A Conceptual Approach to Studying the Learning Process - with a Special Focus on Knowledge Creation

Ambjörn Naeve, Mikael Nilsson, Matthias Palmér, Richard Wessblad, Mia Lindegren, Miltiadis Lytras, Nikos Korfiatis, Bernd Simon, Fridolin Wild, Barbara Kieslinger, et al.

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A CONCEPTUAL MODELING APPROACH TO STUDYING THE LEARNING PROCESS

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APPENDIX

1. INTRODUCTION

In our emerging knowledge society, a firm understanding of the interplay between the management of knowledge and learning is of strategic importance in order to create and maintain effective learning processes in a large variety of non-traditional learning situations (Lytras, Naeve and Pouloudi [36]). For example, as described by Grace and Butler in [18], Zuboff [87] argues that learning, integration and communication become key to leveraging employee knowledge. Accordingly, managers must "switch from being drivers of people to being drivers of learning". Argyris and Schön [3] point out that "there is a virtual consensus that we are all subject to a learning imperative, and in the academic as well as the practical world, organizational learning has become an idea in good currency."

However, as Grace and Butler observe, "learning is a complex phenomenon and the concept of learning within organizations has numerous dimensions, making it even more complicated than individual learning. Multiple levels of learning have been distinguished, including *individual learning*, *group learning* and *organizational level learning* and several processes of learning within an organizational context have been differentiated. Among these are *knowledge creation*, *knowledge acquisition*, *information distribution*, *information interpretation* and *organizational memory* (Fiol and Lyles [16], Levitt and March [33], Nonaka [53])."

1.1. Scope of the paper

In this paper we present a conceptual approach to the study and analysis of learning processes with emphasis on the knowledge-creating types of learning processes that often occur in workplace learning.[1] We present a framework (abstract model) for categorizing knowledge-creating learning processes based on process modeling and Nonaka's (SECI spiral) theory of knowledge creation ([53], [54], [55]). Our framework makes use of assembly-line-style process modeling in order to show how different parts of a learning process are supported by different pedagogical aspects and tools. It also uses the Unified Language Modeling (ULM) technique [43] in order to improve the conceptual overview and increase the visibility and clarity of the structures involved.

By bringing together the three aspects of SECI knowledge creation, process modeling and ULM, the paper in fact describes the present "state of the art" of concept-based e-learning within the Prolearn consortium. Although the validity of many aspects of our SECI process framework is empirically supported by pedagogical research (section 6), we must stress that the framework in its entirety has not yet been applied to the study and classification of learning processes. However, we plan to initiate such studies within the near future, with a special focus on learning processes in the workplace. In fact, our framework suggests a method for describing such learning processes and how they are supported by different pedagogical aspects and tools. Applying this method to the description of concrete learning processes will provide an empirical basis from which we can find out what works well and why it works well, which will lead to more effective ways of creating and managing learning processes in general.

This focus reflects our response to the main criticism from the first Prolearn review in March 2005, which stated that the consortium should strengthen its involvement with learning at the workplace. Because of this critique, the originally planned focus of this paper on LMS brokerage and interoperability issues has been changed, and the corresponding discussion (the openLMS project) has been placed in an appendix.

1.2. Structure of the paper

In section 2 we present a general discussion on knowledge and learning and introduce a definition of knowledge as consisting of efficient fantasies. In section 3 we apply assembly-line process modeling [14] in order to outline a *learning process framework* (abstract model) that indicates how the different parts of a learning process are motivated by different pedagogical aspects and supported by different tools. Instantiating the abstract model at the specific level, we should be able to figure out how each part of a specific learning process is motivated by specific pedagogical or didactical aspects, and how these aspects are supported by the specific tools that are used in the corresponding part of the learning process. At the abstract level, our model considers a learning process as orchestrated by pedagogical/didactical aspects, which are supported by various tools. As an illustration, we

[1] In contrast to e.g., traditional academic learning (courses), where the knowledge exists prior to the execution of the learning process.

instantiate this abstract process/pedagogy/tools model with a specific example of pedagogical aspects and supporting tools. This example is based on the work of the KMR group [88] at KTH as presented in [46].

In section 4 we review (part of) the unified model of dynamic knowledge creation as presented by Nonaka, Toyama and Konno in [55], and apply both process modeling and UML-style conceptual modeling [43] to it in order to construct an abstract model of the most important parts of the knowledge creation process: Four different types of *knowledge-conversions* (*SECI*) supported by four different types of *ba* ('interaction spaces') and resulting in four different types of *knowledge assets*.

In section 5 we combine process modeling (section 3) with SECI knowledge conversion (section 4) in order to formulate the *SECI process framework*, which is an abstract model for the study and classification of knowledge-creating learning processes.

In section 6 we introduce some support for our learning process model from pedagogical research. The empirical results of Yli-Luoma and others are discussed and related to the SECI process framework, showing how they underscore and validate the different parts of the model.

In section 7 (conclusions and future work) we indicate how the SECI process framework can be applied to the knowledge creating processes of the Prolearn NoE – especially *roadmapping* and *knowledge work management*. The section concludes with a discussion on some general research issues that are raised by the models developed in this paper, and which we will attempt to address in the future.

In order to keep a clear focus, a few sections have been placed in an appendix. Sections 10 and 11 describe some basic ideas of conceptual modeling and process modeling, whereas sections 12 and 13 describe related ongoing work within two Swedish projects, the *Open Network for Semantic Collaboration Around Informal Learning* (ONSCAIL) and the *openLMS assessment project* of open source based L(C)MSes that is carried out for the Swedish Netuniversity under the coordination of Uppsala Learning Lab [99].

2. SOME PERSPECTIVES ON KNOWLEDGE AND LEARNING

Since the time of ancient Greece, the philosophical discussions and debates on the nature of knowledge and learning have been recurrent, and several schools of thought have made substantial contributions. As pointed out by Nonaka, Toyama and Konno in [55], in traditional Western epistemology[2] truthfulness is the essential attribute of knowledge. It is the absolute, static and non-human view of knowledge, and it fails to address its relative, dynamic and humanistic dimensions.

According to Sperber and Wilson "Human beings are efficient information-processing devices. This is their most obvious aspect as a species" ([71], p. 45) . This quote from one of the classics of cognitive psychology provides a good example of the Western emphasis on explicit knowledge, as opposed to *tacit knowledge*, a term which was introduced by Michel Polanyi in [62]. The term tacit knowledge refers to the implicit and silent (pre-logical) knowledge that we all carry within ourselves, and which Polanyi expressed as "we can know more than we can tell ([62], p. 4).

In his dialogue seminars, Bo Göranzon [19] has introduced the following different types of knowledge and described useful methods for their exploration:
• *Explicit knowledge* consists of statements, which can be explored through standardized surveys (quantitative studies).
• *Implicit knowledge* consists of statements that are harder to directly recall, and which require more of reflection and introspection. Common ways of exploring implicit knowledge is by deep interviews and ethnographic methods, which are both qualitative in nature and therefore require substantial elements of interpretation.
• *Silent knowledge* consists of knowledge that (for logical reasons) is not available in the form of statements, but which is primarily expressed in the form of practical actions. It can also be studied through deep interviews and ethnographical methods.
• *Sub-conscious knowledge* – or feelings – that can be explored with psychological methods.

In his famous taxonomy of learning, Bloom [8] identifies 6 different levels of knowledge in the cognitive domain. They are shown in Figure 1 (slightly revised by Anderson and Kratwohl [1]). The truncated pyramid

[2] The theory of knowledge.

indicates that each level builds on the ones below it. A similar analysis for the affective domain[3] has been carried out by Kratwohl, Bloom and Marsia [32] and in the psycho-motor domain by Dave [12]. These domains all represent important dimensions of learning, which need to be taken into account in a full analysis, but they will not concern us further here.

