Learning technologies in e-learning

Chapter 6[1]

Learning Technologies in eLearning: An Integrated Domain Model

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1. Introduction

eLearning is a fact nowadays. There is no discussion about whether or not eLearning should be applied or not, the discussion is about how and when it should be applied. Most of the basic technologies are available, the pedagogical principles are worked out to a certain extend, there are different business models available for eLearning, the content can be transformed to be delivered electronically. This sounds really promising, but … in fact there is little knowledge available in the field how to integrate all these different approaches and technologies in order to create the best possible eLearning solution for different needs and situations. There is a lack of a integration and harmonization in the eLearning field and even very basic theories and models about eLearning are missing. There is a lot of conceptual confusion. This hinders implementation and the further development of the field.

In this chapter I will try to bring the different dimensions together by introducing an integrated conceptual framework that enables researchers, developers, implementers, managers and others to understand, organize, classify, plan and approach the issues in eLearning. The framework is presented as a domain model. It defines the field of eLearning and its basic structure, vocabulary and issues.

2. Integrated eLearning Systems

In integrated eLearning, the system under consideration is not restricted to the computer systems, but the complete organization of the educational system. An 'Integrated

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eLearning system' (IEL) is defined here as an educational system that uses network-based learning technologies to support its primary educational functions. Figure 1 provides a basic model of an IEL.

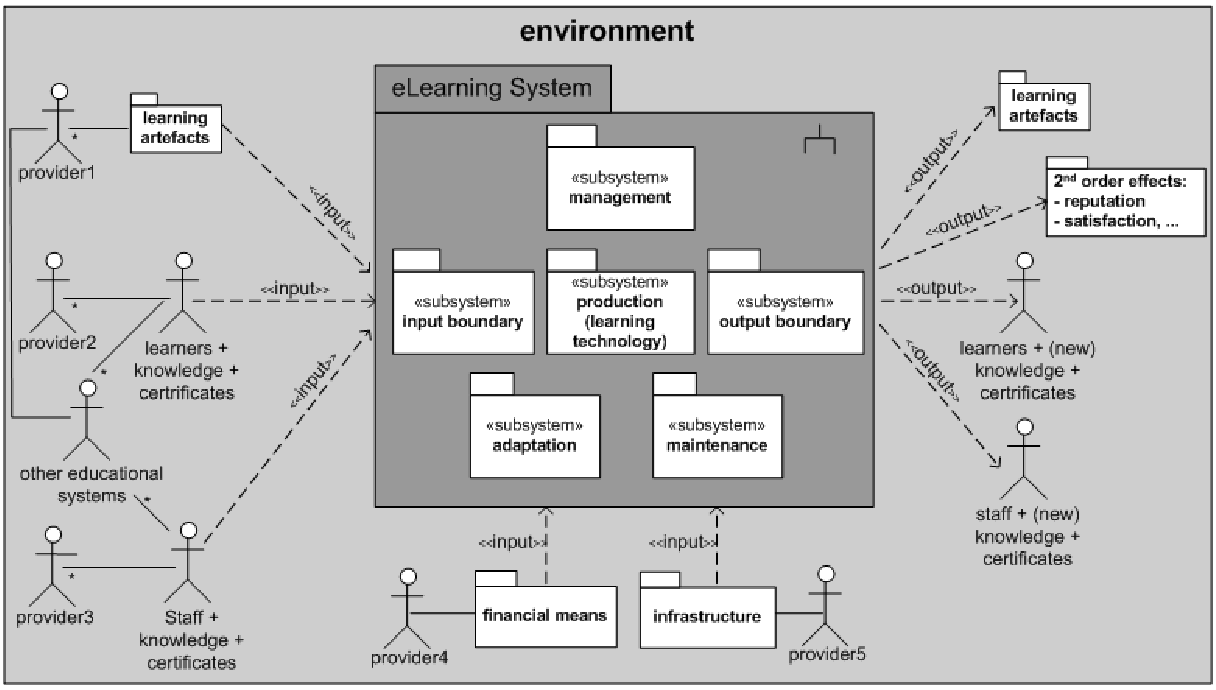

Figure 1. The organisational structure of an Integrated eLearning system

The primary inputs of an IEL are the learners with their entry characteristics. The primary outputs are the 'transformed' learners with additional knowledge (declarative and procedural with a certain competency level) and proofs of that knowledge (e.g. certificates). Other input-output are the staff members, like teachers. Staff members bring their knowledge into the learning process and this knowledge changes during their work. The characteristics of learners and staff members that are changed by the system, are called the *properties* of learners and staff.

