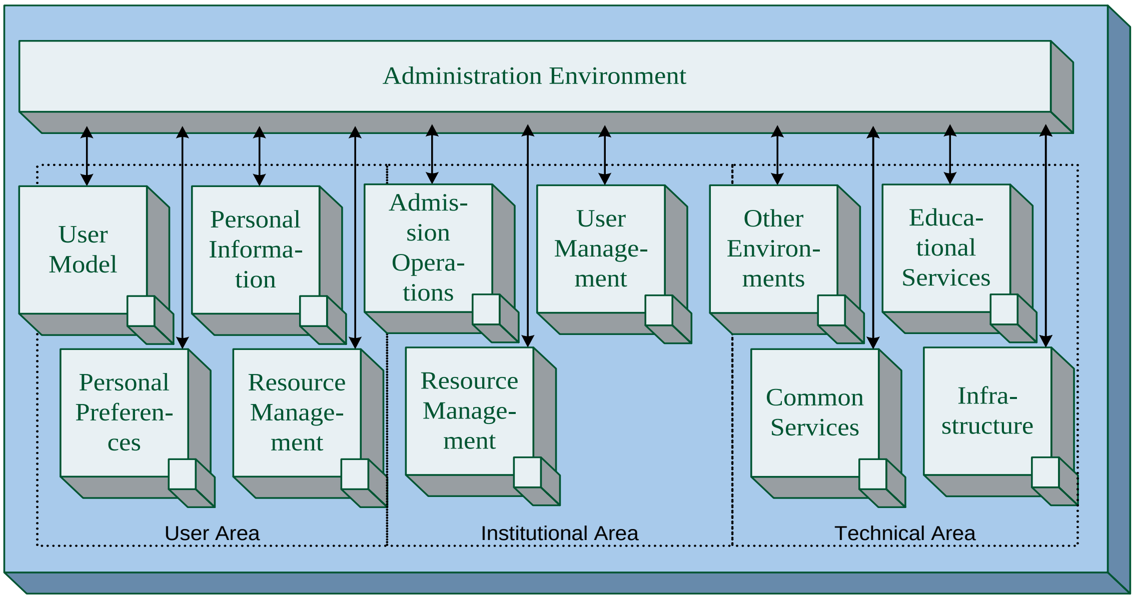

Figure 3.16: The Administration Environment (cp. [Mencke and Dumke, 2007a])

In the following, chosen approaches for the usage of agent technology within the domain of e-Learning system administration are sketched.

3.1.5.1 Multi-Agent System for e-Learning and Skill Management

The Multi-Agent System for e-Learning and Skill Management (MASEL) presented e.g. in [Garro and Palopoli, 2002], [Garro and Palopoli, 2003] and [Garro et al., 2003] targets the automatisation of certain tasks within the context of skill management for employees. That includes for example the individuation of student learning objectives, the evaluation of his competence gaps, the control of his improvements and the creation of the bridge between his individual learning objectives and the ones of the organisation in which he is integrated. The system's architecture is presented in figure 3.17.

In MASEL agents are mainly used for communication between distributed components, for monitoring the environment, for autonomous operations, reasoning and to perform compley message-based operations. Therefore this system was implemented in JADE (cp. 1.2.6.1) making extended usage of XML for ontology representation and handling and for communication. The created MAS itself contains seven agent types and consists of at least one CLO Assistant Agent, one Skill Manager Agent, one Content Agent, one Learning Paths Agent, one CCO Assistant Agent, one User Profile Agent and n Student Assistant Agents, that are described below.

The *CLO Assistant Agent* (CLO) supports the Chief Learning Officer in defining a learning strategy for the intented user in terms of roles and required competencies based on the organisation's learning objectives. Therefore the CLO supports the management of roles and competencies, the management of potential learners, the suggestion of possible suitable employees for certain roles, the definition of priorities and constraints as

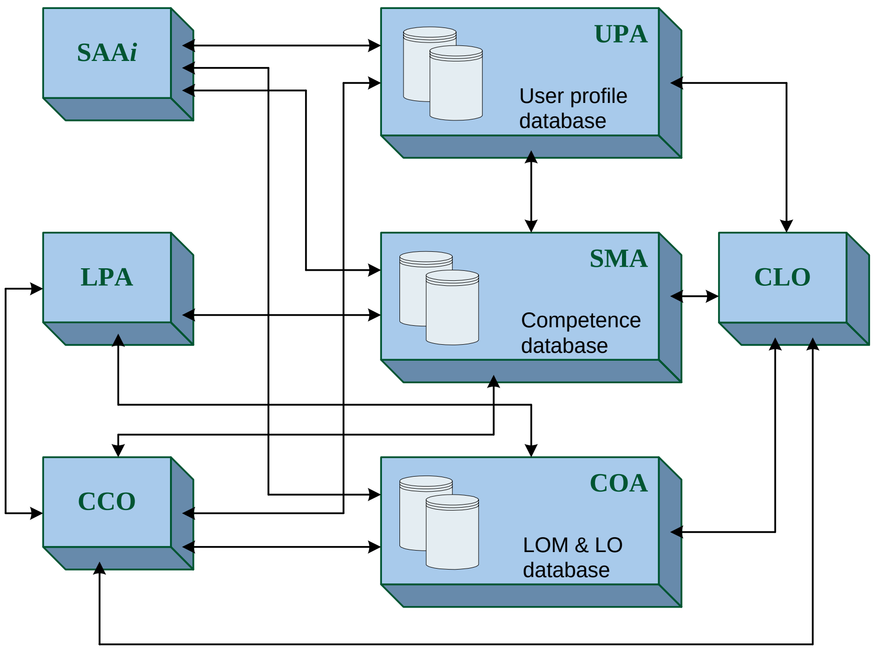

Figure 3.17: Architecture of the MASEL system (cp. [Garro et al., 2003])

well as the presentation of individual learning activities, based on historical data of the employees.

The *Skill Manager Agent* (SMA) manages general skill information of the organisation. Therefore all related data, including the ones processed by the CLO, are stored in an XML document. Additional data are the individual roles and competencies of employees. This agent provides services to insert, delete and update individual and organisational role and competency information and functionality to query the data structures for certain reasons.

The *Learning Path Agent* (LPA) tries to create learning paths to fill identified competency gaps of the employees. It is related to the Student Assistant Agent (SAA) and it is used to create test to identify and evaluate the missing skills, to enrich and modify the learning path and to inform the CCA Assistant Agent for missing learning objects.

The already mentioned *Student Assistant Agent* (SAA) is associated to an individual student and its task is supportive to fill his competency gap for a certain role. Therefore it presents information about the identifies competency gaps, presents the test created by the LPA, modifies the course based on user feedback and manages information about the learning progress.

The *Content Agent* (COA) manages the database consisting the learning objects and thereby provides the content needed by the LPA and SAA to adapt a course. This agents inserts, deletes, modifies and queries the stored learning objects.

The *CCO Assistant Agent* (CCO) supports the Chief Content Officer in dealing with the learning object database. Therefore it cooperates with the COA and can present the learning history of employees.

The last implemented agent type is the *User Profile Agent* (UPA) for the storage of needed user related information. It manages the user's log-in, his profile information and updates his competency levels (together with the SMA and SAA).

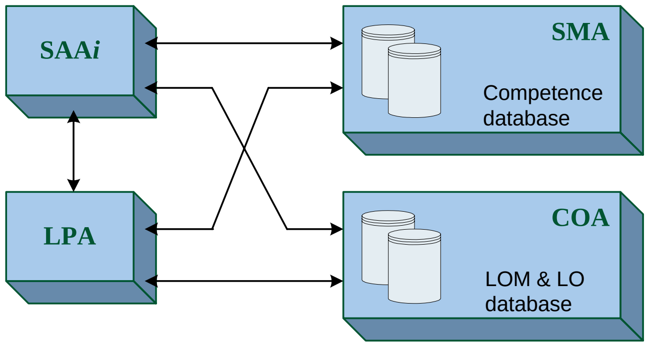

Figure 3.18: Personalised learning path in the MASEL system (cp. [Garro et al., 2003])

To create individual learning paths with the implemented agents (cp. figure 3.18) different learning strategies can be applied, e.g. time minimization and knowledge maximization. The construction process is semi-automatic, three-tier and stops with a complete learning path, reaching the learning objective. Didactics is applied in terms of prerequirements that need to be fulfilled.

- **Step 1:** creation of a set of learning objects based on learning objectives
- **Step 2:** presentation of this set to the user
- **Step 3:** manual choice of appropriate learning objects as a subset

3.1.6 Agent Technology for e-Learning Infrastructure and Common Services Layers

The infrastructure and common support layers provide basic functionalities for the e-Learning services layer and the parts of the environments. This separation idea was adopted from [Open Knowledge Initiative, 2003] and [IMS Global Learning Consortium, Inc., 2003a] and is based on the same motivation. The intended goals are twofold.

- Thereby more complex functionalities of the upper framework elements do not need to re-implement already existing ones; redundancy is avoided.
- By the separation an easier intra-institution work sharing is possible, due to increased portability of the system.

This presented framework differs in the assignment of specific functionalities to certain support layers and environments, as descried below. The infrastructure layer is responsible for basic networking and data transport, selected services are e.g.:

- Exchange of data structures in terms of physical communications, messaging and transaction needs [IMS Global Learning Consortium, Inc., 2003a]
- Support of complex multi-zone agent communication ([Schools Interoperability Framework (SIF) Association, 2007], [Ganchev et al., 2007])
- Provision of the needed agent platform ([Foundation for Intelligent Physical Agents (FIPA), 2002a], [Foundation for Intelligent Physical Agents (FIPA), 2006])
  - Agent management
  - Message transport service
  - Agent directory
  - Services directory
  - Agent communication language (ACL)

The common service layer provides generic functionalities for the upper layer and the framework environments like (adopted and extended from [Open Knowledge Initiative, 2003]):

- Authentication and authorisation [Open Knowledge Initiative, 2003]
- Rights management, validation
- Service discovery, database control e.g. for ([SUN Microsystems, Inc., 2003], [Open Knowledge Initiative, 2003]:
  - Learning content
  - Learning meta data
  - Learning assessment
  - Learning administration
  - User repository
- Filing [Open Knowledge Initiative, 2003]
- Automated resource update
- Logging of technical system aspects
- Virtual centralisation of remote resources

Additional possible services are summarized in a brief overview in [Wilson et al., 2004a] as part of the ELF Initiative that is targeted towards a service-oriented approach for e-Learning.

In the following, chosen approaches for the usage of agent technology within the domain of infrastructure respectively common services are sketched.

3.1.6.1 Knowledge On Demand

The Knowledge On Demand (KOD) project is an initiative of a consortium consisting of five members from four european countries. Its target was the development of a platform independent solution for the publishing, brokering and delivering of learning objects and packages. Thereby interoperation and interchange between different service providers and platform vendors should be enhanced [Trabucchi, 2001].

The presented solution argues to include all important related e-Learning standards by the means of existing Web technologies and agent technology [Sampson and Karagiannidis, 2002]. The proposed architecture is visualised in figure 3.19.

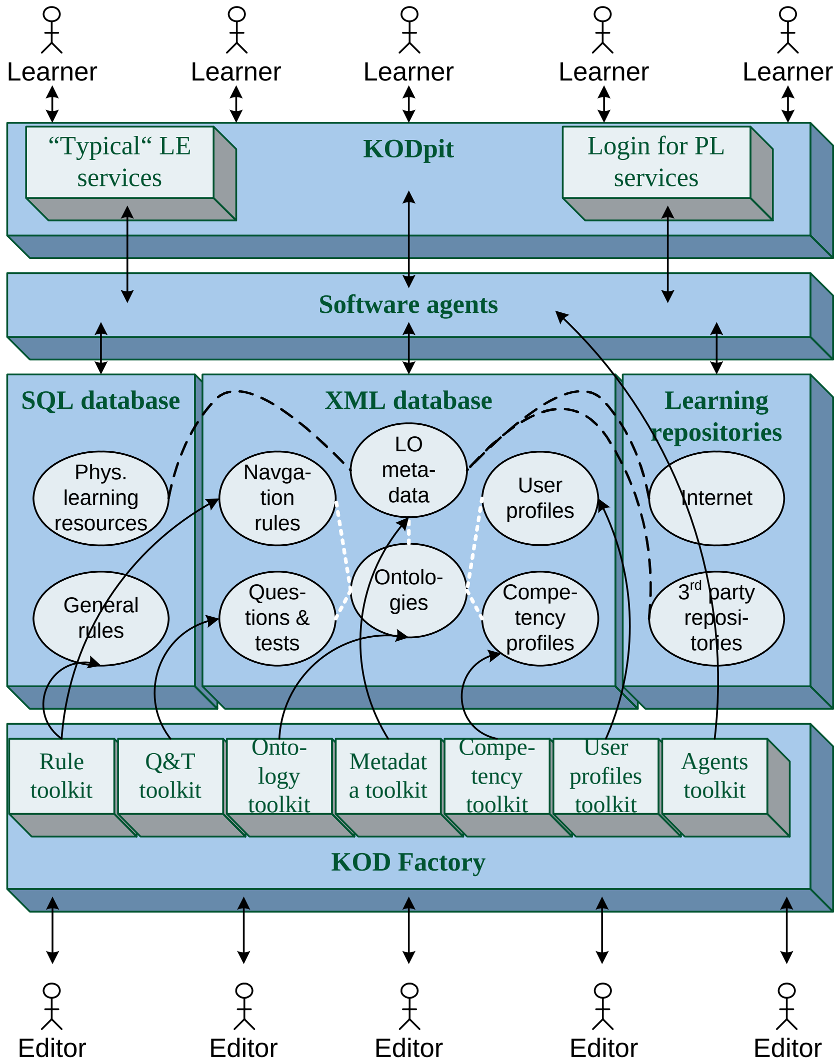

Figure 3.19: Knowledge On Demand architecture (cp. [Sampson et al., 2002])

The intended main features are: individualised learning paths, user profiling, integration of multiple e-Learning standards and the integration of agent technology. Agents are addressed for following tasks [Sampson et al., 2002]:

- Observing the learner
- Interaction of architectural components
- Search for information in internal and external databases
- Knowledge analyse, monitoring, generation, adaptation and delivering

3.1.6.2 Coaching FRED

Coaching FRED is an application targeting the organisation and coordination of the lifelong learning process in a company [Smolle and Sure, 2002]. Agent technology is used for communication and interaction issues among different FRED-implementations.