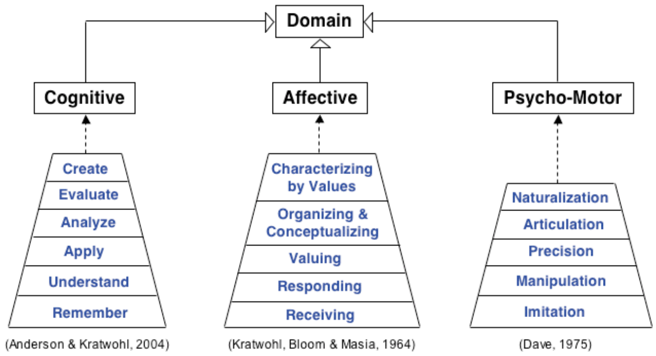

Figure 1. A taxonomy of learning in the cognitive, affective and psycho-motor domains.[4]

Different perspectives on learning will be taken up in section 6, where we will discuss some contributions from e.g., Vygotsky, Kolb, Piaget, Ravenscroft, Keeves, Sweller and Hestenes.

In [43], Naeve defines (mental) *knowledge* as consisting of *efficient fantasies*[5] and describes (mental) *learning* as based on *inspiring fantasies*. Each fantasy has a *context*, a *purpose* and a *target group*, and it is only when we have described how we are going to measure the efficiency of our fantasies - within the given context, with the given purpose, and against the given target group - that we can speak of knowledge in a way that can be validated.

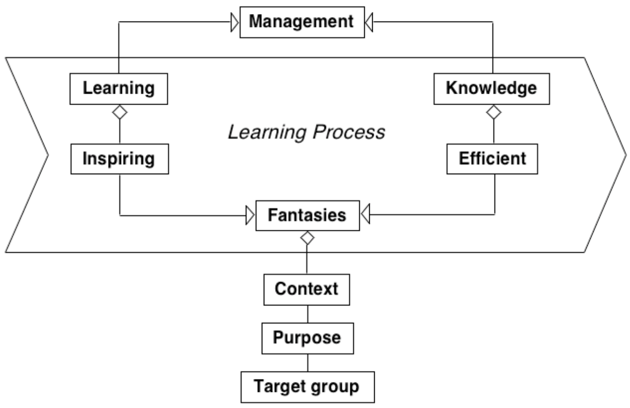

Figure 2. Learning and Knowledge Management perspectives of the Learning Process: Transforming inspiring fantasies into efficient fantasies.

From this perspective, management of the learning process is concerned with exposing the learner to inspiring fantasies and assisting her/him in transforming them into efficient fantasies. This involves two complementary aspects, *learning management*, which is people-oriented and focuses on learning as a process, and *knowledge management*, which (traditionally) is technology-oriented and focuses on knowledge as a resource. See e.g., [18] for a more thorough discussion on the attempts of modern LMSes to bridge this traditional gap and accommodate both of these important perspectives.

[3] which is concerned with the perception of value issues.

[4] The figure is based on Atherton [4].

[5] As opposed to muscular knowledge, which he defines as "efficient reflexes". The word "fantasy" is used instead of the synonymous word "conceptualisation" in order to emphasise that the conceptual structures are constructed from within.

2.1. Knowledge transmission versus knowledge creation

Here we will introduce a distinction between knowledge-*transmitting* and knowledge-*creating* learning processes, a distinction that separates *formal* and *informal* learning. In a knowledge-transmitting type of learning process, the desired knowledge (as expressed e.g., in the curriculum of a traditional course) exists prior to the execution of the learning process, whereas in an informal type of learning process, (substantial parts of) the desired knowledge is often created during the execution of the learning process itself.

Note that our choice of terms does not imply that we believe that transmitted knowledge can be received as knowledge[6]. In contrast, we share the constructivist belief that knowledge has to be constructed by each separate individual, preferably within a collaborative learning process that involves interacting with others. Hence, we are well aware that knowledge creation occurs during the execution of any type of learning process. However, in the knowledge transmission type of learning process, this knowledge creation takes place only among the learners[7], since it is driven by a fixed curriculum, which exists prior to the course.

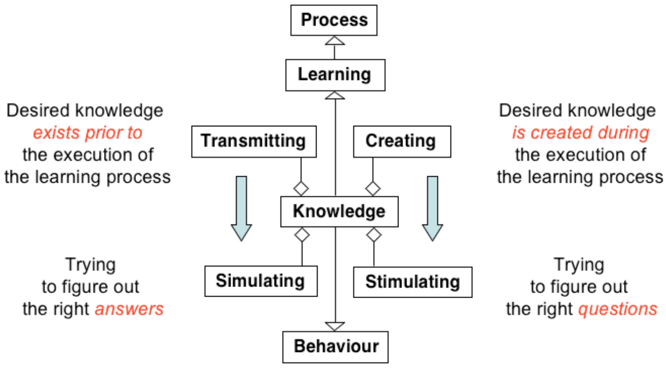

Figure 3. **Kowledge-transmitting versus knowledge-creating learning processes.**

As depicted in Figure 3, a knowledge-*transmitting* type of learning process leads to a knowledge-*simulating* type of behaviour, where the learners are trying to figure out the right *answers*, whereas a knowledge-*creating* learning type of learning process leads to knowledge-*stimulating* type of behaviour, where the learners are trying to figure out the right *questions*. The reader is referred to [39] and [40] for further discussions on these matters.

2.2. Knowledge pushing versus knowledge pulling

In [43] Naeve discusses the demands for flexible and personalizable learning in terms of the distinction between knowledge-pushing and knowledge pulling types of learning processes. The traditional learning processes are based on teacher-centric, curriculum-oriented, knowledge-push. The new demands on learning are largely concerned with a shift along all of these dimensions in order to support more learner-centric, interest-oriented, and knowledge pulling types of learning processes. In [46], it is shown that the infrastructure, frameworks and tools of the KMR group are designed to encourage and support the latter type of learning processes. Since we will make use of these contributions in our modeling examples, we briefly introduce them here for the convenience of the reader.

Over the last few years, members of the WGLN [94] and Prolearn [96] networks have made numerous contributions towards a *Public Knowledge and Learning Management Environment* ([46], [48], [49], [79]) based on open source, open ICT standards and the technology for the emerging next generation Internet – the so-called *Semantic Web* [107]. In this paper, we will instantiate our process/people/tools framework (meta-model) with examples from this work.

The PKLME is structured in the form of a *Knowledge Manifold*, which is an information architecture that consists of a number of linked conceptual information landscapes (context-maps), whose concepts can be filled with content, and where one can navigate, search for, annotate and present all kinds of electronically stored information [39], [40], [41]. The PKLME also includes:

[6] This is the ghist of the so called "transmission theory" of knowledge, which no one seems to believe in these days.

[7] And not among the other stakeholders, such as e.g., teachers or administrators. Of course, when we are dealing with changing the structure of the learning process itself - e.g. by changing a course - new knowledge is created by all stakeholders.

• *The Edutella infrastructure*: A democratic (peer-to-peer) network infrastructure for search and retrieval of information about learning resources [48], [52].
• *The SCAM framework*: (*Standardized Contextualized Access to Metadata*): A framework that helps applications to store and share information about learning resources [59].
• *The SHAME framework* (*Standardized Hyper-Adaptable Metadata Editor*): An editor framework that supports an evolving annotation process of learning resources in a way that enables the growth of an "ecosystem" of quality metadata [51], [91].
• The *Formulator* (or *SHAMEditorEditor*): A tool for editing metadata editors that is built on top of the SHAME framework.
• The *Confolio network*: A network of conceptual electronic portfolios (built on top of SCAM, SHAME and Edutella) that supports collaborative and reflective learning techniques.
• *The Conzilla concept browser*: A knowledge management tool that supports the construction, navigation, annotation and presentation of the information in a knowledge manifold [40], [42].
• *The VWE composer*: An environment for composing learning resources and building customized learning modules.

The knowledge roles of a Knowledge Manifold
The KM architecture supports the following seven different knowledge roles [41]:
• the *knowledge cartographer*, who constructs and maintains context-maps.
• the *knowledge librarian*, who fills context maps with content-components.
• the *knowledge composer*, who constructs customized learning modules.
• the *knowledge coach*, who cultivates questions.
• the *knowledge preacher*, who provides live answers.
• the *knowledge plumber*, who directs questions to appropriate preachers.
• the *knowledge mentor*, who is a role model and supports self-reflection.