Also, the system operates on so called *learning artefacts*, i.e. all the physical products produced before, during or after learning, like courses, programmes, learning designs, activity descriptions, books, reports, tests, remarks and comments. Most IELs add value to the learning artefacts that are provided at the input side; courses can be build from lower level artefacts.

Because an IEL is a kind of educational system, which is in its turn is a kind of organization; it inherits characteristics of organizations and educational systems, e.g. its classification of subsystems (see Daft, 2000). In eLearning systems we can distinguish the following subsystems:

A *production* subsystem that is responsible for the transformation process of the input to the output. In IELs the primary means of the production system are the so-called (network-based) *learning technologies*. Learning technologies are the specific means that establish the functionality of the IEL, i.e. to analyse, design, develop, deliver and evaluate learning opportunities for learners in certain contexts and knowledge domains.

An *adaptation* subsystem that is responsible for the innovation and change of the production system in order to better fit the environmental constraints and opportunities.

A *maintenance* subsystem that is responsible for the status quo of the system, including the training and support of the staff.

An *input boundary spanning* subsystem that communicates directly with the environment to attract and enrol students, to buy resources, to communicate with the financial bodies, etcetera.

An *output boundary spanning* subsystem that communicates directly to the outside world to deliver the products and services like certificates.

The most significant difference of an IEL, as compared to a regular educational system, is that it has a different kind of production subsystem. Instead of classrooms there are computer networks that connect learners, teachers and learning artefacts. This provides a complete new set of possibilities and constraints in the relationship with the outside world, e.g. freedom of place and time, the possibilities to automate parts of the teaching-learning process, the possibility to simulate parts of the learning environment and the possibility to renew the pedagogical models in a complete different way (see Koper, 2001). In this chapter we will focus on the production subsystem.

IEL can be studied at different levels of analysis: at the level of individuals, groups and organizations. Because of the inherent network organization characteristics of the ICT technologies used, we prefer the organization level of analyses. Each of these levels can be studied from a micro, meso, or macro perspective. At the micro level one looks at the function of the smaller parts within the system, at the macro level one looks at the overall functionality of the system in relationship with the environment. We prefer the meso level of analysis that combines both perspectives by looking at the macro phenomena as emergent behaviours that comes from the activities of the subsystems at the micro level (see e.g. Prietula, Carley & Gasser, 1998). This stance is elaborated in the complexity theory (see Waldrop, 1992; Kauffman, 1995), the study of emergence and self-organization (e.g. Johnson, 2001; Varela, Thompson and Rosch, 1991; Maturana and Varela, 1992), computational organization theory (Carley, 1995), pattern analysis

(Gamma et al, 1995; Fowler, 1997; Larman, 2002) and technological approaches as peer-to-peer systems (Barkai, 2002), multi-agent approaches (e.g. Axelrod, 1997; Ferber, 1998) and the GRID (Foster, Kesselman and Tuecke, 2001).

This brings us to an interesting notion in IEL. When establishing an IEL, one creates connections between people and resources that where never available before. When designed properly this can invoke a new kind of *emergent* organization that introduces and supports completely new ways of learning, teaching and knowledge transfer. We tend to name this type of organization a *learning network* and is the scope of our new research and technology programme into learning technologies (see www.learningnetworks.org).

3. Dimensions in the eLearning Domain

In the previous section I introduced the structure of IELs, in this section I will focus on the different characteristics of a IELs to allow its further understanding, comparison and design. Three interrelated dimensions can be distinguished:
The *functional* dimension, that deals with the pedagogical and knowledge issues. The functional dimension is highly related to the production subsystem.
The *organizational* dimension, that deals with the structural characteristics, the contextual characteristics, the economical (or business) characteristics and legal issues.
The *technical* dimension, that deals with the architectural aspects, the interoperability protocols and standards, the network infrastructure, the servers and applications, and the user interfaces.

3.1. The functional dimension

We will now look deeper into this production system to identify what different subsystems it has (figure 2, modelled in UML, see: OMG; Booch, Rumbaugh, & Jacobson, 1999; Warmer, 2001).