The key objectives targeted by the project are the support of a skill-transition strategy, the active information of employees, the improved service for employees, the support of education staff and the general optimisation of the learning process. The system's architecture is sketched in figure 3.20.

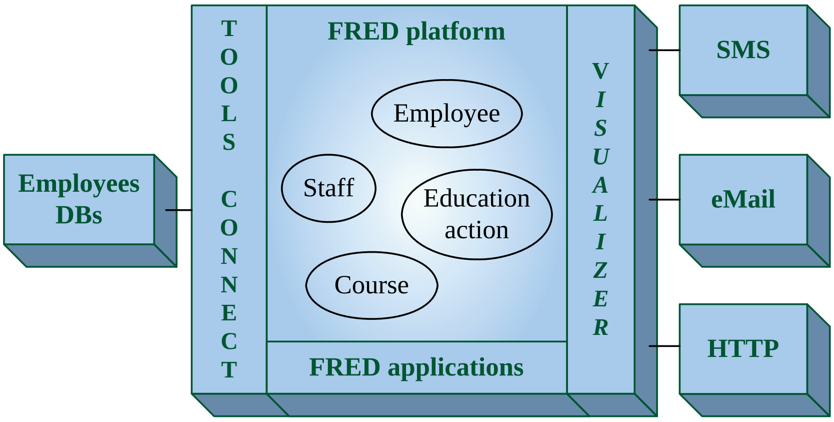

Figure 3.20: FRED solution concept (cp. [Smolle and Sure, 2002])

Several steps for the interaction with the system can be identified:

- **Step 1:** initialisation of the application
- **Step 2:** user: creation of a personal task profile
- **Step 3:** application: offering of courses
- **Step 4:** user: optional creation of a personal interest profile
- **Step 5:** application: offering of additional topics
- **Step 6:** user: feedback of missing offers
- **Step 7:** application: information about new available courses
- **Step 8:** user: adaption of user profile; restart of process

3.1.6.3 Distributed e-Learning Center (DeLC)

Current research activities try to extend the already described Distributed e-Learning Center (DeLC) (cp. section 2.8) by agent technology. The service-oriented e-Learning and e-Teaching should be extended for mobile support. Agents will serve as flexible personal assistants. Agent-related tasks for this second version of DeLC are:

- Intelligent interpretation of data
- Intelligent interpretation of exchanged content
- Communication with existing functional modules (Web services)

Therefore personal agents are developed for the processing of user profiles and the access of services. The service agents' tasks are the processing of profiles and models of existing services.

3.1.7 Agent Technology for Specialised e-Learning Services

This layer provides specialised e-Learning functionalities. Therefore they can be based on services of lower support layers to provide them to the upper environments. Thereby the provided services reveal fundamental educational and/or crossover nature for the certain environments.

As the most specialised support layer this collection of e-Learning specific services represent a second dimension of the proposed framework. The more vertically specialised functionalities of the environments are based on and are supported by multiple adopted implementations of the proposed services. In figure 3.21 the hierarchy of environmental components is depicted in the upper blue boxes, meanwhile the dots within the net below visualise potential cooperation with the educational services.

To profit from the agent-supported realisation of this framework we propose the implementation and offer of certain e-Learning-specific functionalities of the presentation environments as educational services. That e.g. relates to:

1. Content assembly and sequencing service ([SUN Microsystems, Inc., 2003], [Advanced Distributed Learning (ADL), 2006b])
2. Content adaptation service
3. Scheduling service [Open Knowledge Initiative, 2003]
4. Learning planner [IMS Global Learning Consortium, Inc., 2003a]
5. Annotation/link management service
6. Cataloguing service ([IMS Global Learning Consortium, Inc., 2003a], [IEEE LTSC, 2002a])
7. Grouping tool
8. Interface to external office tools
9. Brokering service for educational material [Schools Interoperability Framework (SIF) Association, 2007]

More fundamental services are for example:

10. Evaluation (of e.g. learning progress, learning results, content usage, course usage, user preferences, strategy usage, ...) [IEEE LTSC, 2002a]
    - Collecting evaluation data: logging of education-related events, like learner profiling
    - Storing evaluation data
    - Processing evaluation data
    - Evaluation provision
11. Educational resource management (e.g.: content, learning unit, strategies)
12. Registration for new courses
13. Knowledge management
14. Report management

15. Dictionary [Open Knowledge Initiative, 2003]
16. Mobile learning management [MOBIlearn Project Consortium, 2005]
17. User model service (management, update, . . .)

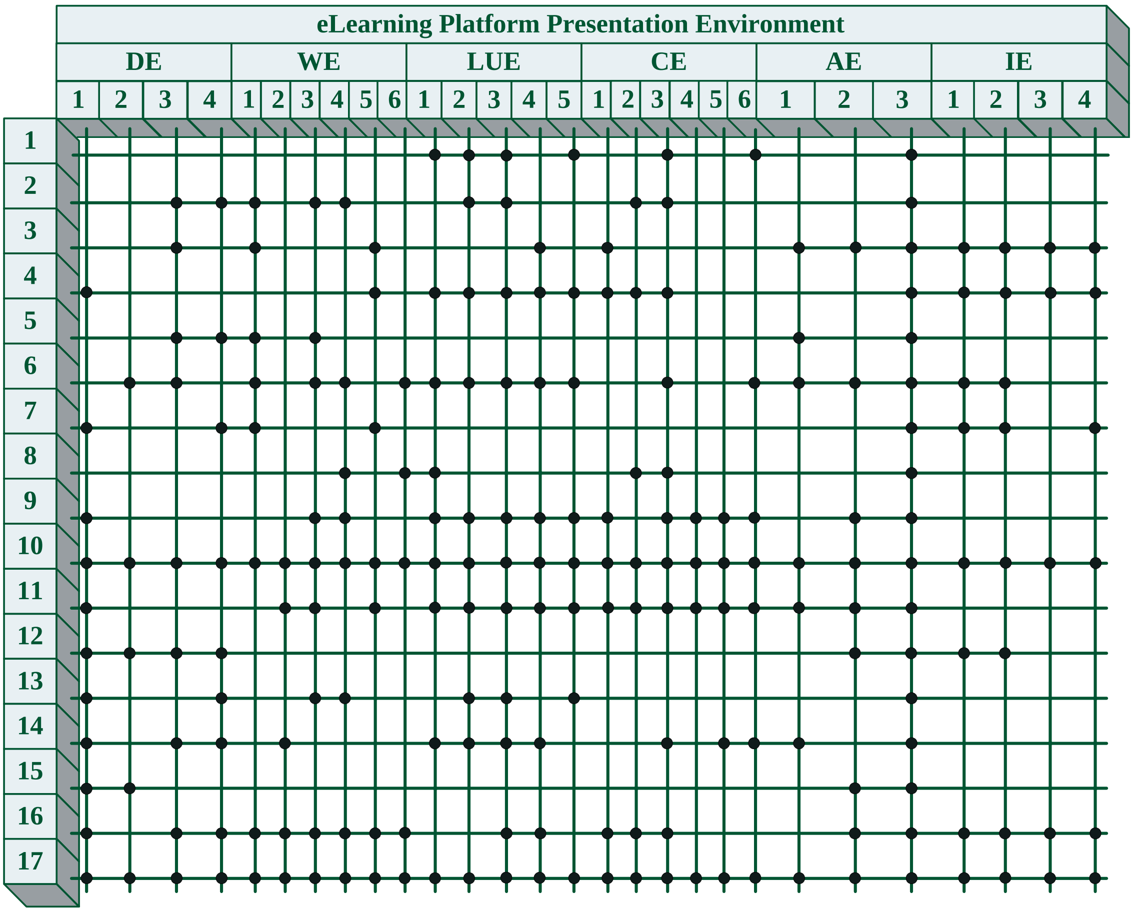

Figure 3.21: Two-dimensionality of environmental functionalities (h) and services (v) (cp. [Mencke and Dumke, 2007a])

In the following, chosen approaches for the usage of agent technology within the domain of e-Learning specific services are sketched.

3.1.7.1 Double Agent Architecture

The double agent architecture for educational applications is presented in [Rahkila, 2001]. It is a user-centred and adaptive multi-agent architecture focussing on the identification of learners and the logging of their actions.

The architecture is named “Double Agent Architecture” because of the dual nature of the used agent that represents the learner as well as the teacher. A user request needs to be verified by an agent before it is processed by an agent. Fundamental aspects of the architecture are sketched in figure 3.22.

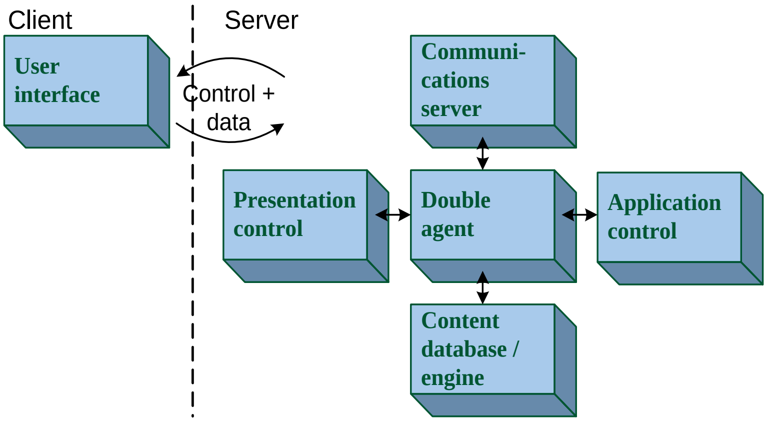

Figure 3.22: Double agent architecture (cp. [Rahkila, 2001])

3.1.7.2 User-Centred and Adaptive Interaction Multi-Agent Architecture

A user-centred and adaptive interaction multi-agent architecture was decribed in [Fernández-Caballero et al., 2003]. It is based on the idea that humans are different and the systems should adapt to them and not the other way around [Preece et al., 1994]. Agent technology artifacts of this architecture are intended to be used for certain aspects of e-Learning, e-Teaching and for interaction purposes. The proposed key features are:

- Social computing
- Logging of interaction and application of appropriate metrics
- Application of appropriate metrics for preference measuring

The interaction aspect of the proposed architecture is depicted by the interaction MAS and is visualized in figure 3.23. The related task-specific agents are the upgrading agent (update the user interface with new information for the student), the preferences agent (logging of learner interaction preferences), the accounting agent (observing the learner's requests for other Web pages), the control agent (transferring learner preferences from preference agent to updating agent) and the performances agent (calculation of preferences metrics).

A next MAS is the E-teaching MAS includes the teaching control agent, which observes the learning system and provides suggestions to the teacher.

The learning MAS intend to maximes course learning. Therefore the learning control agent is the information mediater for the other agents of this MAS. The theory agent deliver appropriate theory Web pages on requests of the control agent of this MAS. The practice agent selects and delivers needed exercises and the test agent requested tests.