2.3. Formal versus informal learning processes

Of course, the knowledge-dimensions of *creating ---- transmitting* and *pushing ---- pulling* are not independent of each other, but in fact highly correlated. For example, it is obvious that a knowledge-transmitting learning process must push the knowledge items on its curriculum in order to be successful. As shown in Figure 4, this is characteristic of *formal learning processes*, such as e.g., traditional academic courses. This type of learning process leads to an *imitative learning* behaviour, where the learners are rewarded for figuring out the right answers.

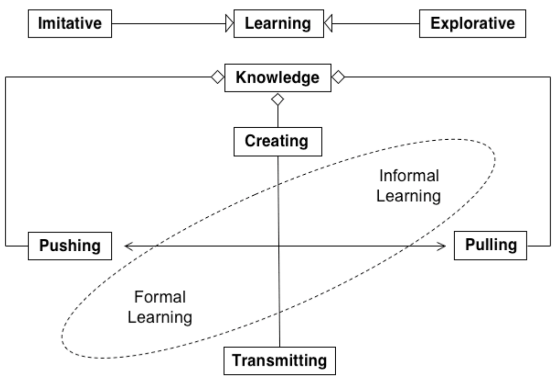

Figure 4. Formal versus informal learning

In contrast, a knowledge-creating learning process creates its own curriculum (more or less) at runtime, i.e., during the time that it executes, which requires more of a knowledge-pulling strategy in order to be effective. This is characteristic of *informal learning*, which occurs e.g., in academic research as well as in many forms of workplace learning - especially among the knowledge-workers of companies that produce knowledge-intensive products and/or services. This type of learning process leads to an *explorative learning* behaviour, where the learners are rewarded for figuring out fruitful questions (and, of course, also for providing answers to them).

In section 4 we will explain how knowledge-creating learning processes can be effectively described by making use of Nonaka's dynamic theory of knowledge creation [53] and the unified model of Nonaka, Toyama and Konno [55]. By combining this theory with process modeling we will arrive at an abstract model that can serve as a basis for the analysis and classification of many professional learning processes.

3. ASSEMBLY LINE MODELING OF THE LEARNING PROCESS

Process modeling presents powerful ways of describing dynamic interactions – ways that seem to have found little use for educational modeling within the TEL community [65].[8] Here we will make use of a type of process modeling described e.g., in [14], where (horizontal) assembly lines and (vertical) support arrows indicate how the various parts of a process are supported by different kinds of resources. The GOAP[9] approach to process modeling is described in the appendix (section 11).

3.1. The process/pedagogy/tools abstract model

In Figure 5 the learning process has been divided into the sub-processes *Analyze*, *Develop*, *Perform* and *Evaluate*, which are high-level abstract descriptions of the different stages of an overall learning process. The vertical arrows show which tools that support which pedagogical aspects in which parts of the process.

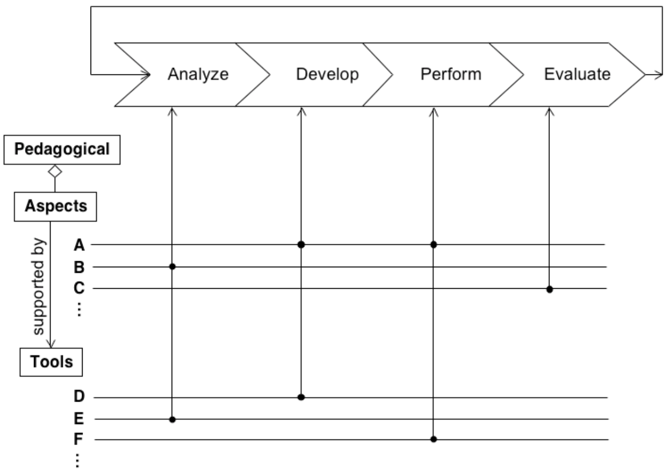

Figure 5. The process/pedagogy/tools abstract model. The learning process is supported by pedagogical aspects, which, in turn, are supported by tools.

In Figure 5 the black dots indicate that the pedagogical aspect B and the tool E support the 'Analyze' part of the process, while the pedagogical aspect A and the tool D support the 'Develop' part of the process, etc. The arrow from 'Evaluate' back to 'Analyze' indicate a feed-back loop that is characteristic for a never-ending (life-long) type of learning process.

3.2. Instantiating the process/pedagogy/tools abstract model

Here we will present a simple example of how the abstract process/pedagogy/tools model can be instantiated to show the interplay between processes, pedagogical aspects and tools in a more specific example. In this example, which is presented in Figure 6, we make use of the knowledge manifold educational architecture (described in section 2.2) where the pedagogical aspects correspond to the knowledge roles, and the tools are divided up into infrastructure, frameworks[10] and tools.

In Figure 6 the learning process is described as the following sequence of sub-processes:
1) *learning needs analysis*, which produces a description of the *knowledge gap* (= the difference between present and desired knowledge).
2) *learning preparation & content development*, which produces a set of learning offerings.
3) *learning process execution* (= LP-performance = LP-instantiation), which produces (some measure of :-) *understanding*.
4) *learning assessment & certification*, which produces quality certificates.

[8] For example, IMS Learning Design [105], a leading international standardization effort that deals with the description of learning processes, does not seem to make use of process modeling in a systematic way.

[9] Goals, Obstacles, Actions, Prerequisites.

[10] Here, the word 'framework' denotes a code library, which could be regarded as a programmer's form of abstract model, which s/he instantiates by writing a computer program that makes use of the library.

In Figure 6, below the description of the learning process there is listed the set of *knowledge roles* for a knowledge manifold educational architecture.[11] These roles represent different types of human involvement in the learning process. Below these roles the figure lists the infrastructure (Edutella), frameworks (SCAM and SHAME) and tools (*Formulator*, *Confolio*, *Conzilla*, *VWE*) of a knowledge manifold, as well as the *Flash-meeting* tool. [12]

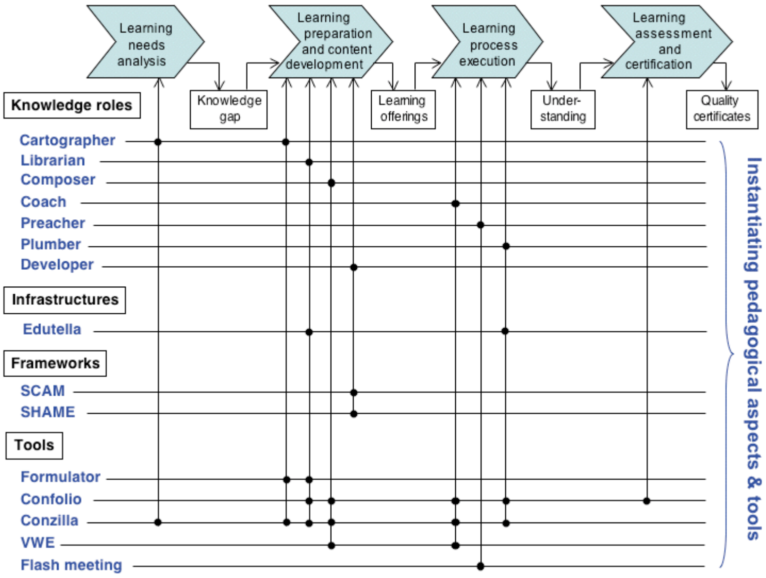

Figure 6. Instantiated pedagogical aspects and tools for a Knowledge Manifold with Flash meeting support.

The information in Figure 6 should be interpreted in the following way:

- During the *learning needs analysis* stage, the *cartographer* makes use of:
    - *Conzilla* in order to map out the present and desired competence of a learner and describe the corresponding *knowledge gap*.

- During the *learning preparation and content development* stage, the *cartographer* makes use of:
    - *Conzilla* in order to create context-maps of the relevant knowledge areas.
    - *Formulator* in order to create suitable metadata editors to describe the various concepts involved.

- During the *learning preparation and content development* stage, the *librarian* makes use of:
    - *Conzilla* in order to fill the context-maps created by the cartographer with information about content.
    - *Edutella* in order to search for and locate information about this content on the Semantic Web.
    - *Formulator* in order to create suitable metadata editors for the description of this information.
    - *Confolio* in order to store this information (and sometimes also the content itself).