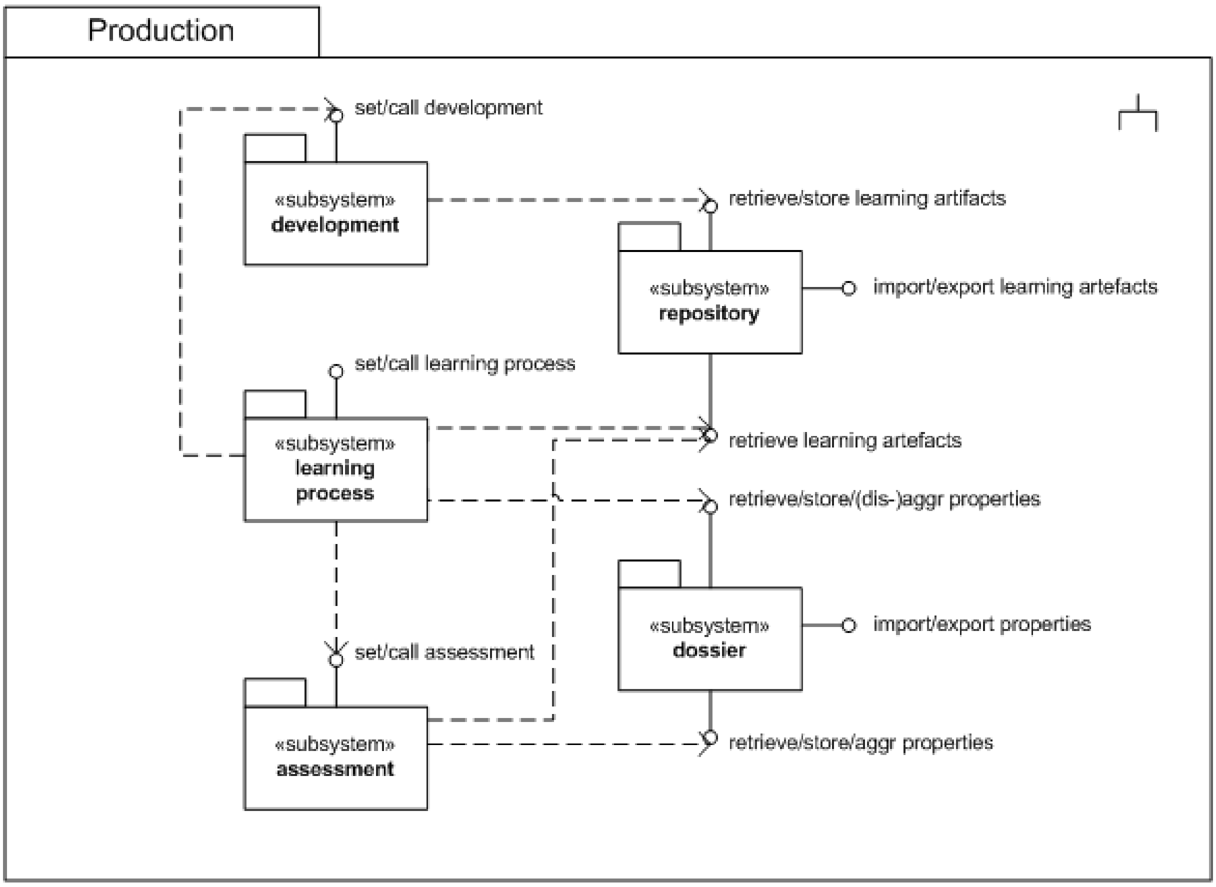

Figure 2. The subsystems of the production system.

In the production subsystem we distinguish three core processes and two data stores:
The *development* process in which learning artefacts are created and adapted. It retrieves existing learning artefacts from the repository. The process can be set and called from outside.
The *repository* is a data store for learning artefacts. It can import and export learning artefacts from other systems.
The *learning* process in which the actual learning and teaching process takes place. It can be set and called from outside. It retrieves existing learning artefacts from the repository and can set and call the development process during learning to create and store new learning artefacts. Besides access to the repository, the learning sub process also has access to the dossier to retrieve and store properties.
The *dossier* is a data store for the properties of individual users, groups and roles that are local or global in scope. The dossier can import/export properties from outside.
The *assessment* process that can be set and called from the learning subsystem at different moments: before learning, during learning and after learning. It uses properties from the dossier and learning artefacts from the repository. It stores new (or

aggregated) properties in the dossier, representing e.g. the learners position, grades, etc.