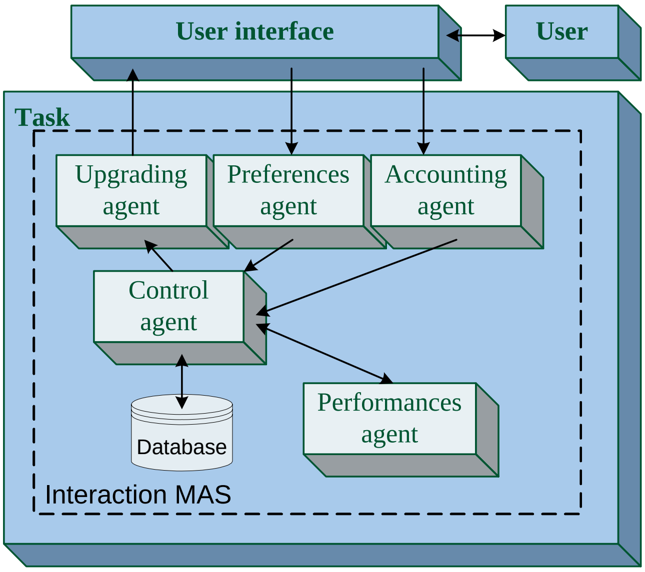

Figure 3.23: Interaction MAS architecture (cp. [Fernández-Caballero et al., 2003])

3.1.7.3 Faded Information Field Architecture

The faded information field architecture is intended to handly a high rate of service provision and utilization requirement [Sadiig, 2005]. It is an approach for improved provision of e-Learning by decentralising it. Therefore information provision is improved by communication improvement in a distributed environment. The architecture (cp. figure 3.24) replicates content on demand to handle increased requirements in terms of service availability and utilization. Therefore the amount of information that is stored as well as the information update frequency are inversely proportional to the distance of the node to the service provider. The authors distribute information accross a network of nodes instead of storing it in a certain node.

Two major types of agents are suggested: pull agents (P1A) as mobile agents for acquiring and providing of certain information for learners and push agents (P2A) that provide the services.

The authors strive for the following advantages:

- Increased reliability
- Reduced access time
- Autonomous determination of amount of stored information
- Efficient update of content
- Improved fault tolerance by decentralisation of information

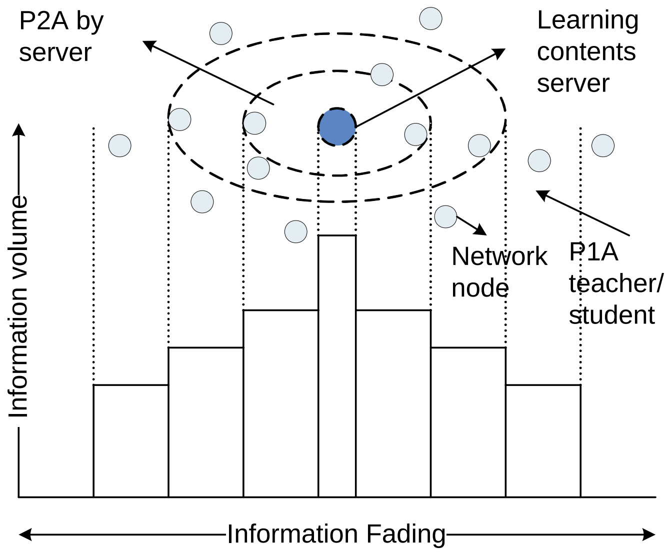

Figure 3.24: Faded information field architecture (cp. [Sadiig, 2005])

3.1.7.4 Agent-Based Personalized Distance Learning System

A very light-weighted and abstract agent-based system for personalized distance learning was proposed by [Koyama et al., 2001]. It uses standard Web technologies with an agent-technology-enhanced server for content delivery (cp. figure 3.25).

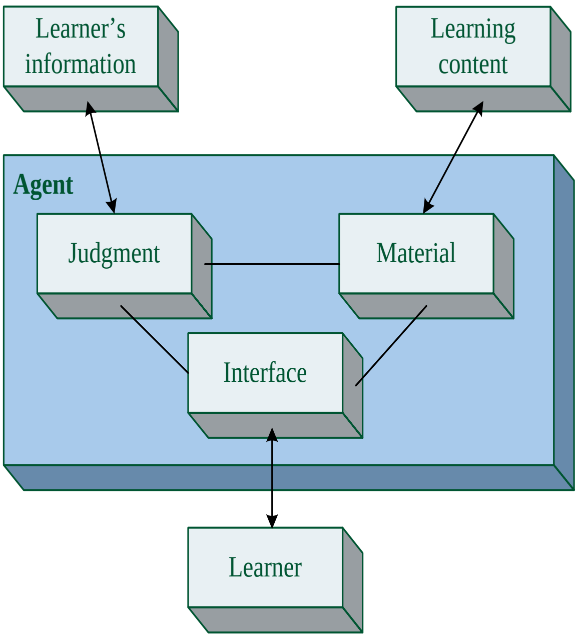

Figure 3.25: Architecture of an agent-based system for personalized distance learning (cp. [Koyama et al., 2001])

The agent's main tasks are:

- ○ Observing the learner and storing relevant information
- ○ Management
- ○ Analysis of information
- ○ Judgement of the learner's progress
- ○ Management of learning content
- ○ Interaction with the learner

3.1.8 Summary

Actual research activities already led to the development of several e-Learning systems using agent technology. The sections described chosen approaches and outlined the used agent types and characteristics. Literature discloses further approaches, e.g. an intelligent tutoring system based on collaborative planning agents [Nkambou and Kabanza, 2001], the Baghera project which proposes a MAS of several agent types to support the learner as well as the tutor [Webber et al., 2001].

Obviously the domain under survey is an actual scientific research area. The future will reveal new trends and noval solutions, as the next section outlines.

3.2 Future of e-Learning with Agent Characteristics

An intensive literature research about possibilities of application of agent technology for several e-Learning aspects reveals certain trends and possible knowledge gaps.

Agents are implemented for different reasons and are affecting different target types. Possible affected targets of processing are the user itself, internal application components, internal databases and external applications (as proxy). Figure 3.26 elucidates the focus of actual research towards user-centred agent technology for e-Learning.

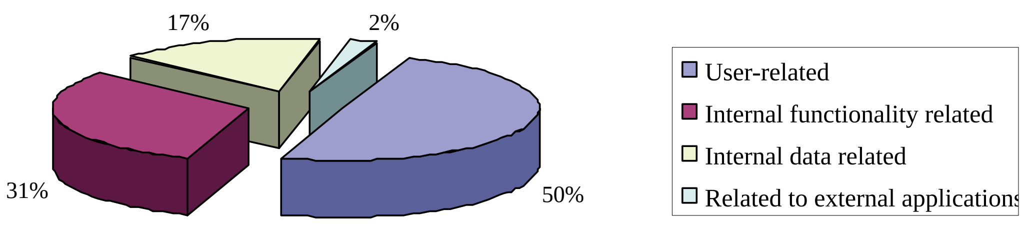

Figure 3.26: E-Learning data artefact coverage by agents (cp. [Mencke and Dumke, 2007a])

Figure 3.27 visualises application possibilities of agents for certain types of e-Learning functionality. Again user centred functionality is one main aspect for the usage of agents; that refers to e.g. knowledge delivery, notification, motivation and several objectives of human-computer-interfaces in general. Chosen observable targets are the user, learning objects, other knowledge resources and certain system artefacts. The “support” class of functionality summarises aspects like decision taking, recommendations, tutoring and search capabilities. Furthermore agents are used to manage knowledge, system components, learning activities and several aspects of user models, meanwhile another application area for this technology is the processing of several knowledge as for example content, several learning units or evaluation data. Agents are used for adaptation and generation, too.

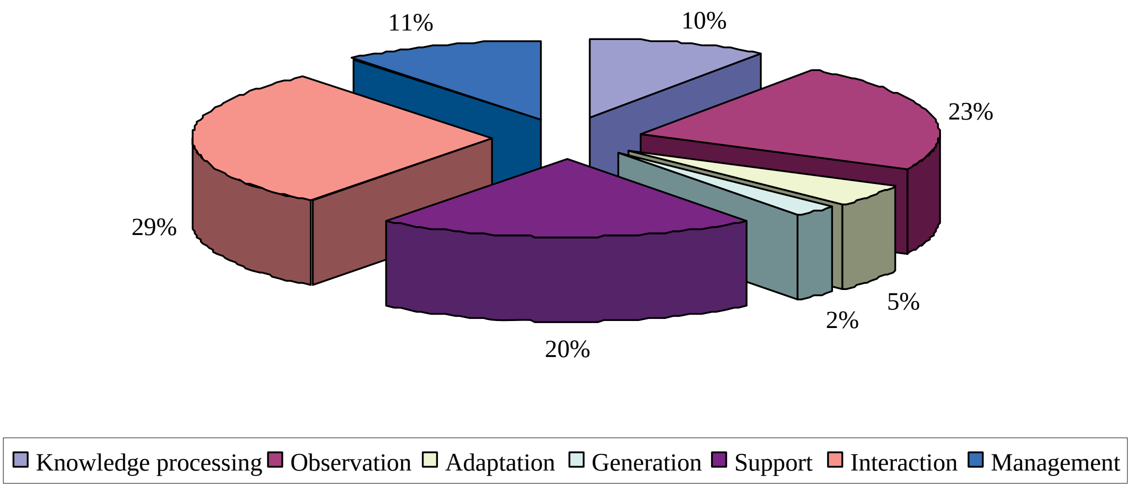

Figure 3.27: E-Learning functionality coverage by agents (cp. [Mencke and Dumke, 2007a])

Related to the framework presented in section 3.1 we identified a quite well-balanced distribution of agent-based support approaches. The pattern emerges because of the possible application of the approaches in different environments. The following list relates architectural components of the framework to the number of approaches for agent-supported e-Learning that can be classified according to the framework.

Delivery Environment: 52
Working Environment: 69
Learning Unit Environment: 58
Content Environment: 50
Administration Environment: 52
Interaction Environment: 47
E-Learning Services Layer: 52
Common Services Layer: 10
Infrastructure Layer: 0
Relations to other platforms: 4

The different pattern among the three services layers has its origin in the specialised e-Learning focus of the analysed resources and the increasing fundamental nature of the lower layers.

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Bibliography

[Advanced Distributed Learning (ADL), 2006a] Advanced Distributed Learning (ADL) (2006a). Sharable Content Object Reference Model (SCORM) 2004 3rd Edition Content Aggregation Model. Technical report, Advanced Distributed Learning (ADL).

[Advanced Distributed Learning (ADL), 2006b] Advanced Distributed Learning (ADL) (2006b). Sharable Content Object Reference Model (SCORM) 2004 3rd Edition Overview. Technical report, Advanced Distributed Learning (ADL).

[Advanced Distributed Learning (ADL), 2006c] Advanced Distributed Learning (ADL) (2006c). Sharable Content Object Reference Model (SCORM) 2004 3rd Edition Run-Time Environment. Technical report, Advanced Distributed Learning (ADL).

[Advanced Distributed Learning (ADL), 2006d] Advanced Distributed Learning (ADL) (2006d). Sharable Content Object Reference Model (SCORM) 2004 3rd Edition Sequencing and Navigation. Technical report, Advanced Distributed Learning (ADL).

[AgentLink III, 2007] AgentLink III (2007). Agent Software List. URL: http://eprints.agentlink.org/view/type/software.html.

[Aggarwal, 2000] Aggarwal, A. K. (2000). *Web-Based Learning and Teaching Technologies: Opportunities and Challenges*. Idea Group Publishing, Hershey, PA, USA.

[Aggarwal and Bento, 2000] Aggarwal, A. K. and Bento, R. (2000). Web-based education. In Aggarwal, A. K., editor, *Web-Based Learning and Teaching Technologies: Opportunities and Challenges*, pages 2–16. Idea Group Publishing, Hershey, PA, USA.

[Aïmeur, 2001] Aïmeur, E. (2001). Strategic Use of Conflicts in Tutoring Systems. In *Conflicting Agents: Conflict Management in Multi-Agent Systems*, pages 223–250. Kluwer Academic Publishers, Norwell, MA, USA.

[American Society for Training & Development (ASTD), 2007] American Society for Training & Development (ASTD) (2007). E-learning Glossary. URL: http://www.learningcircuits.org/glossary.html.

[Andronico et al., 2003] Andronico, A., Carbonaro, A., Casadei, G., Colazzo, L., Molinari, A., and Ronchetti, M. (2003). Integrating a Multi-Agent Recommendation System into a Mobile Learning Management System. In *Proceedings of the 5th Conference in Artificial Intelligence in Mobile System 2003*, Seattle, USA.

[Angehrn et al., 2001] Angehrn, A., Nabeth, T., and Roda, C. (2001). Towards Personalised, Socially Aware and Active e-Learning Systems - Illustrated with the agent-based system K-InCA. White Paper of Centre for Advanced Learning Technologies (CALT) - INSEAD.

[Anghel and Salomie, 2003] Anghel, C. and Salomie, I. (2003). JADE Based Solutions for Knowledge Assessment in eLearning Environments. *EXP - in search of innovation (Special Issue on JADE).*

[Austin, 2005] Austin, J. L. (2005). *How to Do Things With Words*. Harvard University Press, 2nd edition.

[Bangert-Drowns et al., 1985] Bangert-Drowns, R. L., Kulik, J. A., and Kulik, C.-L. C. (1985). Effectiveness of Computer-Based Education in Secondary Schools. *Journal of Computer-Based Instruction*, 12(3):59–68.

[Barbuceanu and Lo, 2000] Barbuceanu, M. and Lo, W.-K. (2000). Conversation Oriented Programming for Agent Interaction. In *Issues in Agent Communication*, pages 220–234, London, UK. Springer-Verlag.