- During the *learning preparation and content development* stage, the *composer* makes use of:
    - *Conzilla* in order to locate relevant material for a certain learning module from the context-maps created by the cartographer.
    - *Confolio* in order to locate relevant material for a certain learning module from the material gathered by the librarian.
    - *VWE* in order to assemble the located material into a customized learning module.

- During the *learning preparation and content development* stage, the *developer* makes use of:
    - *SCAM* in order to develop relevant material in the form of computer programs.
    - *SHAME* in order to develop relevant material in the form of computer programs.

[11] In order to illustrate the connection with the frameworks (code libraries) SCAM and SHAME, the *knowledge-mentor* has been substituted for the *knowledge-developer*, which is not part of the original seven knowledge roles for a knowledge manifold. The latter role could also be called *LearningObject-developer*, or *Content-developer*.

[12] Flash meeting is developed by the Knowledge Media Institute of the Open University under the coordination of Peter Scott.

• During the *learning process execution* stage, the *coach* makes use of:
  • *VWE* in order to run (execute) the learning process in the learning module created by the composer.
  • *Conzilla* in order to let the learners map their own knowledge as it develops over time.
  • *Confolio* in order to let the learners collect and present their own material, as well as to reflect and comment on the material of others.

• During the *learning process execution* stage, the *preacher* makes use of:
  • *Flash meeting* in order to "preach on request" and present live answers to learner questions, and record them for future access and storage in the Conzilla-based knowledge archive.

• During the *learning process execution* stage, the *plumber* makes use of:
  • *Conzilla* in order to browse different context-maps looking for relevant preachers to answer a question.
  • *Confolio* in order to browse different content archives looking for relevant preachers to answer a question.
  • *Edutella* in order to search the Semantic Web looking for relevant preachers to answer a question.

• During the learning assessment and certification stage, someone[13] makes use of:
  • *Confolio* in order to let the learners presents the knowledge they have gained during the learning process.

The scenario described above is related to *question-based learning* as described in [39] and [40].

3.3. Refining the process part of the model

Observe that the description of the learning process still remains very abstract and general. In fact, process modeling is typically performed top-down, where each sub-process is divided into different parts and described in more detail, until satisfactory level of concretion is reached. For example, two of the sub-processes in Figure 6 are named in an aggregated way that immediately suggests subdivision into parts. These two sub-processes are "*learning preparation and content development*" and "*learning assessment and certification*." In Figure 7 we show the refinement of the model with respect to the former of these sub-processes.

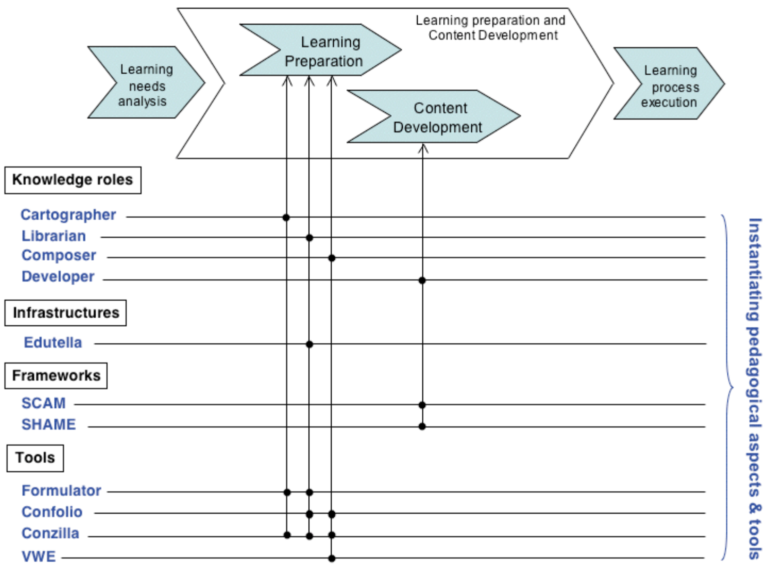

Figure 7. Refining the process part of the framework

The names of the other three sub-processes of Figure 6 do not directly suggest how to break them up into parts, and the way to do this will in fact be a characteristic of the actual learning process under study. Hence, by modeling the way that different learning processes refine the abstract process model, we can in fact create an empirical basis for their classification.

[13] Here a supporting tool is introduced without specifying who (= which knowledge role) is making use of it.

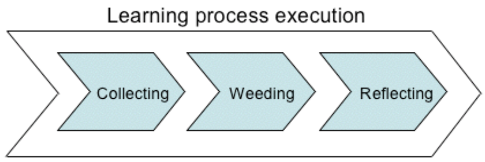

Figure 8. Breaking *learning process execution* into smaller parts (sub-processes)

To give a brief indication of how this works, in Figure 8 the *learning process execution* process has been broken up into the three sub-processes *collecting*, *weeding* and *reflecting*, and in Figure 9 the *reflecting* process has been broken up into the three sub-processes *constructing*, *testing* and *refactoring*.[14]

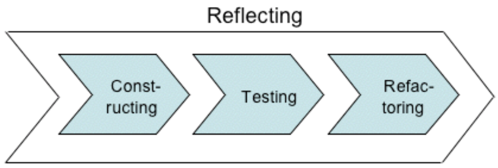

Figure 9. Breaking the *reflecting* process into smaller parts (sub-processes)

4. THE SECI KNOWLEDGE CREATION PROCESS

In their award-winning book from 1995 *The Knowledge Creating Company* [54], Nonaka and Takeuchi introduce their theory of organizational knowledge creation, first put forward by Nonaka [53] in 1994. Although it is well known within the knowledge management community, it seems to have had relatively little influence within the learning management community, which could be taken as an indicator of the strong traditional separation between these two communities.

According to Nonaka and Takeuchi, the Cartesian split between subject and object, the knower and the known, has given birth to a western view of an organization as a mechanism for information processing. While this view has proven to be effective in explaining how an organization functions, it does not really explain the concepts of innovation and knowledge creation. In the Nonaka-Takeuchi theory of knowledge creation, the cornerstone is the distinction between *tacit* and *explicit* knowledge. The dominant form of knowledge in the West is explicit knowledge, which can be easily transmitted across individuals - formally and systematically. In contrast, the Japanese view knowledge as primarily tacit – something that is not easily visible and expressible, but which is deeply rooted in an individual's actions and experiences.

4.1. The SECI modes of knowledge conversion

According to Nonaka [53] the key to knowledge creation lies in the following four (SECI) modes of knowledge conversion, that occur when tacit and explicit knowledge interact with each other:

• *Socialization*, which is the process of sharing experiences (tacit knowledge), thereby creating new tacit knowledge.
• *Externalization*, which is the process of articulation and conversion of tacit knowledge into explicit knowledge.
• *Combination*, which is the process of restructuring and aggregating explicit knowledge into new explicit knowledge.
• *Internalization*, which is the process of reflecting on and embodying explicit knowledge into tacit knowledge.

[14] Naturally, in Figures 4, 5, and 6 there are also feedback loops with 'breakout criteria' for the different process chains, but for reasons of simplicity they are not shown in these figures.

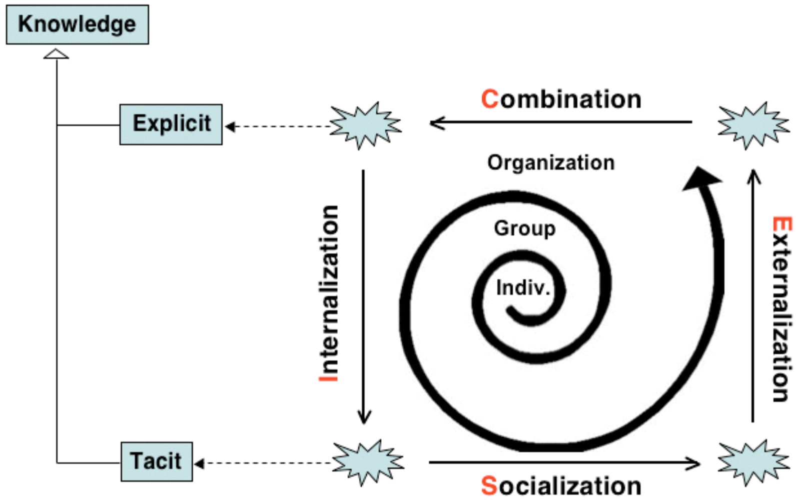

Figure 10. The SECI spiral of knowledge creation

As illustrated in Figure 10, which is based on Naeve [43], a knowledge-creating spiral occurs when these modes of interaction between tacit and explicit knowledge are elevated from the *individual*, to the *group* and *organizational* levels. Organizational knowledge creation, therefore, should be understood as a spiraling process that organizationally amplifies the knowledge created by individuals and crystallizes it as a part of the knowledge network of the organization. This process takes place within an expanding "community of interaction" which crosses intra- and inter-organizational levels and boundaries ([74], p. 51).