For each of these subsystems and combinations of them, different issues can be identified, again perceived from the dimensions functionality, organization and technology. More complex issues are related to the relationship of the subsystems.

3.2. The organizational dimension

Any organization has structural characteristics and contextual characteristics. Table I sums them up (from Daft, 2000). The structural characteristics are the internal characteristics that allow the measurement and comparison of different organizations (see scale of Marcic, 1996). The contextual characteristics describe the complete organization in its relationship with the environment.

Table I. Structural and contextual characteristics of an organization.

Structural Characteristics	Contextual Characteristics
1. formalization	1. targets & strategy
2. specialization	2. environment
3. standardisation of work process	3. size
4. hierarchy	4. technology type (= education)
5. complexity	5. culture
6. centralization	
7. professionalism	
8. personnel ratios	

In the organization theory several patterns have been derived from the comparison of the characteristics of organizations. For instance, certain contextual characteristics are correlated to certain structural characteristics, e.g. a big size, routine technology and a stable environment is correlated to high formalization, standardization, specialization and centralization. In the eLearning field it is still unknown how these characteristics are related to the organization of institutes delivering eLearning; what the optimal characteristics are for IELs and how organizations can change.

3.3. The technical dimension

Also in the technical dimension we can identify a large number of issues, a selected list of more important issues are the following:
There is a big need for interoperable, *reference architectures* in eLearning, but at the moment there are to many architectures (e.g. LTSC WG1; Sim, 2002; Livingston Vale, and Long, 2003); they are incomplete and a lot of underlying protocols and standards are missing. We cannot expect any concrete worked out architecture to be standardized in the near future. However it is good to sketch and update the architecture at this moment in time to see how the lower level issues fit together.
Interoperability specifications are crucial for the establishment of larger interconnected networks and collaborations like learning networks and the GRID. There are several successful initiatives releasing specifications at a regular basis in the eLearning field. Examples are the AICC, IMS, IEEE LTSC and ISO SC36. The most important initiative up to date is IMS, a consortium of eLearning vendors, universities and training departments. The current status is however that there are still lots of specifications missing in this field and that others have to be harmonized.
Having reference architectures is one, having the actual implementations in terms of *network facilities, servers and applications* is another question. Most of this work, except from several specific services and applications, is not driven by eLearning, but are more generic facilities for all types of application fields. The major problems in this domain are the lack of standardisation and the lack of valid and accepted ideas about eLearning requirements and specifications.
Last but not least, *user-interfaces* are of specific importance in eLearning. The requirements are different than in most business applications (like word processors), because these interfaces are the primary means for the realisation of learning. This issue is addressed in chapter 8 of this book.

4. Improvement of eLearning

Current eLearning systems have a lot of shortcomings. Besides implementation issues, one of the major aspects that causes problems are the restrictions of the current learning technologies used in the production subsystem. To further improve IELs at least the following learning technologies must be improved:

- The *development* subsystem of IELs: the facilities that allow providers, teachers, and learners to develop learning artefacts in a more effective, efficient, attractive, accessible and adaptable way.
- The facilities to support the *sharing and reuse* of learning artefacts within and between organizations. This issue is related to the improvement of the repository.

- The facilities for *differentiated delivery and use* of learning artefacts by different groups and individuals. This issue is related to the improvement of the learning process subsystem and the dossier.
- The *assessment* possibilities of IELs: the facilities must support assessment in the most effective, efficient, attractive and accessible and adaptable way. This issue is related to the improvement of the assessment subsystem and the dossier.

4.1. Development issues

In IELs, one has to develop digital learning artefacts such as units of learning (courses, programmes) and learning objects. A major problem for organizations when introducing eLearning is the question *how* to deal with this development process of digital learning artefacts. The development process is complex and expensive. Technology puts a lot of new possibilities and constraints and there are several major copyright and interoperability issues. Possibly the most challenging point is, that in eLearning the expected quality of the units of learning cannot easily be provided by the one person who is traditionally responsible for this job, the teacher. Multidisciplinary teamwork is one approach to create units of learning at an acceptable level of quality, taken into account issues as interactivity, personalization, use of multimedia, granularisation of the units, coding of content in standard formats (e.g. xhtml, jpeg, mathml, smile, etc.). The issue of the work processes in eLearning is elaborated in chapter 10 of this book.