[Bauer and Müller, 2004] Bauer, B. and Müller, J. P. (2004). Methodologies and Languages. In Luck, M., Ashri, R., and d'Inverno, M., editors, *Agent-based Software Development*, pages 77–131. Artech House, Boston, USA.

[Baxter, 1990] Baxter, E. P. (1990). Comparing Conventional and Resource Based Education in Chemical Engineering: Student Perceptions of a Teaching Innovation. *Higher Education*, 19(3):323–340.

[Belanger and Jordan, 2000] Belanger, F. and Jordan, D. H. (2000). *Evaluation and Implementation of Distance Learning: Technologies, Tools and Techniques*. Idea Group Publishing.

[Berlecon Research, 2001] Berlecon Research (2001). Growth Market E-learning - Requirements, Stakeholders and Perspectives on the German Market (In german). Report.

[Berlo, 1960] Berlo, D. K. (1960). *The Process of Communication: An Introduction to Theory and Practice*. Holt, Rinehart and Winston, New York, USA.

[Biggs, 1987] Biggs, J. B. (1987). *Student Approaches to Learning and Studying*. Australian Council for Educational Research, Melbourne, Australia.

[Blackboard Inc., 2007a] Blackboard Inc. (2007a). Blackboard. URL: http://www.blackboard.com.

[Blackboard Inc., 2007b] Blackboard Inc. (2007b). Webct. URL: http://www.webct.com/webct/.

[Bloom, 1956] Bloom, B. S. (1956). *Taxonomy of Educational Objectives - Handbook I: Cognitive Domain*, volume 1. Longman, Green and Co.

[Bloom et al., 1964] Bloom, B. S., Krathwohl, D. R., and Masia, B. B. (1964). *Taxonomy of Educational Objectives - Handbook II: Affective Domain*. Longman, Green and Co.

[Boyle, 1997] Boyle, T. (1997). *Design for Multimedia Learning*. Prentice Hall, London, UK.

[Brandon Hall Research Group, 2006] Brandon Hall Research Group (2006). LMS and LCMS Demystified. *ELearning! Magazine*.

[Brenner et al., 1998] Brenner, W., Zarnikow, R., and Wittig, H. (1998). *Intelligent Software Agents (in German)*. Springer Verlag.

[Brooks and Brooks, 1999] Brooks, J. G. and Brooks, M. G. (1999). *In Search of Understanding: The Case for Constructivist Classrooms*. Association for Supervision & Curriculum Development.

[Brooks, 1991] Brooks, R. A. (1991). Intelligence without Representation. In Myopoulos, J. and Reiter, R., editors, *Proceedings of the 12th International Joint Conference on Artificial Intelligence (IJCAI-91)*, pages 569–595, Sydney, Australia. Morgan Kaufmann Publishers Inc.: San Mateo, CA, USA.

[Brown and Duguid, 2000] Brown, J. S. and Duguid, P. (2000). *The Social Life of Information*. Harvard Business School Press, Boston, USA.

[Brusilovsky et al., 1998] Brusilovsky, P., Kobsa, A., and Vassileva, J., editors (1998). *Adaptive Hypertext and Hypermedia*. Kluwer Academic Publishers.

[Brusilovsky and Nejdl, 2004] Brusilovsky, P. and Nejdl, W. (2004). Adaptive Hypermedia and Adaptive Web. In Singh, M. P., editor, *The Practical Handbook of Internet Computing*. CHAPMAN & HALL/CRC.

[Brusilovsky and Pesin, 1998] Brusilovsky, P. and Pesin, L. (1998). Adaptive Navigation Support in Educational Hypermedia: An Evaluation of the ISIS-Tutor. *Journal of Computing and Information Technology*, 6(1):27–38.

[Brusilovsky and Weber, 2001] Brusilovsky, P. and Weber, G. (2001). ELM-ART: An Adaptive Versatile System for Web-Based Instruction. *International Journal of Artificial Intelligence in Education*, 12(4):351–384.

[Bryce and Cremonini, 2001] Bryce, C. and Cremonini, M. (2001). Coordination and Security on the Internet. In Omicini, A., Zambonelli, F., Klusch, M., and Tolksdorf, R., editors, *Coordination of Internet Agents: Models, Technologies, and Applications*, pages 274–298. Springer.

[Buraga, 2003] Buraga, S.-C. (2003). Developing Agent-Oriented E-Learning Systems. In Ioan Dumitrache, C. B., editor, *Proceedings of The 14th International Conference on Control Systems And Computer Science*, volume 2, Bucharest, Romania. Politehnica Press.

[Caire et al., 2001] Caire, G., Garijo, F., Leal, F., Chainho, P., and Massonet, P. (2001). PIR4.3: Case Study Development. EURESCOM Project P907 Technical Information.

[Canales et al., 2007] Canales, A., Peña, A., Peredo, R., Sossa, H., and Gutiérrez, A. (2007). Adaptive and Intelligent Web Based Education System: Towards an Integral Architecture and Framework. *Expert Systems with Applications: An International Journal*, 33(4):1076–1089.

[Cannataro and Pugliese, 2004] Cannataro, M. and Pugliese, A. (2004). A Survey of Architectures for Adaptive Hypermedia. In *Web Dynamics - Adapting to Change in Content, Size, Topology and Use*, pages 357–386. Springer.

[Castelfranchi, 1995] Castelfranchi, C. (1995). Commitments: From Individual Intentions to Groups and Organizations. In Lesser, V. R. and Gasser, L., editors, *Proceedings of the First International Conference on Multiagent Systems*, pages 41–48, San Francisco, California, USA. The MIT Press.

[Castelfranchi, 1996] Castelfranchi, C. (1996). To Be or Not To Be an Agent. In Müller, J. P., Wooldridge, M., and Jennings, N. R., editors, *Intelligent Agents III, Agent Theories, Architectures, and Languages, ECAI '96 Workshop (ATAL), Budapest, Hungary, August 12-13, 1996, Proceedings*, pages 37–39, Budapest, Hungary.

[CEN Workshop Agreement CWA 14040, 2000] CEN Workshop Agreement CWA 14040 (2000). A Standardisation Work Programme for "Learning and Training Technologies & Educational Multimedia Software". URL: http://www.cenorm.be/isss/cwa_download_area/cwa14040.pdf.

[Cerri, 2002] Cerri, S. A. (2002). Human and Artificial Agent's Conversations on the GRID. In *Proceedings of 1st LEGE-WG International Workshop on e-Learning and GRID Technologies: Educational Models for GRID Based Services*.

[Chaib-draa et al., 2006] Chaib-draa, B., Labrie, M.-A., Bergeron, M., and Pasquier, P. (2006). DIAGAL: An Agent Communication Language Based on Dialogue Games and Sustained by Social Commitments. *Autonomous Agents and Multi-Agent Systems*, 13(1):61–95.

[Chainho et al., 2000] Chainho, P., Massonet, P., Garijo, F., Sanz, J. G., Pavon, J., Caire, G., Leal, F., and Stark, J. (2000). Analysis of the UPA Case Study (PIR4.2 Case Study 1 B1). Eurescom project p907 technical information, EURESCOM.

[Chiaramella, 1997] Chiaramella, Y. (1997). Browsing and Querying: Two Complementary Approaches for Multimedia Information Retrieval. In *Proceedings of Hypertext - Information Retrieval - Multimedia '97: Theorien, Modelle und Implementierungen integrierter elektronischer Informationssysteme (HIM '97)*, pages 9–26, Dortmund, Germany.

[Choe and Kim, 2005] Choe, H. and Kim, T. (2005). An Enhanced LTSA Model Providing Contextual Knowledge for Intelligent e-Learning Systems. *Journal of Information Science and Engineering*, 21:849–858.

[Claußen, 1999] Claußen, S. (1999). Lern-Server und elektronischer Studienassistent als virtuelle Dienstleister in der ViKar-Lernumgebung. Interner Bericht 9, Universität Karlsruhe, Fakultät für Informatik.

[Claußen, 2001] Claußen, S. (2001). Software Architekture for the ViKar-Campus (In german). In Wagner, E. and Kindt, M., editors, *Virtueller Campus*, number 14 in Medien in der Wissenschaft, pages 292–301, Hildesheim, Germany. Waxmann Verlag GmbH.

[Cockayne and Zyda, 1997] Cockayne, W. R. and Zyda, M. (1997). *Mobile Agents*. Manning Publications Co.

[Cohen and Levesque, 1990] Cohen, P. R. and Levesque, H. J. (1990). Intention is Choice with Commitment. *Artificial Intelligence*, 42(2-3):213–261.

[Cohen and Levesque, 1991] Cohen, P. R. and Levesque, H. J. (1991). Confirmations and Joint Action. In Mylopoulos, J. and Reiter, R., editors, *Proceedings of the 12th International Joint Conference on Artificial Intelligence (IJCAI'1991)*, pages 951–959, Sydney, Australia. Morgan Kaufmann.

[Corbière and Choquet, 2004] Corbière, A. and Choquet, C. (2004). Designer Integration in Training Cycles: IEEE LTSA Model Adaptation. In *Proceedings of the International Conference on Computer Aided Learning in Engineering Education (CALIE 2004)*, Grenoble, France.

[Cramer, 1994] Cramer, S. F. (1994). Assessing Effectiveness in the Collaborative Classroom. In Bosworth, K. and Hamilton, S., editors, *Collaborative Learning: Underlying Processes and Effective Technique*, pages 69–81. Jossey-Bass.

[Daft and Lengel, 1986] Daft, R. L. and Lengel, R. H. (1986). A Proposed Integration among Organizational Information Requirements, Media Richness, and Structural Design. *Management Science*, 32:554–571.

[Darbyshire and Lowry, 2000] Darbyshire, P. and Lowry, G. (2000). An Overview of Agent Technology and its Application to Subject Management. In *Proceedings of the 2000 Information Resources Management Association International Conference on Challenges of Information Technology Management in the 21st Century*, pages 509–512, Hershey, PA, USA. Idea Group Publishing.

[de Vrieze and van Bommel, 2004] de Vrieze, P. and van Bommel, P. (2004). A Generic Engine for User Model Based Adaptation. In *Proceedings of the 8th ERCIM Workshop - User Interfaces for All*.

[Decker, 1987] Decker, K. S. (1987). Distributed Problem Solving: A Survey. *IEEE Transactions on Systems, Man, and Cybernetics*, 17(5):729–740.

[DeTina and Poehlman, 2002] DeTina, P. and Poehlman, W. F. S. (2002). DISTRIBUTED SYSTEMS II – A Survey of Software Agent Attributes. Technical Report CAS 2002-02-SP, McMaster University, Hamilton, Ontario, Canada, Hamilton, Ontario, Canada.

[Dimitrova et al., 2003a] Dimitrova, M., Hatzipanagos, S., Stadler, C., Chera, P., Murphy, A., and Bakry, W. M. (2003a). Learning Behaviour Patterns in Flexible Distance Higher Education in Asia and North Africa. In *Proceedings of International Conference on Distance Education*, Hong Kong.

[Dimitrova et al., 2003b] Dimitrova, M., Stadler, C., Hatzipanagos, S., and Murphy, A. (2003b). Addressing Learner Diversity by Promoting Flexibility in e-Learning Environments. In *Proceedings of the 14th International Workshop on Database and Expert Systems Applications (DEXA'03)*.

[Dolog et al., 2003] Dolog, P., Henze, N., Nejdl, W., and Sintek, M. (2003). Towards the Adaptive Semantic Web. In François Bry, Nicola Henze, J. M., editor, *Proceedings of the International Workshop on Principles and Practice of Semantic Web Reasoning (PPSWR 2003)*, volume 2901 of *Lecture Notes in Computer Science*, pages 51–68, Mumbai, India. Springer.

[Domjan, 1998] Domjan, M. (1998). *Principles of Learning and Behaviour*. Pacific Grove: Brooks/Cole.

[Dumke et al., 2003] Dumke, R., Lother, M., Wille, C., and Zbrog, F. (2003). *Web Engineering*. Pearson Education Publ.

[Dumke et al., 2000] Dumke, R. R., Koeppe, R., and Wille, C. (2000). Software Agent Measurement and Self-Measuring Agent-Based Systems. Preprint, Otto-von-Guericke University of Magdeburg.

[Dvorak and Buchanan, 2002] Dvorak, J. D. and Buchanan, K. (2002). Using Technology to Create and Enhance Collaborative Learning. In *Proceedings of 14th World Conference on Educational Multimedia, Hypermedia and Telecommunications (ED-MEDIA 2002)*, Denver, Co, USA.

[e-Learning Centre, 2007] e-Learning Centre (2007). Learning Objects and Standards. URL: http://www.e-learningcentre.co.uk/eclipse/Resources/contentmgt.htm (last checked November 07, 2007).

[Eklund and Zeiliger, 1996] Eklund, J. and Zeiliger, R. (1996). Navigating the Web: Possibilities and Practicalities for Adaptive Navigational Support. In *Proceedings of Ausweb'96: The Second Australian World Wide Web Conference*. Southern Cross University Press.