4.2. Ba – a place for interactive knowledge creation

Nonaka and Takeuchi emphasize that, on the organizational level, the spiral of knowledge creation is guided by dialectical thinking[15] and driven by organizational intention, i.e. an organization's aspiration to achieve its goals. Moreover, they introduce the Japanese concept of *ba* (which roughly means "place for interactions") as a crucial enabler for effective knowledge creation. The Japanese word 'ba' is a concept that unifies *physical* space (such as e.g., an office space), *virtual* space (such as e.g., e-mail), and *mental* space (such as e.g., shared ideas). Within an organizational context, it is the role of middle managers to maintain the necessary manifestations of such ba in order to support the knowledge creation spiral and make it efficient for the purposes of the organization.

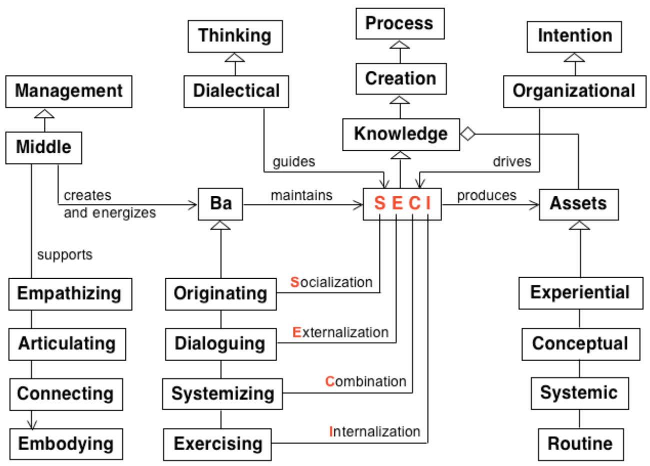

Figure 11. A conceptual model of the SECI knowledge creation process.

There are four types of ba that support the four different modes of knowledge conversion: *originating* ba, *dialoguing* ba, *systemizing* ba and *exercising* ba [55]. Each ba offers a context for a specific step in the knowledge-creating process. Building, maintaining and utilising ba is important to facilitate organizational knowledge creation.

[15] Which tries to transcend paradox by achiving a Hegelian synthesis between thesis and anti-thesis.

• *Originating ba* provides a context for socialization. It is a place where individuals transcend the boundaries between self and others by sympathising or empathising with others and sharing tacit knowledge in the form of experiences, feelings, emotions and mental models. From originating ba emerge care, love, trust and commitment, which form the basis for knowledge conversion among individuals.

• *Dialoguing ba* provides a context for externalisation. Tacit knowledge is shared and articulated through dialogues amongst participants. Dialoguing ba is the place where individuals' mental models and skills are shared, converted into common terms, and articulated as concepts. The articulated knowledge is also brought back into each individual, and further articulation occurs through self-reflection.

• *Systemising ba* provides a context for the combination of existing explicit knowledge into new forms. Information technology, through such things as on-line networks, groupware, electronic mailing lists, news groups, databases, etc., offers a virtual collaborative environment for the creation of systemizing ba.

• *Exercising ba* provides a context for internalisation. Here, individuals embody explicit knowledge that is communicated through virtual media, such as written manuals or simulation programs. Exercising ba synthesises the transcendence and reflection through action, while dialoguing ba achieves this through thought.

Ba exists at many levels that may be connected to form a greater ba. Individuals form the ba of groups/teams, which in turn form the ba of organisation. Then, the market environment becomes the ba for the organisation. Ba is a concept that transcends the boundary between micro and macro, and the organic interactions amongst these different levels of ba can amplify the knowledge-creating process.

4.3. Knowledge assets

At the base of knowledge-creating processes are knowledge assets. Nonaka, Toyama, and Konno [55] define knowledge assets as “firm-specific resources that are indispensable to create values for the firm”. According to them “knowledge assets are the inputs, outputs and moderating factors of the knowledge-creating process. For example, trust amongst organizational members is created as an output of the knowledge-creating process, and at the same time it moderates how ba functions as a platform for the knowledge-creating process.”

Knowledge assets must be built and used internally in order for their full value to be realized, as they cannot be readily bought and sold. To understand how knowledge assets are created, acquired and exploited, Nonaka, Toyama, and Konno propose to categorize knowledge assets into four types – corresponding to the four (SECI) modes of knowledge conversion: *experiential* knowledge assets, *conceptual* knowledge assets, *systemic* knowledge assets, and *routine* knowledge assets (see Figure 11). They give the following characterization of these four types ([55], p. 21-22):

• *Experiential knowledge assets* consist of the shared tacit knowledge that is built through shared hands-on experience amongst the members of the organisation, and between the members of the organisation and its customers, suppliers and affiliated firms. Skills and know-how that are acquired and accumulated by individuals through experiences at work are examples of experiential knowledge assets. Other examples of such knowledge assets include emotional knowledge, such as care, love and trust, physical knowledge such as facial expressions and gestures, energetic knowledge such as senses of existence, enthusiasm and tension, and rhythmic knowledge such as improvisation and entrainment.

• *Conceptual knowledge assets* consist of explicit knowledge articulated through images, symbols and language. They are the assets based on the concepts held by customers and members of the organization. Brand equity, which is perceived by customers, and concepts or designs, which are perceived by the members of the organization, are examples of conceptual knowledge assets.

• *Systemic knowledge assets* consist of systematized and packaged explicit knowledge, such as explicitly stated technologies, product specifications, manuals, and documented and packaged information about customers and suppliers. A characteristic of systemic knowledge assets is that they can be transferred relatively easily. This is the most visible type of knowledge asset, and current knowledge management focuses primarily on managing systemic knowledge assets, such as intellectual property rights.

• *Routine knowledge assets* consist of the tacit knowledge that is ‘routinized’ and embedded in the actions and practices of the organisation. Know-how, organisational culture and organizational routines for carrying out the day-to-day business of the organisation are examples of routine knowledge assets. A characteristic of routine knowledge assets is that they are practical.

4.4. Leading the SECI knowledge-creating process

As mentioned above, the SECI process is guided by dialectical thinking, which focuses on transcending paradox by creating a synthesis between opposing forces, such as between order and chaos, micro and macro, tacit and explicit, body and mind, emotion and logic, and action and cognition. As pointed out by Nonaka, Toyama and Konno in [55], the SECI process cannot be managed in the traditional sense of management, which centers on controlling the flow of information. In contrast, top and middle management take a leadership role by "reading the situation", as well as leading it, working on all three elements[16] of the knowledge-creating process. Leaders provide the knowledge vision, develop and promote the sharing of knowledge assets, create and energize ba, and enable and promote the continuous spiral of knowledge creation. This overall organizational knowledge creation process is modeled in Figure 12.[17]

Especially crucial to the SECI process is the role of knowledge producers, i.e. middle managers who actively interact with others to create knowledge by participating in and leading ba. Nonaka, Toyama and Konno emphasize that in order to create knowledge dynamically and continuously, an organization needs a vision that synchronizes it. It is the role of top management to articulate the knowledge vision and communicate it throughout (and outside) the company. The knowledge vision defines what kind of knowledge the company should create and in what domain. In short, it determines how the organization and its knowledge base evolve over the long term. The knowledge vision also defines the value system that evaluates, justifies and determines the quality of the knowledge the company creates.