Another problem is the question of *what* to develop. What must be developed, in what format and in what level of detail, in order to provide for a (re-) usable unit of learning that can be delivered through a computer facility? What is needed to answer these questions is an integrative model that describes the semantic components and the relationships between these components. In recent years we have worked on this model, which has been published as the 'Educational Modelling Language' (Koper et al, 2000; see chapter 7 of this book). EML has provided the basis for the IMS Learning Design specification (IMSLD, 2002). This model describes the semantic structure of a unit of learning in an abstract and generic way. It is based on a pedagogical meta-model or better, an abstraction of instructional design theories and models (see Koper, 2001). This abstraction can be summarized as follows: in a designed learning situation, learners and staff members are engaged in one or more activities that are dynamically related in a learning design method. Every activity is performed in an environment that consists of a collection of one or more learning objects and services. Specific learning design (instructional design) models, like the 4C/ID model discussed in chapter 2 of this book, are specialisations of this abstract model. The specific models prescribe the preferred type of activities, the preferred method and the preferred environment (see e.g. Duffy & Cunningham, 1996, p. 171). An actual unit of learning uses an instance of such a specialized model. In figure 2 a summary of the abstract model is presented. Besides the relationship discussed before, it states that a unit of learning contains a 'learning design' that organizes physical resources in a semantic instructional framework. The learning design method connects the learners and staff members to activities and environments.