[Etzioni and Weld, 1995] Etzioni, O. and Weld, D. S. (1995). Intelligent Agents on the Internet: Fact, Fiction, and Forecast. *IEEE Expert: Intelligent Systems and Their Applications*, 10(4):44–49.

[Felder and Silverman, 1988] Felder, R. M. and Silverman, L. K. (1988). Learning and Teaching Styles in Engineering Education. *Engineering Education*, 78(7):674–681.

[Ferber, 1999] Ferber, J. (1999). *Multi-Agent Systems*. Addison Wesley, Harlow, UK.

[Fernández-Caballero et al., 2003] Fernández-Caballero, A., López-Jaquero, V., Montero, F., and González, P. (2003). Adaptive Interaction Multi-Agent Systems in E-Learning / E-Teaching on the Web. In Lovelle, J. M. C., Rodríguez, B. M. G., Aguilar, L. J., Gayo, J. E. L., and del Puerto Paule Ruíz, M., editors, *Proceedings of the International Conference on Web Engineering (ICWE 2003)*, volume 2722 of *Lecture Notes in Computer Science*, pages 144–153, Oviedo, Spain. Springer.

[FIN Working Group WDOK, Otto-von-Guericke University of Magdeburg, 2007] FIN Working Group WDOK, Otto-von-Guericke University of Magdeburg (2007). educomponents. URL: http://wdok.cs.uni-magdeburg.de/forschung/projekte/educomponents.

[Foner, 1993] Foner, L. (1993). What's An Agent, Anyway? A Sociological Case Study. Agents memo 93-01, Cambridge, MA: MIT Media Lab.

[Foundation for Intelligent Physical Agents (FIPA), 2002a] Foundation for Intelligent Physical Agents (FIPA) (2002a). FIPA Abstract Architecture Specification. Technical report, Foundation for Intelligent Physical Agents (FIPA).

[Foundation for Intelligent Physical Agents (FIPA), 2002b] Foundation for Intelligent Physical Agents (FIPA) (2002b). FIPA ACL Message Structure Specification. Technical report, Foundation for Intelligent Physical Agents (FIPA).

[Foundation for Intelligent Physical Agents (FIPA), 2002c] Foundation for Intelligent Physical Agents (FIPA) (2002c). FIPA Communicative Act Library Specification. Technical report, Foundation for Intelligent Physical Agents (FIPA).

[Foundation for Intelligent Physical Agents (FIPA), 2006] Foundation for Intelligent Physical Agents (FIPA) (2006). FIPA Agent Management Specification. Technical report, Foundation for Intelligent Physical Agents (FIPA). Available from http://www.fipa.org/.

[Franklin and Graesser, 1996] Franklin, S. and Graesser, A. C. (1996). Is it an Agent, or Just a Program?: A Taxonomy for Autonomous Agents. In *Intelligent Agents III, Agent Theories, Architectures, and Languages, ECAI '96 Workshop (ATAL), Budapest, Hungary, August 12-13, 1996, Proceedings*, pages 21–35, Budapest, Hungary.

[Freeman et al., 1999] Freeman, E., Arnold, K., and Hupfer, S. (1999). *JavaSpaces Principles, Patterns, and Practice*. Addison-Wesley Longman Ltd., Essex, UK, UK.

[Gaede, 2000] Gaede, B. (2000). The Instructional Material Description Language and the production system for interactive learning software ProfiL (in German). In *Proceedings of the 10. Arbeitstreffen der GI-Fachgruppe Intelligente Lehr-/ Lernsysteme*, Hamburg, Germany.

[Ganchev et al., 2007] Ganchev, I., Stojanov, S., O'Droma, M., and Meere, D. (2007). An InfoStation-Based Multi-Agent System Supporting Intelligent Mobile Services Across a University Campus. *Journal of Computers*, 2(3):21–33.

[Garcia et al., 2004] Garcia, A. F., de Lucena, C. J. P., and Cowan, D. D. (2004). Agents in Object-Oriented Software Engineering. *Software Practice and Experience*, 34(5):489–521.

[Garrison, 1990] Garrison, D. R. (1990). An Analysis and Evaluation of Audio Teleconferencing to Facilitate Education at a Distance. *The American Journal of Distance Education*, 4(3):16–23.

[Garro et al., 2003] Garro, A., Leone, N., and Ricca, F. (2003). Logic Based Agents for E-learning. In *Proceedings of the Workshop on Knowledge Representation and Automated Reasoning for E-Learning Systems (18th International Joint Conference on Artificial Intelligence (IJCIA 2003))*, pages 36–45, Acapulco, Mexico.

[Garro and Palopoli, 2002] Garro, A. and Palopoli, L. (2002). An XML Multi-Agent System for e-Learning and Skill Management. In Ryszard Kowalczyk, Jörg P. Müller, H. T. R. U., editor, *Agent Technologies, Infrastructures, Tools, and Applications for E-Services*, volume 2592 of *Lecture Notes in Computer Science*, pages 283–294. Springer. Third International Symposium on Multi-Agent Systems, Large Complex Systems, and E-Businesses (MAL-CEB'2002), Erfurt, Thuringia (Germany).

[Garro and Palopoli, 2003] Garro, A. and Palopoli, L. (2003). MASeL: A Multi-Agent System for e-Learning and Skill Management. *EXP - in search of innovation (Special Issue on JADE)*, 3(3):126–136.

[Gelernter and Carriero, 1992] Gelernter, D. and Carriero, N. (1992). Coordination Languages and their Significance. *Communications of the ACM*, 35(2):97–107.

[Genesereth and Fikes, 1992] Genesereth, M. R. and Fikes, R. E. (1992). Knowledge Interchange Format, Version 3.0 Reference Manual. Technical Report Logic-92-1, Stanford University, Stanford, CA, USA.

[Genesereth and Ketchpel, 1994] Genesereth, M. R. and Ketchpel, S. P. (1994). Software Agents. *Communications of the ACM*, 37(7):48–53.

[Giotopoulos et al., 2005] Giotopoulos, K. C., Alexakos, C. E., Beligiannis, G. N., and Likothanassis, S. D. (2005). Integrating Agents and Computational Intelligence Techniques in E-learning Environments. In *International Enformatika Conference (IEC'05)*, pages 231–238, Prague, Czech Republic.

[Goodwin, 1993] Goodwin, R. (1993). Formalizing Properties of Agents. Technical Report CMU-CS-93-159, School of Computer Science, Carnegie Mellon University.

[Grosof and Labrou, 2000] Grosof, B. N. and Labrou, Y. (2000). An Approach to Using XML and a Rule-Based Content Language with an Agent Communication Language. In *Issues in Agent Communication*, pages 96–117. Springer-Verlag, London, UK.

[Grosz and Sidner, 1990] Grosz, B. and Sidner, C. (1990). Plans for Discourse. In Cohen, P. R., Morgan, J., and Pollack, M. A., editors, *Intentions in Communication*. MIT Press.

[Gruber, 1993] Gruber, T. R. (1993). A Translation Approach to Portable Ontology Specifications. *Knowledge Acquisition*, 5(2):199–220.

[Habermas, 1984] Habermas, J. (1984). *The Theory of Communicative Action, Volume 1: Reason and the Rationalization of Society (The Theory of Communicative Action, Vol 1)*. Heinemann.

[Hall, 1997] Hall, B. (1997). *Web-Based Training Cookbook*. John Wiley & Sons.

[Hall, 2000] Hall, B. (2000). *Learning Management Systems: How to Choose the Right System for Your Organization*. Brandon-hall.com.

[Hambrecht & CO, 2000] Hambrecht & CO (2000). Corporate eLearning: Exploring a new Frontier. Analyst Report. http://www.internettime.com/Learning/articles/hambrecht.pdf.pdf.

[Haugeneder and Steiner, 1998] Haugeneder, H. and Steiner, D. (1998). Co-operating Agents: Concepts and Applications. In Jennings, N. R. and Wooldridge, M. J., editors, *Agent Technology: Foundations, Applications, and Markets*, pages 175–202. Springer-Verlag New York, Inc., Secaucus, NJ, USA.

[Haywood, 1998] Haywood, M. (1998). *Managing Virtual Teams: Practical Techniques for High-Technology Project Managers*. Artech House Publishers.

[Hayzelden and Bigham, 1999a] Hayzelden, A. L. and Bigham, J., editors (1999a). *Software Agents for Future Communication Systems*. Springer-Verlag New York, Inc., Secaucus, NJ, USA.

[Hayzelden and Bigham, 1999b] Hayzelden, A. L. G. and Bigham, J. (1999b). Agent Technology in Communications Systems: An Overview. *Knowledge Engineering Review*, 14(4):341–375.

[Hettrich and Koroleva, 2003] Hettrich, A. and Koroleva, N. (2003). Market Analysis: Learning Management Systems and Learning Content Management Systems (In German). Technical report, Fraunhofer Institut Arbeitswirtschaft und Organisation, Stuttgart, Germany.

[Hindriks et al., 2000] Hindriks, K. V., de Boer, F. S., van der Hoek, W., and Meyer, J.-J. C. (2000). Semantics of Communicating Agents Based on Deduction and Abduction. In Dignum, F. and Greaves, M., editors, *Issues in Agent Communication*, Lecture Notes in Artificial Intelligence, pages 63–79. Springer.

[Hoole and Hoole, 2000] Hoole, D. and Hoole, S. R. H. (2000). Web-based Teaching: Infrastructure Issues in the Third World. In Aggarwal, A. K., editor, *Web-Based Learning and Teaching Technologies: Opportunities and Challenges*, pages 33–41. Idea Group Publishing, Hershey, PA, USA.

[Huang et al., 2000] Huang, Z., Eliens, A., van Ballegooij, A., and de Bra, P. (2000). A Taxonomy of Web Agents. In *Proceedings of the 11th International Workshop on Database and Expert Systems Applications (DEXA'00)*.

[IBM, 2002] IBM (2002). Aglets. URL: http://www.trl.ibm.com/aglets/.

[IEEE LTSC, 2002a] IEEE LTSC (2002a). IEEE P1484.1/D9 Draft Standard for Learning Technology: Learning Technology Systems Architecture (LTSA). Technical report, IEEE.

[IEEE LTSC, 2002b] IEEE LTSC (2002b). IEEE P1484.2, PAPI Learner, Draft 8 Specification. Technical report, IEEE. available from URL: http://edutool.com/papi/.

[IEEE LTSC, 2003] IEEE LTSC (2003). IEEE 1484.12:2002, Standard for Learning Object Metadata. Technical report, IEEE.

[IMS Global Learning Consortium, Inc., 2001] IMS Global Learning Consortium, Inc. (2001). IMS Learner Information Package Specification. Technical report, IMS Global Learning Consortium, Inc.

[IMS Global Learning Consortium, Inc., 2003a] IMS Global Learning Consortium, Inc. (2003a). IMS Abstract Framework: White Paper. Technical report, IMS Global Learning Consortium, Inc.

[IMS Global Learning Consortium, Inc., 2003b] IMS Global Learning Consortium, Inc. (2003b). IMS Content Packaging Best Practice Guide. Technical report, IMS Global Learning Consortium, Inc.

[IMS Global Learning Consortium, Inc., 2003c] IMS Global Learning Consortium, Inc. (2003c). IMS Learner Simple Sequencing Specification. Technical report, IMS Global Learning Consortium, Inc.

[IMS Global Learning Consortium, Inc., 2003d] IMS Global Learning Consortium, Inc. (2003d). IMS Learning Design Specification. Technical report, IMS Global Learning Consortium, Inc.

[IMS Global Learning Consortium, Inc., 2006] IMS Global Learning Consortium, Inc. (2006). IMS Learner Question and Test Interoperability. Technical report, IMS Global Learning Consortium, Inc.

[IMS Global Learning Consortium, Inc., 2007] IMS Global Learning Consortium, Inc. (2007). IMS Learner Content Packaging Specification. Technical report, IMS Global Learning Consortium, Inc.

[Ivers and Barron, 1998] Ivers, K. S. and Barron, A. E. (1998). *Multimedia Projects in Education*. Teacher Ideas Press.

[Jafari, 2002] Jafari, A. (2002). Conceptualizing Intelligent Agents for Teaching and Learning. *EQ Educause Quaterly*, 3(3):28–34.

[Jain et al., 2002] Jain, L. C., Chen, Z., and Ichalkaranje, N., editors (2002). *Intelligent Agents and their Applications*. Physica-Verlag GmbH.

[Jennings and Wooldridge, 1998a] Jennings, N. R. and Wooldridge, M. J. (1998a). *Agent Technology - Foundation, Application, and Markets*. Springer Publ.

[Jennings and Wooldridge, 1998b] Jennings, N. R. and Wooldridge, M. J. (1998b). Applications of Intelligent Agents. In *Agent Technology: Foundations, Applications, and Markets*, pages 3–28. Springer-Verlag New York, Inc., Secaucus, NJ, USA.