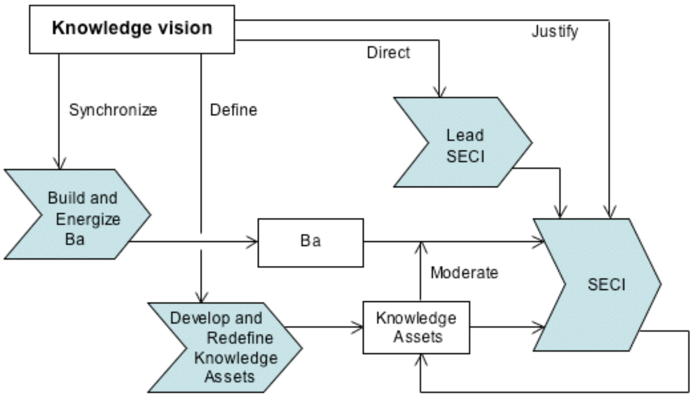

Figure 12. The overall organizational knowledge creation process

5. THE SECI PROCESS FRAMEWORK

By combining learning process modeling (section 3) with the SECI theory of knowledge creation (section 4), we can create a *SECI process framework* (*abstract model*) for the description and classification of knowledge-creating learning processes. In Figure 13 we have introduced the four different kinds of ba, as well as their corresponding tools of support. *Socialization* occurs in *originating ba*, where *experiencing* and *empathizing* activities are supported by *community building tools*. *Externalization* occurs in *dialoguing ba*, where *articulating* and *conceptualizing* activities are promoted by *discussion supporting tools*. *Combination* occurs in *systemizing ba*, where *connecting* and *deducing* activities are supported by *conceptual modeling tools*. *Internalization* occurs in *exercising ba*, where *reflecting* and *embodying* activities are supported by *reflective analysis tools.*

[16] SECI, ba and knowledge assets.

[17] which is a process model version of Figure 8 from [55].

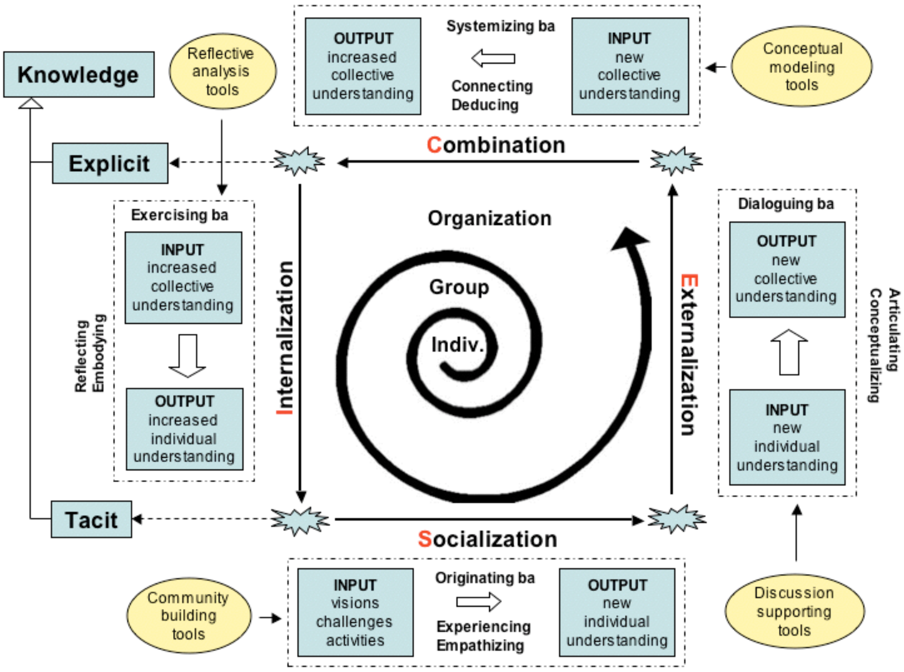

Figure 13. **The SECI process framework: increasing understanding through experiencing, articulating, deducing and reflecting.**

In each of the four SECI knowledge conversion stages a learning process takes place. As shown in Figure 13, sharing experiences in the socialization process, with input from *visions*, *challenges* and *activities*, produces *new individual understanding* of the issues at stake. This new individual understanding is then externalized and articulated into *new collective understanding* of the same issues. Then the combination process deductively produces *increased collective understanding*, which is then internalized by reflection and embodied into *increased individual understanding*.

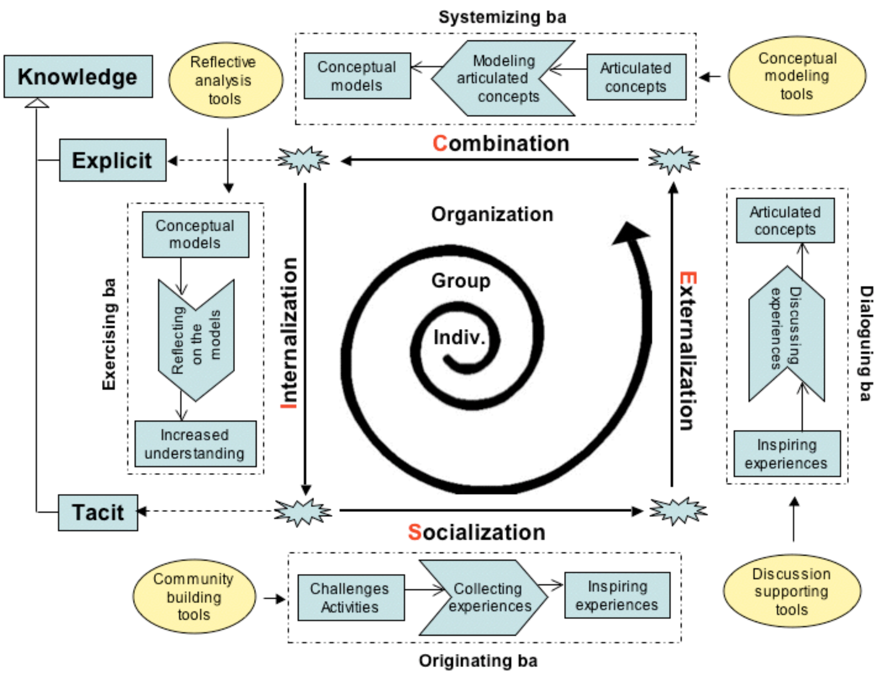

Figure 14. **The SECI process framework with a process model within each ba.**

In Figure 14 the different knowledge conversions have been modeled as processes. During the socialization process we respond to *challenges* and *activities* by collecting *inspiring experiences*. During the externalization process they form the input for discussions, which produce *articulated concepts*. During the combination process, these articulated concepts are connected and combined into *conceptual models*, and during the internalization process, these conceptual models are reflected upon, which results in *increased understanding* of the issues involved.

In Figure 14 we think of each process as described by the kind of process/pedagogy/tools model that was introduced in section 3. This is difficult to draw in the overall diagram, but in the Conzilla-based version, a double-click on the top diagram within each ba would open up the corresponding process/pedagogy/tools abstract model. In order to describe a concrete professional learning process we can then "drill down" of the processes in each ba and perform a top-down construction of their corresponding process/pedagogy/tools model. By mapping out concrete learning processes in this way, we lay the empirical foundation for their future classification. Hence the SECI process framework provides a methodology for researching the structure of knowledge-creating learning processes.

6. EMPIRICALLY VALIDATED PEDAGOGICAL SUPPORT

6.1. Introduction and overview

We will now present some previous research into the development and testing of pedagogical ideas related to the SECI process framework (Figure 16). The corresponding learning model involves four latent variables, namely ***Socialization, Externalization, Combination,*** and ***Internalization***, which will be reviewed from a pedagogical perspective. These latent variables consist of the measurable processes: ***Collecting experiences, Discussing experiences, Modeling articulated concepts***, and ***Reflecting on the models*** (Figure 14*)*. These processes take place within the corresponding ***ba*** (space of interaction, which has been marked with a dashed rectangle and a descriptive name in Figure 14. In front of every process variable we have inserted a descriptive variable of the available tools. The ***Socialization*** variable in the learning model consists of ***Collecting experiences***, which will take place by interacting with other learners in ***Originating ba***. In this 'space' a collaborative learning group will be formed with ***Inspiring Experiences*** as an end product. When forming the learner group *Community building* tools will be used.