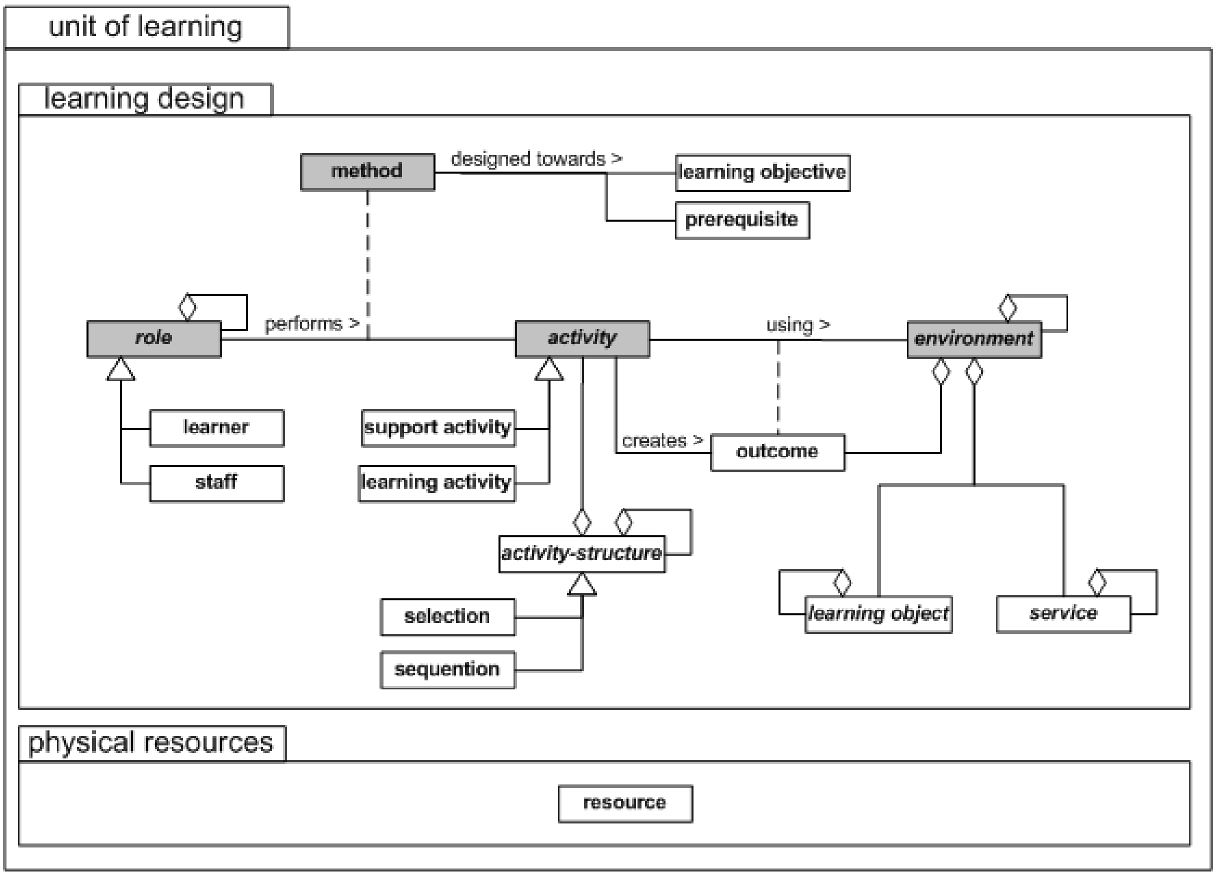

Figure 2. The abstract structure of a unit of learning, expressed as an UML class diagram.

This model can be used in a variety of ways: it defines the semantic components and the relationships between the components that have to be developed in the development process. It serves as a framework to identify the validity of a unit of learning in terms of its structure and completeness. It can be used to compare specific instructional design approaches in research settings. Furthermore the model can be used to create XML bindings to design and express concrete courses and programmes in a format that can be interpreted with a computer programme. Example applications of this model are EML and the IMS Learning Design.

The last problem to be discussed in this paragraph related to development is the issue of the *tools* needed to support the development process. In a complete development process one needs tools to design, edit, search, store, manage and test the units of learning and the underlying learning resources. In eLearning there are still many practical problems with the development tools. Simply stated: the real interoperable tools are still to be developed. All current solutions are suboptimal.

4.2. Sharing & Reuse issues

Maybe the most promising, but also one of the most complex, advantages of eLearning is that it provides the possibility of the sharing and reuse of learning artefacts. This will increase the economic benefit of eLearning. However, there are several issues to be solved before sharing and reuse will be feasible.

The first issue addresses the question w*hich* types of learning artefacts are reusable and which aren't? The basic idea is that courses are the less reusable units and the smaller underlying non-purposed learning objects are the most reusable (e.g. Downes, 2000). Besides the learning objects, we expect that also the learning activities, the environments and the learning designs can be reused in different units of learning.

The second issue is about the *granularisation* of learning artefacts (e.g. Wiley, 2002; Duncan, 2003). How small or how large must a learning artefact be, in order to make it suitable for reuse? For what purpose and for which actors are the learning artefacts available: for authors, teachers and learners? The smallest meaningful unit for learners is a learning activity that includes the necessary environment and the connected support activities. Also developers can easily build new units of learning from these activities, by repurposing and sequencing them into an instructional method.

The third issue is the problem of *aggregation and repurposing*. How can lower level resources and artefacts be aggregated to activities and units of learning? Are there rules and principles that can support the automation of this process, so that the task is made easier?

The fifth issue is the problem of *disaggregation* of existing course materials. In most institutes there is a large amount of existing materials that are not prepared or suitable for eLearning or for reuse. How to deal with these materials? From an economical point of view it is not suitable to develop everything new for eLearning.

The last issue identified here is the problem of *finding* and *sharing* learning artefacts for reuse. Presumed is a shared, large, distributed repository where users can search for learning artefacts, get them, adapt them, store new ones and where legal and economic principles are supported in a workable way. Such a repository functions in the context of what is called a learning object economy. The principles for success for such an economy are not well known yet. Campbell (2003) identifies the following issues in a learning object economy: the granularity, interoperability, resource description and discovery, incentives, quality control and peer review, intellectual property rights and digital rights management, pedagogical frameworks and cultural barriers. There are already some sharing initiatives put into practice, like Ariadne (Forte et al, 1997), Cuber (Krämer, 2000) and Merlot (merlot.org), but overall evaluation data of the success and failure factors for the approaches are still missing.

4.3. Differentiated delivery issues

One of the possible advantages of eLearning is the ability to provide for differentiation (or personalisation) in the delivery and use of learning artefacts. Usage can be varied according to factors as:

- Characteristics and preferences of learners (pre-knowledge, learning style, needs, personal circumstances, disabilities)
- Context characteristics (integrated into the work environment, classroom teaching, distance teaching).
- Delivery medium (web, print, DVD, …)
- The quantity and quality of the educational services offered (amount of tutoring, assessment services).