[Jeon et al., 2000] Jeon, H., Petrie, C. J., and Cutkosky, M. R. (2000). JATLite: A Java Agent Infrastructure with Message Routing. *IEEE Internet Computing*, 4(2):87–96.

[Juneidi and Vouros, 2005] Juneidi, S. J. and Vouros, G. A. (2005). Engineering an E-learning Application using the ARL Theory for Agent Oriented Software Engineering. In *2005 AAAI Fall Symposium*, Arlington, Virginia, USA. MIT press.

[Kabassi and Virvou, 2003] Kabassi, K. and Virvou, M. (2003). Learner Modelling in a Multi-Agent System through Web Services. In Devedzic, V., Spector, J. M., Sampson, D. G., and Kinshuk, editors, *Proceedings of 2003 IEEE International Conference on Advanced Learning Technologies: Technology Enhanced Learning - ICALT 2003*, pages 115–119, Athens, Greece.

[Kadiyala and Crynes, 1998] Kadiyala, M. and Crynes, B. L. (1998). Where's the Proof? A Review of Literature in Effectivenes of Information Technology in Education. In *Proceedings of the 1998 Frontiers in Education Conference (FIE 1998)*, volume 1, pages 33–37, Tempe Arizona, USA.

[Kaipa, 1998] Kaipa, P. (1998). Design Organizations that Learn: An Executive Guide to Learning. *Chinmaya Management Review*.

[Kargl et al., 1999] Kargl, F., Illmann, T., and Weber, M. (1999). CIA - a Collaboration and Coordination Infrastructure for Personal Agents. In *Proceedings of the IFIP WG 6.1 International Working Conference on Distributed Applications and Interoperable Systems II (DAIS 1999)*, pages 213–218, Helsinki, Finland. Kluwer, B.V.

[Kearney et al., 2000] Kearney, P., Stark, J., Leal, F., and Rodrigues, J. P. (2000). Analysis of the ACSOSS Case Study (PIR 4.2 B.0). Eurescom project p907 technical information, EURESCOM.

[Kernchen, 2004] Kernchen, S. (2004). Evaluation of ALIVE - Implemented with the Grasshopper Technology (Case study in german). Technical report, University of Magdeburg.

[Kernchen, 2005] Kernchen, S. (2005). Adaptive Web-Content in the Context of Lecture Notes (in German). Master's thesis, Otto-von-Guericke University of Magdeburg.

[Kernchen and Dumke, 2007] Kernchen, S. and Dumke, R. (2007). Autonomous Management of User Models for Lifelong Learning. *IEEE Multidisciplinary Engineering Education Magazine*, 2(2):44–50. ISSN 1558-7908.

[Kernchen et al., 2006] Kernchen, S., Farooq, A., Dumke, R., and Wille, C. (2006). Evaluation of Java-Based Agent Technologies. In Abran, A., Bundschuh, M., Büren, G., and Dumke, R., editors, *Proceedings of the International Workshop on Software Measurement and DASMA Software Metrik Kongress (IWSM/MetriKon 2006)*, Potsdam, Germany. Shaker Verlag.

[Kernchen and Vornholt, 2004] Kernchen, S. and Vornholt, S. (2004). The Agent System ALIVE (in German). Internship Report at the University of Magdeburg.

[Kinny et al., 1994] Kinny, D., Ljungberg, M., Rao, A. S., Sonenberg, L., Tidhar, G., and Werner, E. (1994). Planned Team Activity. In *MAAMAW '92: Selected Papers from the 4th European Workshop on Modelling Autonomous Agents in a Multi-Agent World, Artificial Social Systems*, pages 227–256, London, UK. Springer-Verlag.

[Klimecki and Lassleben, 1999] Klimecki, R. and Lassleben, H. (1999). What causes organizations to learn? In Easterby-Smith, M., Araujo, L., and Burgoyne, J., editors, *Proceedings of the 3rd International Conference on Organizational Learning*, volume 2, pages 551–577, Lancaster, UK.

[Klobas and Renzi, 2000] Klobas, J. and Renzi, S. (2000). Selecting Software and Services for Web-Based Teaching and Learning. In Aggarwal, A. K., editor, *Web-Based Learning and*

Teaching Technologies: Opportunities and Challenges, pages 43–59. Idea Group Publishing, Hershey, PA, USA.

[Kobsa and Wahlster, 1998] Kobsa, A. and Wahlster, W. (1998). *User Models in Dialog Systems*. Springer.

[Koper, 2001] Koper, R. (2001). Modeling Units of Study from a Pedagogical Perspective the Pedagogical Meta-Model behind EML. URL http://dspace.ou.nl/bitstream/1820/36/1/Pedagogical+metamodel+behind+EMLv2.pdf.

[Koper and Olivier, 2004] Koper, R. and Olivier, B. (2004). Representing the Learning Design of Units of Learning. *Educational Technology & Society*, 7(3):97–111.

[Koper and Sloep, 2003] Koper, R. and Sloep, P. (2003). Learning Networks - Connecting People, Organizations, Autonomous Agents and Learning Resources to Establish the Emergence of Effective Lifelong Learning. Link: http://learningnetworks.org.

[Koyama et al., 2001] Koyama, A., Barolli, L., Tsuda, A., and Cheng, Z. (2001). An Agent-Based Personalized Distance Learning System. In *Proceedings of the 15th International Conference on Information Networking (ICOIN'01)*, pages 895–899, Beppu City, Japan.

[Kron and Sofos, 2003] Kron, F. W. and Sofos, A. (2003). *Media Didactic (in German)*. Ernst Reinhardt Verlag.

[Kruse, 2003] Kruse, W. (2003). Lifelong Learning in Germany - Financing and Innovation: Skill Development, Education Networks, Support Structures. Technical report, Federal Ministry of Education and Research (BMBF).

[Kukulska-Hulme, 2002] Kukulska-Hulme, A. (2002). Cognitive, Ergonomic and Affective Aspects of PDA Use for Learning. In *Proceedings of the European Workshop on Mobile and Contextual Learning*, pages 32–33, Birmingham, UK.

[Kulik and Kulik, 1991] Kulik, C.-L. C. and Kulik, J. A. (1991). Effectiveness of Computer-Based Instruction: An Updated Analysis. *Computer in Human Behaviour*, 7(1-2):75–94.

[Kulik, 1994] Kulik, J. M. (1994). Meta-analytic studies of findings on computer-based instruction. In O'Neil, H. F. and Baker, E. L., editors, *Technology Assessment in Education and Training*, pages 9–33. Lawrence Erlbaum Associates.

[Kuwabara et al., 1995] Kuwabara, K., Ishida, T., and Osato, N. (1995). AgenTalk: Coordination Protocol Description for Multiagent Systems. In Lesser, V. R. and Gasser, L., editors, *Proceedings of the First International Conference on Multiagent Systems*, page 455, San Francisco, California, USA. The MIT Press.

[Laakko and Hiltunen, 2005] Laakko, T. and Hiltunen, T. (2005). Adapting Web Content to Mobile User Agents. *IEEE Internet Computing*, 9(2):46–53.

[Labrou and Finin, 1997] Labrou, Y. and Finin, T. (1997). A Proposal for a new KQML Specification. Technical Report TR CS-97-03, Computer Science and Electrical Engineering Department, University of Maryland Baltimore County, Baltimore, MD 21250. Also available online at http://www.cs.umbc.edu/kqml/.

[Labrou and Finin, 1998] Labrou, Y. and Finin, T. (1998). Semantics and Conversations for an Agent Communication Language. In *Readings in Agents*, pages 235–242. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA.

[Lange and Oshima, 1998] Lange, D. B. and Oshima, M. (1998). *Programming and Deploying Java(TM) Mobile Agents with Aglets(TM)*. Addison-Wesley.

[Lin and Yang, 2004] Lin, H. and Yang, C. (2004). Chemical Reaction Metaphor in Distributed Learning Environments. In Robert Orchard, Chunsheng Yang, M. A., editor, *Proceedings of the International Conference on Industrial & Engineering. Applications of Artifical Intelligence & Expert Systems (IEA/AIE-2004)*, volume 3029 of *Lecture Notes in Computer Science*, pages 857–866, Ottawa, Ontario, Canada. Springer.

[Liu and Ye, 2001] Liu, J. and Ye, Y., editors (2001). *E-Commerce Agents, Marketplace Solutions, Security Issues, and Supply and Demand*, volume 2033 of *Lecture Notes in Computer Science*. Springer.

[Maddocks et al., 2000] Maddocks, A. P., Sher, W. D., and Wilson, A. (2000). A Web-Based Personal and Professional Development Tool to Promote Lifelong Learning Within the Construction Industry. *Educational Technology and Society*, 3(1):77–83.

[Maes, 1996] Maes, P. (1996). Intelligent Software: Easing the Burdens that Computers Put on People. *IEEE Expert: Intelligent Systems and Their Applications*, 11(6):62–63.

[Maes, 1997] Maes, P. (1997). Agents that Reduce Work and Information Overload. In *Software Agents*, pages 145–164. MIT Press, Cambridge, MA, USA.

[Malone and Crowston, 1994] Malone, T. W. and Crowston, K. (1994). The Interdisciplinary Study of Coordination. *ACM Computing Surveys*, 26(1):87–119.

[Malone and Lepper, 1987] Malone, T. W. and Lepper, M. R. (1987). Making Learning Fun: A Taxonomy of Intrinsic Motivations for Learning. In Snow, R. E. and Farr, M. J., editors, *Aptitude, Learning and Instruction: III. Conative and Affective Process Analyses*, pages 223–253. Erlbaum: Hilsdale.

[Mantyla and Gividen, 1997] Mantyla, K. and Gividen, J. R. (1997). *Distance Learning: A Step-by-Step Guide for Trainers*. American Society for Training and Development.

[Marchionini, 2006] Marchionini, G. (2006). Exploratory Search: From Finding to Understanding. *Communications of the ACM*, 49(4):41–46.

[Markham et al., 2003] Markham, S., Ceddia, J., Sheard, J., Burvill, C., Weir, J., Field, B., Sterling, L., and Stern, L. (2003). Applying Agent Technology to Evaluation Tasks in e-Learning Environments. In *Proceedings of the Exploring Educational Technologies Conference*, pages 1–7, Melbourne, Australia.

[Mason, 1998] Mason, R. (1998). Models of Online Courses. In *Proceedings of the Conference "Networked Lifelong Learning: Innovative Approaches to Education and Training Through the Internet"*, Sheffield, UK.

[Matsubayashi and Tokoro, 1993] Matsubayashi, K. and Tokoro, M. (1993). A Collaboration Mechanism on Positive Interactions in Multi-agent Environments. In Bajcsy, R., editor, *Proceedings of the 13th International Joint Conference on Artificial Intelligence (IJCAI 1993)*, pages 346–351, Chambéry, France. Morgan Kaufmann.

[Maurer and Dietinger, 1997] Maurer, H. and Dietinger, T. (1997). MANKIND: A General Description.

[McArdle, 1999] McArdle, G. E. (1999). *Training Design and Delivery*. American Society for Training and Development.

[Mencke, 2007] Mencke, N. (2007). Development of a General Interface for the Coupling of Real Control Units with Virtual Facilities (In german). Master's thesis, Diploma Thesis at the Otto-von-Guericke University of Magdeburg. (Diploma Thesis).

[Mencke and Dumke, 2007a] Mencke, S. and Dumke, R. R. (2007a). A Framework for Agent-Supported E-learning. In Auer, M. E., editor, *Proceedings of the International Conference on Interactive Computer aided Learning (ICL2007)*, Villach, Austria.

[Mencke and Dumke, 2007b] Mencke, S. and Dumke, R. R. (2007b). A Hierarchy of Ontologies for Didactics-Enhanced E-learning. In Auer, M. E., editor, *Proceedings of the International Conference on Interactive Computer aided Learning (ICL2007)*, Villach, Austria.

[Milgrom et al., 2001] Milgrom, E., Chainho, P., Deville, Y., Evans, R., Kearney, P., and Massonet, P. (2001). MESSAGE - Methodology for Engineering Systems of Software Agents (Final Guidelines for the Identification of Relevant Problem Areas where Agent Technology is Appropriate). Technical report, EURESCOM.

[Müller et al., 2005] Müller, C., Trier, M., and Herzog, M. A. (2005). Process-oriented Production of Learning Units for sustainable E-Learning Offerings. In Breitner, M. H. and Hoppe, G., editors, *E-Learning - Einsatzkonzepte und Geschäftsmodelle*, pages 331–348. Physica-Verlag, Heidelberg, Germany.

[Müller, 1996] Müller, J. P. (1996). *The Design of Intelligent Agents: A Layered Approach*, volume 1177 of *Lecture Notes in Computer Science*. Springer.

[Müller et al., 1995] Müller, J. P., Pischel, M., and Thiel, M. (1995). Modeling Reactive Behaviour in Vertically Layered Agent Architectures. In *ECAI-94: Proceedings of the Workshop on Agent Theories, Architectures, and Languages on Intelligent Agents*, pages 261–276, New York, NY, USA. Springer-Verlag New York, Inc.