Community building tools include a *support process* (at least in academic learning level), which is partly covered by an *Interaction process*, which might activate the *Exploratory learning behaviour*. The exploratory behaviour is activated only if the interaction process is good enough. Self-esteem is the first endogenous variable, which is predicted by the quality of the interaction process. On the other hand, the intrinsic motivation is further predicted by learner's self-esteem. First when the intrinsic motivation is activated, the exploratory behaviour or the process of *Collecting experiences* under ***Socialization*** is activated. This part has been empirically tested by Yli-Luoma using the *LISREL* method ([83], p. 211; [84], pp. 15-28). Here he shows that the *Collecting experiences* process is emotionally ([82], p. 106; [83], p. 211) and socially ([77], p. 163) loaded. It should be observed that the quality of the emotional network of the social group would seem to increase the self-esteem of the group, which further activates the *Collecting experiences* process.

Within the ***Externalization*** phase, the *Discussing experiences* process is still emotional. However, cognitive dimensions are needed ([22], p. 114), where creativity is also activated ([10], p. 152). Kolb argues further that this process becomes effective in the form of teamwork (see further [28]).

When the Externalization phase goes over to the ***Combination*** phase, the *Modeling* process is activated, and *Hypothetical-Deductive* thinking abilities are needed for the modeling approach ([25], p. 209; [27], p. 117; [26], pp. 388-390; [18], p. 175). It should be observed here that the *Constructivistic* learning process only covers the *Socialization* and *Externalization* phases of the learning process ([27], p. 175). In any type of learning that involves deductive or abductive reasoning, such as e.g. the learning of science and mathematics, a modeling approach is needed ([15], p. 1; Hestenes [20]).

The learning process requires further that students engage in seeking to understand and explain the conceptual models developed in the Combination process ([81], pp. 92-93; [61], p. 1), which means that the process of ***Internalization*** is activated. This is a process, where learners reflect on the new structures (models) by using critical thinking abilities when testing or applying them.

6.2. Socialization process

In the Socialization process, the social interaction between students and their teachers is included. Yli-Luoma ([83], p. 175; [84], p. 27) has observed that when this interaction is good enough, and when it covers three special dimensions: *emotional attachment*, *cognitive support*, and *moral values*, it will advance the internal working models, which include *intrinsic motivation*. The intrinsic motivation, however, is mainly activated by *strong self-esteem*, which is a product of the interaction process. So the best support would seem to be the advancement of strong self-esteem among the learners in order to activate their learning processes. Bowlby ([9], p. 238) argues that secure emotional attachment activates exploratory behaviour, which is best conceived as mediated by a set of behavioural systems evolved for the special function of extracting information from the environment. Activation results from novelty and termination from familiarity.

The activation process was tested empirically by using a *LISREL* model. The model (Figure 15) was run with one exogenous variable (*Interaction*) and three endogenous variables (*Self-Esteem, Motivation, and Learning*). The measures used are shown in the boxes above the latent variables. The beta-coefficient (between self-esteem and motivation) and the gamma-coefficient (between teacher-student interaction and self-esteem) were both statistically very significant ($\gamma_{21} = 0.54$, $p < 0.001$; $\beta_{32} = 0.44$, $p < 0.001$), and the beta-coefficient between motivation and learning ($\beta_{43} = 0.52$, $p < 0.001$) (Figure 15) was also very significant.

The *Interaction* variable was measured by three dimensions: *Emotional*, *Supporting*, and *Moral*. The *Self-Esteem* variable was measured with *Social and Academic* dimensions - according to Shavelson et al. ([68], p. 407). The latent variable *Motivation* has the dimensions of *Intrinsic* motivation and *Extrinsic* motivation as a measurement model. The learning process was measured with two types of learning: *Imitative* and *Explorative*.

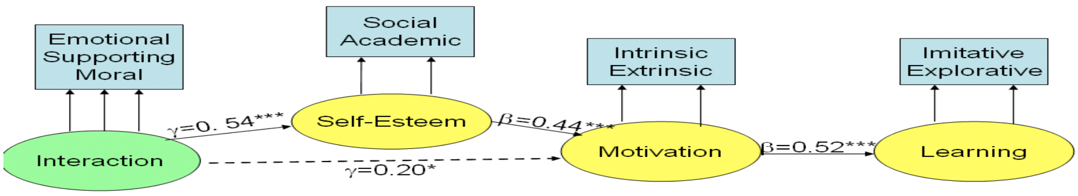

Figure 15. The *LISREL* model of the interaction process

Vygotsky ([76], [77]) claims that the social context has a significant impact on the learning process. He argues further that it takes place on two levels, the *social* and the *psychological* level. The social interaction process is observed by inter-personal relationships. The psychological process takes place on the intra-psychological level, which means that the learners construct new information with their thinking abilities. This type of approach has made a contribution to social constructivism, which was developed by Berger and Luckman ([6]).

The interaction process above refers to synchronous face-to-face learning. What about synchronous or asynchronous distance learning? How do we activate the exploratory behaviour (i.e., how do we motivate) at a distance and asynchronously? Interaction design is the art of effectively creating interesting and compelling experiences for others ([70]).

The distance in time and place seems to impede the process of bonding (attachment) and of building cohesion in a group. Cohesiveness in a group is positively reinforced if the group goals match the members' personal goals, if the group interacts effectively and harmoniously, and if the members are attracted to each other ([67]). To build trust and create a feeling of cohesion, intensive personal attention and presence is required, which is difficult to achieve via Internet-based communication. Bonding (social attachment) is much easier to advance if members have met face-to-face first.

The social interaction among the online learners is crucial not only for knowledge construction and mutual support, but for the reduction of isolation and anxiety during the independent learning process (compare Vygotsky's psychological level).

Comparing face-to-face learning and online learning, the social context might be the one dimension, where most differences can be found. The social context, however, is one of the cornerstones in the learning process. How then can online learning be arranged in order to take place in such a way that the participants maintain mutual caring and understanding through the interactions, which can be offered online? A good arrangement would mean that the online learners would be able to develop a sense of belonging, social-emotional bonds or attachment, and supportive relationships.

Collecting experiences is positioned in the *Socialization* knowledge conversion process, which is emotionally and/or affectively loaded. If the learner does not like the subject, s/he would not be interested to collect any new information or experiences either. The Kolbian approach replaces these two aspects together ([28], [22]). Moreover, brain research has demonstrated that ***learning is based on collecting experiences*** ([9]). In his study of Kolbian learning styles, Yli-Luoma ([85]) has observed that *collecting experiences* is one of the basic learning styles, but if it remains the preferred style of the learner, then the learning process would seem to remain qualitatively quite week. It would further seem to haven a negative prediction ability for college and university performance. This would mean that the students with this learning style only would not seem to perform well in their studies.

6.3. Externalization process

The Socialization process is needed in order to activate a collaborative discussing phase between the online learners ([22], [28]). Ravenscroft ([64]) argues further that a socio-cultural framework is needed for cognitive change. According to the argumentation of Vygotsky ([76]), the higher cognitive processes provide a basis and motivation for collaborative, argumentative and reflective discourse.

Bransford et al. ([10]) suggest further that the collaborative discussing phase includes *creativity*. Zohar ([86]) argues that the creative thinking process demands that we can break old rules or are able even for a shift of paradigms. Some brain researchers argue that this kind of thinking is placed in human brains within the same area as motivation, vision, value and meaning.

According to Keeves ([27]), the constructivist approach still works in this phase. Students construct the information and experiences towards their new knowledge using the Piagetian cognitive developmental stage at the Concrete Operational Stages, but they do not need to go beyond these stages. Keeves argues further that at least in the fields of mathematics and science, the basic principles of constructivism are incomplete and inadequate for both learning and teaching these fields. This argument is strongly supported by the modeling theory of Hestenes ([46], p. 355-356), which he has applied to the education of high-school physics teachers for almost two decades ([20]).

Sweller ([73]) questions strongly the efficacy of so-called 'constructivist based' learning and argues that evidence for the effectiveness of these learning procedures is almost totally missing with a lack of systematic and controlled experimentation. The experimentation, however, should be re-positioned after the modeling process (or the Combination process as it is called in the present study).