At this moment smooth differentiation is still one of the future promises of eLearning. The basic mechanisms are available, but the integrated models, tools, and guidelines for use are still missing. It is also unknown what the cost-benefit balance will look like. Does differentiated use and delivery increase the effectiveness and efficiency of the educational system? Does it attract new target groups; does it make education more accessible to certain groups? Some further complications in differentiation are the following issues:
Who should *control* the differentiation under which conditions: the learner, the teacher, an intelligent agent, the developer or a mixture of these?
There is a need for a tide *integration of development and delivery mechanisms*. Students should be able to use the development environment to add or adapt learning artefacts or to create personalized learning routes. Also designers must be able to adapt learning artefacts and it must be possible to easily integrate the learning artefacts that are created in runtime (e.g. during collaborative learning) in new units of learning.

Differentiation implies several things that are not very well known yet. It implies for instance the availability of *global dossiers* for learners, where the preferences and characteristics are stored independent of the units of learning. These dossiers must be accessible from a variety of different implementations. The IMS Learner Information Package (IMSLIP, 2002) in combination with the IMS Learning Design property mechanisms provide the first mechanisms for this, but are not well integrated or tested yet. This also implies the problem of the positioning of learners in a kind of global competency grid.

Differentiation seems to be an important improvement, but further technology development is needed before it can be put into real practice.

4.4. Assessment issues

Assessment in IEL has the regular educational purposes: feedback, monitoring, tracking, quality rating and overall evaluation of the effectiveness of the educational system. In eLearning there are still a lot of problems in this area, mostly because of the repositioning of the function of assessment in modern education. The field is evolving rather rapidly. New, alternative assessment methods are developed and applied (see e.g. Hambilton, 1996; Sluijsmans, 2002) and also new problems occur in eLearning environments, specifically the problem of learner positioning in learning networks: what is the current state of knowledge of the learner relative to the learning opportunities provided. This is needed to allow for differentiated delivery.

In most current eLearning systems traditional tests are implemented, but the newer aren't. Also, the only open specification available in the assessment field, the IMS QTI restricts itself to traditional tests. It specifies the interoperability format at a rather technical level, but doesn't connect this to the functional use of a test within the context of a unit of learning. What is missing is an integrated model specifying what assessment method should be applied under what conditions in a very specific but semantic way. In order to provide for such a model we first did some preliminary work (Vermetten, Daniëls, Ruijs, Schlusmans & Koper, in press). We defined a matrix of assessment methods, considering five basic questions: *what* is assessed, *how* is it assessed, *why* is it assessed, *when* is it assessed, and *who* assesses (e.g. Brown & Glasner, 1999; Van der Vleuten & Driessen, 2000). These questions can be applied to any assessment form and map all components in a systematic way. Secondly we start working towards the creation of a semantic domain model specifying all types of interactions with the learners within the context of a unit of learning in a semantic way (Hermans, Van den Berg, Vogten, Brouns & Verhooren, 2002). Such integrative frameworks are needed to specify the assessment requirements for eLearning systems in a later stage (figure 3).