[MMB Institut für Medien- und Kompetenzforschung, 2004] MMB Institut für Medien- und Kompetenzforschung (2004). E-learning Employee Usage Potentials (In german). Study of the nordmedia - Die Mediengesellschaft Niedersachsen / Bremen mbH.

[MOBIlearn Project Consortium, 2005] MOBIlearn Project Consortium (2005). MOBIlearn - Final Project Report. Technical report, MOBIlearn Project Consortium.

[Mohammed and Mohan, 2005] Mohammed, P. and Mohan, P. (2005). Agent Based Learning Objects on the Educational Semantic Web. In *Proceedings of the 2nd Annual e-Learning Conference on Intelligent Interactive Learning Object Repositories (I2LOR-2005)*, Vancouver, Canada.

[Montaner et al., 2003] Montaner, M., López, B., and De La Rosa, J. L. (2003). A Taxonomy of Recommender Agents on the Internet. *Artificial Intelligence Review*, 19(4):285–330.

[Moodle Project, 2007] Moodle Project (2007). URL: http://moodle.org/.

[Moore, 1973] Moore, M. G. (1973). Towards a Theory of Independent Learning and Teaching. *Journal of Higher Education*, 44(9):661–679.

[Moore, 2000] Moore, S. A. (2000). On Conversation Policies and the Need for Exceptions. In Dignum, F. and Greaves, M., editors, *Issues in Agent Communication*, pages 144–159. Springer-Verlag, London, UK.

[Nelson, 2000] Nelson, M. (2000). *Buckets: Smart Objects in Digital Libraries*. PhD thesis, Old Dominion University.

[Netquest, 1998] Netquest (1998). Tutorial Markup Language (TML). URL: http://www.ilrt.bris.ac.uk/netquest/about/lang/.

[Newell and Simon, 1976] Newell, A. and Simon, H. A. (1976). Computer Science as Empirical Enquiry. *Communication of the ACM*, 19:113–126.

[Nkambou, 2006] Nkambou, R. (2006). Towards Affective Intelligent Tutoring System. In *Proceedings of the 8th International Conference on Intelligent Tutoring Systems*, Jhongli, Taiwan.

[Nkambou and Kabanza, 2001] Nkambou, R. and Kabanza, F. (2001). Designing Intelligent Tutoring Systems: A Multiagent Planning Approach. *SIGCUE Outlook*, 27(2):46–60.

[Nonaka and Takeuchi, 1995] Nonaka, I. and Takeuchi, H. (1995). *The Knowledge Creating Company*. Oxford University Press, New York, USA.

[Nwana, 1996] Nwana, H. S. (1996). Software Agents: An Overview. *Knowledge Engineering Review*, 11(3):205–244.

[Nwana et al., 1997] Nwana, H. S., Lee, L. C., and Jennings, N. R. (1997). Coordination in Multi Agent Systems. In *Software Agents and Soft Computing: Towards Enhancing Machine Intelligence*, volume 1198 of *Lecture Notes in Artificial Intelligence*, pages 42–58. Springer.

[Nwana and Ndumu, 1998] Nwana, H. S. and Ndumu, D. T. (1998). A Brief Introduction to Software Agent Technology. In *Agent Technology: Foundations, Applications, and Markets*, pages 29–47. Springer-Verlag New York, Inc., Secaucus, NJ, USA.

[Object Management Group (OMG), 2000] Object Management Group (OMG) (2000). Mobile Agent Facility Specification. Technical report, Object Management Group (OMG).

[Oblinger and Rush, 1998] Oblinger, D. G. and Rush, S. C. (1998). *The Future Compatible Campus*. Anker Publisher Company, Inc.

[O'Leary, 1998] O'Leary, D. E. (1998). Enterprise Knowledge Management. *IEEE Computer Journal*, 31(3):54–61.

[O'Malley and DeLoach, 2002] O'Malley, S. A. and DeLoach, S. (2002). Determining When to Use an Agent-Oriented Software Engineering Paradigm. In *AOSE '01: Revised Papers and Invited Contributions from the Second International Workshop on Agent-Oriented Software Engineering II*, pages 188–205, London, UK. Springer-Verlag.

[Omicini et al., 2001] Omicini, A., Zambonelli, F., Klusch, M., and Tolksdorf, R., editors (2001). *Coordination of Internet Agents - Models, Technologies, and Applications*. Springer.

[Open Knowledge Initiative, 2003] Open Knowledge Initiative (2003). O.K.I. Architectural Concepts. Technical report, Massachusetts Institute of Technology.

[Ormrod, 2004] Ormrod, J. E. (2004). *Human Learning*. Pearson Education, Inc.

[Pankratius et al., 2004] Pankratius, V., Sandel, O., and Stucky, W. (2004). Retrieving Content with Agents in Web Service E-Learning Systems. In *The Symposium on Professional Practice in AI, IFIP WG12.5 - First IFIP Conference on Artificial Intelligence Applications and Innovations (AIAI)*, Toulouse, France.

[Pankratius and Vossen, 2003] Pankratius, V. and Vossen, G. (2003). Towards E-Learning Grids: Using Grid Computing in Electronic Learning. In *Proceedings of the IEEE Workshop on Knowledge Grid and Grid Intelligence (in conjunction with 2003 IEEE/WIC International Conference on Web Intelligence / Intelligent Agent Technology)*, pages 4–15, Halifax, Canada.

[Papadopoulos, 2001] Papadopoulos, G. A. (2001). Models and Technologies for the Coordination of Internet Agents: A Survey. In Omicini, A., Zambonelli, F., Klusch, M., and Tolksdorf, R., editors, *Coordination of Internet Agents: Models, Technologies, and Applications*, pages 25–56. Springer.

[Papert, 1993] Papert, S. (1993). *The Children's Machine: Rethinking School in the Age of the Computers*. Basic Books, New York, USA.

[Parunak, 1996] Parunak, H. V. D. (1996). Applications of Distributed Artificial Intelligence in Industry. In O'Hare, G. M. P. and Jennings, N. R., editors, *Foundations of Distributed Artificial Intelligence*, pages 71–76. John Wiley & Sons.

[Pawlowski, 2000] Pawlowski, J. M. (2000). The Essen Learning Model a Multi-Level Development Model. *Staff and Education Development International*, 4.

[Pawlowski, 2001] Pawlowski, J. M. (2001). *The Essen Learning Model: A model for the development of computer-supported learning environments.* PhD thesis, University of Essen.

[Petrie, 2000] Petrie, C. J. (2000). Agent-Based Software Engineering. In Ciancarini, P. and Wooldridge, M., editors, *First International Workshop on Agent-Oriented Software Engineering (AOSE 2000)*, pages 59–76. Springer, Limerick, Ireland.

[Phillips and Soltis, 1991] Phillips, D. C. and Soltis, J. F. (1991). *Perspectives on Learning*. Teachers College Press.

[Phorncharoen and Chittayasothorn, 2005] Phorncharoen, S. and Chittayasothorn, S. (2005). The Extended of IEEE LTSA Model for an e-Learning VUIS based on Object-Oriented Database. In Hamza, M. H., editor, *Proceedings of the 15th IASTED Conference on Applied Simulation and Modelling (ASM 2005)*, Benalmádena, Spain.

[Pitt and Mamdani, 2000] Pitt, J. and Mamdani, A. (2000). Communication Protocols in Multi-Agent Systems: A Development Method and Reference Architecture. In Dignum, F. and Greaves, M., editors, *Issues in Agent Communication*, volume 1916 of *Lecture Notes in Computer Science*, pages 160–177. Springer.

[Porter, 1994] Porter, D. (1994). New directions in distance learning: Interim report.

[Porter, 1997] Porter, L. R. (1997). *Creating the Virtual Classroom: Distance Learning with the Internet* . John Wiley & Sons, Inc.

[Preece et al., 1994] Preece, J., Rogers, Y., Sharp, H., and Benyon, D. (1994). *Human-Computer Interaction*. Addison-Wesley Longman Ltd., Essex, UK.

[Race and Brown, 1995] Race, P. and Brown, S. (1995). Getting the word right. In Percival, F., Land, R., and Edgar-Nevill, D., editors, *Computer-Assisted and Open Access Education*, Aspects of Educational and Training Technology Series, London, UK. Kogan Page, Limited.

[Rahkila, 2001] Rahkila, M. (2001). A Double Agent Architecture for eLearning Applications. In *Proceedings of the ICEE 2001 Conference*, volume 1, Oslo, Norway.

[Rao and Georgeff, 1991] Rao, A. S. and Georgeff, M. P. (1991). Modelling Rational Agents within a BDI-Architecture. In *Proceedings of the Second International Conference on Principles of Knowledge Representation and Reasoning*, pages 473–484. Morgan Kaufman Publishers.

[Rodríguez-Artacho and Maíllo, 2004] Rodríguez-Artacho, M. and Maíllo, M. F. V. (2004). Modeling Educational Content: The Cognitive Approach of the PALO Language. *Educational Technology & Society*, 7(3):124–137.

[Rodríguez-Artacho et al., 1999] Rodríguez-Artacho, M., Maíllo, M. F. V., Mayorga, J. I., and Calero, M. Y. (1999). Using a High-Level Language to Describe and Create Web-Based Learning Scenarios. In *Proceedings of the 29th ASEE/IEEE Frontiers in Education Conference*, San Juan, Puerto Rico.

[Rossi et al., 2001] Rossi, D., Cabri, G., and Denti, E. (2001). Tuple-based Technologies for Coordination. In Omicini, A., Zambonelli, F., Klusch, M., and Tolksdorf, R., editors, *Coordination of Internet Agents: Models, Technologies, and Applications*, pages 83–109. Springer.

[Russell and Norvig, 1995] Russell, S. and Norvig, P. (1995). *Artificial Intelligence: A Modern Approach*. Prentice Hall.

[Russell, 2001] Russell, T. L. (2001). *The No Significant Difference Phenomenon*. The International Distance Education Certification Center, 5th edition.

[Sadiig, 2005] Sadiig, I. A. M. J. (2005). An Autonomous Mobile Agent-Based Distributed Learning Architecture-A Proposal and Analytical Analysis. *The Turkish Online Journal of Distance Education*, 6(4):106–117.

[Salmon, 2004] Salmon, G. (2004). *E-Moderating, The Key to Teaching and Learning Online*. Taylor & Francis.

[Sampson and Karagiannidis, 2002] Sampson, D. and Karagiannidis, C. (2002). Knowledge-on-Demand in e-Learning and e-Working Settings. *Educational Technology & Society*, 5(2).

[Sampson et al., 2002] Sampson, D., Karagiannidis, C., and Cardinali, F. (2002). An Architecture for Web-based e-Learning Promoting Re-usable Adaptive Educational e-Content. *Educational Technology & Society*, 5(4).

[Schools Interoperability Framework (SIF) Association, 2007] Schools Interoperability Framework (SIF) Association (2007). Schools Interoperability Framework Implementation Specification 2.0r1. Technical report, Schools Interoperability Framework (SIF) Association.

[Schoop, 2001] Schoop, M. (2001). An Introduction to the Language-Action Perspective. *ACM SIGGROUP Bulletin*, 22(2):3–8.

[Searle, 1969] Searle, J. R. (1969). *Speech Acts: An Essay in the Philosophy of Language*. Cambridge University Press.

[Self, 1994] Self, J. (1994). Formal Approaches to Student Modelling. In Greer, J. E. and McCalla, G. I., editors, *Student Modelling: The Key to Individualized Knowledge-Based Instruction*, volume 25 of *NATO ASI Series F: Computer and Systems Sciences*. Springer.

[Shannon, 1948] Shannon, C. E. (1948). A Mathematical Model of Communication. *Bell Systems Technical Journal*, 27(3):379–423.

[Shannon and Weaver, 1949] Shannon, C. E. and Weaver, W. (1949). *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, Illinois, USA.

[Sheppard et al., 1998] Sheppard, S. D., Reamon, D., Friedlander, L., Kerns, C., Leifer, L., Marincovich, M., and Toye, G. (1998). Assessment of Technology-Assisted Learning in Higher Education: It Requires New Thinking by Universities and Colleges. In *Proceedings of 1998 Frontiers in Education Conference*, pages 141–145, Tempe, USA.

[Shi et al., 2000] Shi, H., Shang, Y., and Chen, S.-S. (2000). A Multi-Agent System for Computer Science Education. In *Proceedings of the 5th Annual Conference on Innovation and Technology in Computer Science Education (ITiCSE 2000)*, pages 1–4, Helsinki, Finland.

[Shneiderman, 1998] Shneiderman, B. (1998). *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA.

[SIVECO Romania SA., 2005] SIVECO Romania SA. (2005). Advanced eLearning Objects.

[Skarmeas, 1999] Skarmeas, N. (1999). *Agents as Objects with Knowledge Base State*. Imperial College Press.

[Smith, 1980] Smith, R. G. (1980). The Contract Net Protocol: High-Level Communication and Control in a Distributed Problem Solver. *IEEE Transactions on Computers*, C-29(12):1104–1113.