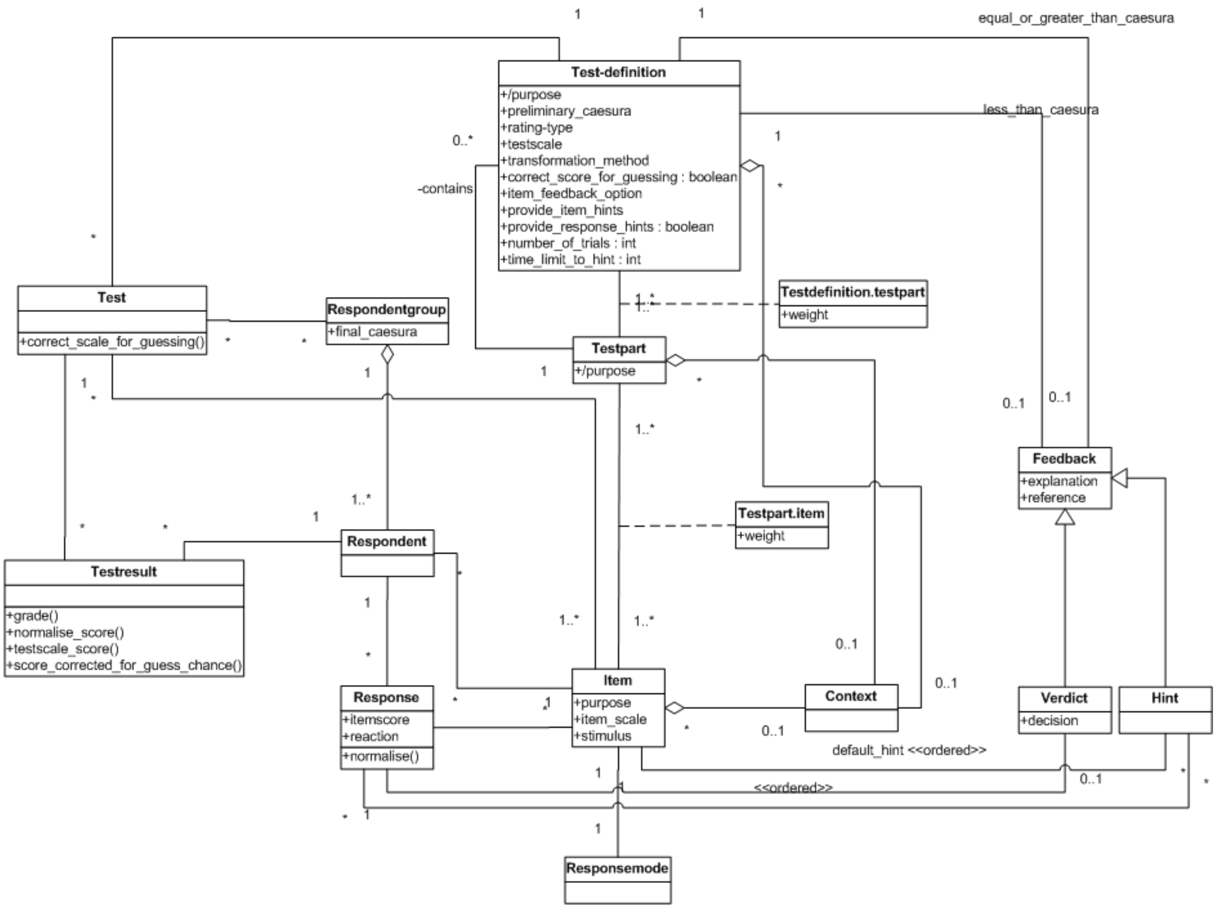

Figure 3. (part of the) semantic domain model specifying interactions types

5. In conclusion

In this chapter I presented an integrative domain model for IEL. Basically it states that eLearning issues must be approached at the organizational level of analysis. IEL are approached as complex, dynamic, non-linear, evolving and adaptive systems. The model deals with two aspects of IELs: the subsystems (adaptation, production, management, maintenance, boundary spanning) and the dimensions (functional, organizational and technical). The most critical part for the effectiveness of an eLearning system is the production subsystem. This subsystem typically uses network-based learning technologies and contains five interrelated sub-subsystems (development, repository, learning process, dossier and evaluation). For each of the sub-subsystems of the production subsystem several issues for future improvement where addressed from the functional, organizational and technical perspective.

The framework presented here provides the basic terminology, definitions and some of the models. It can be used in a variety of ways, e.g.:

- To identify future research and development questions in the field.

- To build better eLearning systems by integrating the requirements from the issues discussed in the model.
- To stimulate and plan effective implementation.
- To be able to identify the different issues to build eLearning courses and curricula.

As is said before the most interesting, but also complex issues deal with the coherence, connectivity and emergence aspects of the different fragments in the model. In future attention should not only be paid to the isolated issues of eLearning, but especially to the integrative relationships that are responsible for the overall effectiveness, efficiency, attractiveness, accessibility and adaptability of eLearning. The approach that we will take is to look at these issues from the perspective of so-called learning networks, i.e. self-organized, emergent, distributed systems, created to facilitate (lifelong) learning in some knowledge domain (see www.learningnetworks.org). These learning networks have the promise to change our future ways of learning in a fundamental way.

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