[Smolle and Sure, 2002] Smolle, P. and Sure, Y. (2002). FRED: Ontology-based Agents for Enabling E-Coaching Support in a Large Company. In *Second International Workshop on Ontologies in Agent Systems (OAS 2002), held at the 1st International Conference on Autonomous Agents & Multiagent Systems*, Bologna, Italy.

[Sánchez, 1997] Sánchez, J. A. (1997). A Taxonomy of Agents. Technical Report ICT-97-1, Universidad de las Américas-Puebla, México.

[Soh et al., 2005a] Soh, L.-K., Blank, T., Miller, L. D., and Person, S. (2005a). ILMDA: An Intelligent Learning Materials Delivery Agent and Simulation. In *Proceedings of the 2005 IEEE International Conference on Electro Information Technology (EIT'2005)*, Lincoln, USA.

[Soh et al., 2004] Soh, L.-K., Jiang, H., and Ansorge, C. (2004). Agent-Based Cooperative Learning: A Proof-of-Concept Experiment. In *Proceedings of the 35th SIGCSE Technical Symposium on Computer Science Education*, pages 368–372, Norfolk, USA.

[Soh et al., 2005b] Soh, L.-K., Miller, L. D., Blank, T., and Person, S. (2005b). ILMDA: Intelligent Learning Materials Delivery Agents. In *IEEE International Conference on Electro Information Technology*, Lincoln, USA.

[Soliman et al., 1999] Soliman, F., Duncan, G., and Beckett, R. (1999). A Comprehensive Organizational Model for Enterprise Knowledge Management. In *Proceedings of the 1st International Conference on Enterprise Information Systems*, page 783, Setubal, Portugal.

[Soloway, 1998] Soloway, E. (1998). The Need: Moving Beyond Ease of Use To Supporting Learning. In *Human Factors in Computing Systems: Learner Centered Design Workshop*, Los Angeles, CA, USA.

[Süss, 2000] Süss, C. (2000). Adaptive Knowledge Management: A Meta-Modeling Approach and its Binding to XML. In Klein, H.-J., editor, *12th GI-Workshop Grundlagen von Datenbanken*.

[Stojanov et al., 2005] Stojanov, S., Ganchev, I., Popchev, I., O'Droma, M., and Doychev, E. (2005). An Approach for the Development of Agent-Oriented Distributed eLearning Center. In *International Conference on Computer Systems and Technologies - CompSysTech' 2005*, Varna, Bulgaria.

[Stone and Veloso, 2000] Stone, P. and Veloso, M. M. (2000). Multiagent Systems: A Survey from a Machine Learning Perspective. *Autonomous Robots*, 8(3):345–383.

[SUN Microsystems, Inc., 2003] SUN Microsystems, Inc. (2003). E-learning Framework. Technical report, SUN Microsystems, Inc.

[Sycara et al., 1996] Sycara, K., Pannu, A., Williamson, M., Zeng, D., and Decker, K. (1996). Distributed Intelligent Agents. *IEEE Expert: Intelligent Systems and Their Applications*, 11(6):36–46.

[Tanenbaum and van Steen, 2002] Tanenbaum, A. S. and van Steen, M. (2002). *Distributed Systems: Principles and Paradigms*. Prentice Hall.

[Tannenbaum, 1998] Tannenbaum, R. S. (1998). *Theoretical Foundations of Multimedia*. W. H. Freeman & Co., New York, NY, USA.

[Telecom Italia, 2007] Telecom Italia (2007). JADE. URL: http://jade.tilab.com/.

[Tessier et al., 2001] Tessier, C., Chaudron, L., and Müller, H.-J., editors (2001). *Conflicting Agents - Conflict Management in Multi-Agent Systems*. Kluwer Academic Publishers.

[Tetiwat and Igbaria, 2000] Tetiwat, O. and Igbaria, M. (2000). Opportunities in Web-Based Teaching: The Future of Education. In Aggarwal, A. K., editor, *Web-Based Learning and Teaching Technologies: Opportunities and Challenges*, pages 17–32. Idea Group Publishing, Hershey, PA, USA.

[The MadKit Project, 2005] The MadKit Project (2005). MadKit. URL: http://www.madkit.org/.

[Tidhar et al., 1992] Tidhar, G., Rao, A., Ljungberg, M., Kinny, D., and Sonenberg, E. (1992). Skills and Capabilities in Real-Time Team Formation. Technical Report 27, Australian Artificial Intelligence Institute.

[Tight, 1996] Tight, M. (1996). *Concepts in Adult Education and Training*. Routledge, London, UK.

[Trabucchi, 2001] Trabucchi, R. (2001). The KOD (Knowledge on Demand) Packaging Toolkit. In *3rd SCHEMAS Workshop*, Budapest, Hungary.

[Ueno, 2001] Ueno, M. (2001). Student Models Construction by using Information Criteria. In *Proceedings of IEEE International Conference of ALT*, pages 331–334.

[Ueno, 2005] Ueno, M. (2005). Intelligent LMS with an Agent that Learns from Log Data. In Richards, G., editor, *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education (ELEARN) 2005*, pages 3169–3176, Vancouver, Canada.

[UNESCO, 1987] UNESCO (1987). *UNESCO, Distance Learning Systems and Structures: Training Manual, Report of a Sub-Regional Training Workshop*. Bangkok : UNESCO Regional Office for Education in Asia and the Pacific, Colombo, Sri Lanka.

[van Rosmalen et al., 2005] van Rosmalen, P., Brouns, F., Tattersall, C., Vogten, H., van Bruggen, J., Sloep, P., and Koper, R. (2005). Towards an Open Framework for Adaptive, Agent-Supported E-learning. *International Journal of Continuing Engineering Education and Lifelong Learning*, 15(3-6):261–275.

[Vasudevan, 1998] Vasudevan, V. (1998). Comparing Agent Communication Languages. Url: http://www.objs.com/agility/tech-reports/9807-comparing-acls.html, Object Services and Consulting, Inc.

[Virvou and Kabassi, 2002] Virvou, M. and Kabassi, K. (2002). F-SMILE: An Intelligent Multi-Agent Learning Environment. In *Proceedings of 2002 IEEE International Conference on Advanced Learning Technologies - ICALT 2002*.

[Virvou and Katsionis, 2003] Virvou, M. and Katsionis, G. (2003). Web Services for an Intelligent Tutoring System that Operates as a Virtual Reality Game. In *IEEE International Conference on Systems, Man and Cybernetics 2003*, volume 1, pages 378–383, Washington, D.C., USA.

[Virvou et al., 2005] Virvou, M., Katsionis, G., and Manos, K. (2005). Combining Software Games with Education: Evaluation of its Educational Effectiveness. *Educational Technology & Society*, 8(2):54–65.

[vom Brooke, 2005] vom Brooke, J. (2005). Multi-Channel Strategies for the Dissemination of Technology-Enhanced Learning Processes. Technical Report Working Report Nr. 3, European Research Center for Information Systems - Universitäty of Münster.

[Voskamp and Hambach, 2001] Voskamp, J. and Hambach, S. (2001). Extending the IEEE - LTSA. In Montgomerie, C. and Viteli, J., editors, *Proceedings of the World Conference on Educational Multimedia, Hypermedia and Telecommunications (EDMEDIA 2001)*, pages 1967–1972, Norfolk, Canada.

[Walther, 1992] Walther, J. B. (1992). Interpersonal Effects in Computer-Mediated Interaction: A Relational Perspective. *Communication Research*, 19:52–90.

[Walther, 1995] Walther, J. B. (1995). Relational Aspects of Computer-Mediated Communication: Experimental Observations Over Time. *Organization Science*, 6:186–203.

[Walton and Krabbe, 1995] Walton, D. N. and Krabbe, E. C. W. (1995). *Commitment in Dialogue: Basic Concepts of Interpersonal Reasoning*. State University of New York Press.

[Waycott et al., 2002] Waycott, J., Scanlon, E., and Jones, A. (2002). Evaluating the Use of PDAs as Learning and Workplace Tools: An Activity Theory Perspective. In *Proceedings of the European Workshop on Mobile and Contextual Learning*, pages 34–35, Birmingham, UK.

[Webber et al., 2001] Webber, C., Bergia, L., Pesty, S., and Balacheff, N. (2001). The Baghera Project: A Multi-Agent Architecture for Human Learning. In *Proceedings of the Workshop Multi-Agent Architectures for Distributed Learning Environments (AIED 2001)*, pages 1060–1069, San Antonio, USA.

[Webster and Hackley, 1997] Webster, J. and Hackley, P. (1997). Teaching Effectiveness in Technology-Mediated Distance Learning. *Academy of Management Review*, 40(6):1282–1309.

[Wegner, 1996] Wegner, P. (1996). Coordination as Constrained Interaction. In Ciancarini, P. and Hankin, C., editors, *Coordination Languages and Models - Proceedings of the 1st International Conference (COORDINATION'96)*, volume 1061 of *Lecture Notes in Computer Science*, pages 28–33, Cesana, Italy. Springer.

[Weiss and Jakob, 2005] Weiss, G. and Jakob, R. (2005). *Agent-Oriented Software Development (in German)*, chapter MadKit, pages 231–243. Springer.

[Whalen and Hackley, 1998] Whalen, T. and Hackley, P. (1998). Distance Training in the Virtual Workplace. In Igbaria, M. and Tan, M., editors, *The Virtual Workplace*. Idea Group Publishing, Hershey, PA, USA.

[Wild and Quinn, 1998] Wild, M. and Quinn, C. (1998). Implications of Educational Theory for the Design of Instructional Multimedia. *British Journal of Educational Technology*, 29(1):73–82.

[Wiley, 2000] Wiley, D. A. (2000). *Learning Object Design and Sequencing Theory*. PhD thesis, Brigham Young University.

[Wille, 2005] Wille, C. (2005). *Agent Measurement Framework*. PhD thesis, Otto-von-Guericke University of Magdeburg.

[Wille et al., 2002] Wille, C., Dumke, R., and Stojanow, S. (2002). Quality Assurance in Agent-Based Systems - Current State and Open Problems. Technical report, Otto-von-Guericke University of Magdeburg.

[Williams et al., 1988] Williams, F., Rice, R. E., and Rogers, E. M. (1988). *Research Methods and the New Media*. Series in Communication Technology and Society. Free Press, New York, USA.

[Wilsker, 1996] Wilsker, B. (1996). A Study of Multi-Agent Collaboration Theories. Technical Report ISI/RR-96-449, University of Southern California.

[Wilson et al., 2004a] Wilson, S., Blinco, K., and Rehak, D. (2004a). An e-Learning Framework - A Summary. Technical report, DEST and JISC-CETIS and Industry Canada.

[Wilson et al., 2004b] Wilson, S., Olivier, B., Jeyes, S., Powell, A., and Franklin, T. (2004b). A Technical Framework to Support e-Learning. Technical report, JCLT.

[Winograd and Flores, 1986] Winograd, T. and Flores, F. (1986). *Understanding Computers and Cognition: A New Foundation for Design*. Norwood/NJ: Ablex.

[Wong and Sycara, 2000] Wong, H. C. and Sycara, K. (2000). A Taxonomy of Middle-Agents for the Internet. In *Proceedings of the Fourth International Conference on MultiAgent Systems (ICMAS-2000)*, page 465, Washington, DC, USA. IEEE Computer Society.

[Wooldridge and Jennings, 1995] Wooldridge, M. and Jennings, N. R. (1995). Intelligent Agents: Theory and Practice. *Knowledge Engineering Review*, 10(2):115–152.

[Wooldridge, 1996] Wooldridge, M. J. (1996). Agents as a Rorschach Test: A Response to Franklin and Graesser. In Müller, J. P., Wooldridge, M., and Jennings, N. R., editors, *Intelligent Agents III, Agent Theories, Architectures, and Languages, ECAI '96 Workshop (ATAL), Budapest, Hungary, August 12-13, 1996, Proceedings*, pages 47–48, Budapest, Hungary.

[Wooldridge, 2002] Wooldridge, M. J. (2002). *An Introduction to Multi-agent Systems*. Wiley.

[Wooldridge and Jennings, 1994] Wooldridge, M. J. and Jennings, N. R. (1994). Agent Theories, Architectures, and Languages: A Survey. In Wooldridge, M. J. and Jennings, N. R., editors, *Intelligent Agents: ECAI-94 Workshop on Agent Theories, Architectures, and Languages*, pages 1–39. Springer, Berlin,.

[World Wide Web Consortium (W3C), 2005] World Wide Web Consortium (W3C) (2005). Glossary of Terms for Device Independence. Technical report, World Wide Web Consortium (W3C).

[Wu, 2002] Wu, H. (2002). Designing a Reusable and Adaptive E-learning System. Master's thesis, University of Saskatchewan, Saskatoon, Canada.

[Yeaxlee, 1929] Yeaxlee, B. A. (1929). *Lifelong Education*. Cassel, London, UK.

[Yi et al., 2001] Yi, X., Siew, C. K., and Syed, M. R. (2001). Agent-Mediated Online Learning - AMOL. In *Workshop on Agent Supported Cooperative Work*, Montreal, Canada.