We stress the relevancy of cognitivism in the Externalization phase. One of the learning strategies that support cognitivism is *concept mapping* (Novak [57]), which is a technique for the expression and visualization of domain concepts and their relationships. Concept maps are tools for organizing and representing knowledge. They include concepts and propositions. Concepts are defined as a perceived regularity in events or objects, or records of events or objects, designated by a label (Novak [58]). Propositions are statements about some object or event in the universe, either naturally occurring or constructed. Propositions contain two or more concepts connected with other words to form a meaningful statement.

6.4. Combination process

The Modeling approach (modeling articulated concepts) takes place in *Systemizing ba* after Externalization (Figure 14). Here the learners need *Conceptual modeling tools* in order to advance the articulated concepts towards forming *Conceptual models*. For these kinds of processes, higher thinking abilities with advanced modeling tools are needed. The Piagetian Formal Operations Stage would seem to fulfill this demand. At the formal operational stage, students are able to formulate and test a single hypothesis - they are able to go beyond the data. When the problem is more complex - and several hypotheses are needed - a model approach would seem to be more suitable. Kaplan ([25], p. 117) argues that the term 'model' is useful when the symbolic system it refers to is significant as a structure - a system that allows for exact deductions and explicit correspondences. The value of the model lies in the deductive fertility of the model, so that the unexpected consequences can be predicted and then tested by observation and experiment. Evers ([15]) has presented a connectionist model of artificial neural networks in an educational situation. Penner's article ([61]), titled 'Cognition, Computers, and Synthetic Science: Building Knowledge and Meaning through Modeling', laid the foundations for a shift towards what he recognizes to be a modeling approach. However, Penner fails to recognize that a model must be tested for adequacy. While he considers practical work in the traditional teaching of science, he does not see clearly its role in a modeling approach. Keeves ([27]), however, argues very clearly for a modeling approach, which has to satisfy the following requirements:

- a model should lead to a prediction of consequences,
- a model should contain both associative and structural relationships,
- a model should reveal a causal direction leading to explanations, and
- a model should give rise to new concepts and new relationships.

Keeves has identified several types of models:
- *analogue* models,
- *semantic* models,
- *schematic* models,
- *mathematical* models, and
- *causal* models.

These modeling processes might well be described as construction processes, and the term 'constructionism' could be employed. Nevertheless, the term 'constructionism' has already been used in association with social constructivism and in this context it has a very different meaning. Since most often a simple construction with the characteristics of a model is not being built through social constructionism, the term 'constructionism' is best avoided and an alternative word should be sought. That is why the term 'modeling' could be adopted. In the present learning model, the term *Combination* (Figure 14) is also used for this process. The Combination process in the present study is closely related to the *Kolbian Learning Style* of the *Theorist*. Its predictive value in the academic learning process is the highest possible ([85]). In the very same comparative study of Kolbian learning styles, which uses a new measurement model advanced by Yli-Luoma ([85]), it is shown that the Kolbian theorist (closely related to our *Systemizing ba*) is very rare as the preferred learning style among European polytechnic students (Finland 10.0%, France 23.8%, Italy 3.3%, and Spain 13.0%).

The modeling approach has already been used in Bloom’s taxonomy ([8]). For example, at the *Apply* level (see Figure 1) the learner should be able to construct a model of the phenomenon under study and demonstrate how it will work. At the *Analyze* level the learner should be able to make a flow chart to show the critical stages of knowledge or construct a graph to illustrate the selected information. Moreover, Novak ([56]) has turned modeling into a real cognitive tool in his conceptual mapping procedure. While constructing good concept maps ([110]) the learner is modeling e.g., a laboratory activity, or a particular problem or question that s/he is trying to understand.

During the Combination phase, case-based reasoning (CBR) is also important, as an approach to learning and problem solving based on previous experiences (Kolodner [29]). Past experiences are stored in the form of solved problems (‘cases’) in a so-called case base. A new problem is solved based on adapting solutions of known similar problems to this new problem. This kind of inference is necessary for addressing ill-defined or complex problems. Key to such reasoning is a memory that can access the right experiences (cases) at the times they are needed.

6.5. Internalization process

The *Internalization process* consists of *Reflection on the models*, which takes place in *Exercising ba* (Figure 14). This would mean that the learners should already have conceptual models of the knowledge (theory) they are articulating. They should now advance experiments, laborations etc. in order to test the conceptual models they have developed. This process should increase their understanding.

Yli-Luoma's ([81], p. 92) comparative study among pre-university students of physics learning reveals the importance of experimental and testing processes. He had access to data from seven different countries of which three made use of an experimental approach (*Exercising ba*) and the remaining four did not. The results expose how pre-university students understand physics without having evolved their understanding in an experimental context. In those countries in which the students were involved with an experimental approach, the thinking abilities and understanding of physics were much better developed than in the countries where the experimental approach was missing. The Test on Understanding Physics for those **using an experimental approach** (*Exercising ba*) the score was $\mu = 38.3$, $\sigma = 9.0$ and for those **not using an experimental approach** (no *Excersising ba*) $\mu = 11.5$, $\sigma = 4.8$ and for these two groups (***Exercising ba*** and ***no Exercising ba***) the *t*-test value was calculated $t = 36.9$, $p < 0.001$. This would seem to give a very strong evidence for advancing a well working ***Excersising ba***.

From the above it can be concluded that the theoretical approach in a learning process is not enough, but an experimental learning approach (*Exercising ba)*, with testing of knowledge, will lead to a better quality of learning.

How is the experimental learning process implemented in online learning? Simulations might be useful as laboration tools in an experimental approach. Nakajima ([47]) tested it in physics-learning, using chat-forum as a reflection tool. His experiment would seem to confirm the idea of using simulations as a part of the experimental approach.

7. CONCLUSIONS AND FUTURE WORK

In this paper we have presented a conceptual approach to the studying of learning processes. We have introduced the process/pedagogy/tools model and shown how its assembly-line style of process modeling can be used to describe which pedagogical aspects and which tools that support which parts of a specific learning process.

Moreover we have introduced the distinction between knowledge-transmitting and knowledge-creating learning processes, a distinction that separates formal learning from informal learning, as well as (traditional) courses from research. Finally, we have presented the SECI process framework for the study and analysis of knowledge-creating learning processes, and we have shown how the different SECI modes of knowledge conversion are empirically supported by pedagogical research.

Naturally, both knowledge-transmitting and knowledge-creating learning processes have to be supported in workplace learning. As the percentage of "knowledge workers" is rapidly increasing and 50% of all employee skills become outdated in three to five years (Moe and Blodgett [38]), re-qualification plays an important role. Since re-qualification is often based on learning already existing knowledge and skills, knowledge transmission is typically required in such situation. On the other hand, companies also need to collect and analyze the feedback from customers and their own employees, investigate the market, compare their products with those of the competition, and design and develop innovations. In such situations new knowledge has to be created, and this is also the critical demand of the present "knowledge age". Hence our deliverable focuses on a type of learning process – knowledge creation - that is crucial for workplace learning, and which in the past has not been investigated as much as knowledge transmission.

7.1. Applying the framework models to Prolearn

The major aim of this paper has been to formulate abstract conceptual models that could provide a foundation for useful ways to characterize and classify work place learning processes. We believe that both the process/pedagogy/tools model (section 3.1) and the SECI process framework (section 5) are very relevant for studying learning at the workplace. When applied to the knowledge-creation of the Prolearn NoE, the SECI spiral goes from *Core* partners to *Associate* partners and further outwards to the *Scientific Community & Industry*, as illustrated in Figure 16. In fact, this framework has already been adopted as the basis for the Prolearn roadmapping process (Kamtsiou et al. [24]), and we also plan to apply it to the study of work place learning within the Prolearn workpackage on knowledge work management.[18] In fact, this work will be part of the deliverable D 7.5 (*Antecedents for Effective Learning Management at the Workplace*), which is due on month 24. As discussed earlier, work place learning tends to be much more knowledge-creating than traditional course-based learning, which is why we have chosen the SECI theory of knowledge creation as a basis for this conceptual approach.

[18] In fact, the Prolearn Virtual Competence Centre provides an excellent ba for this type of research process.

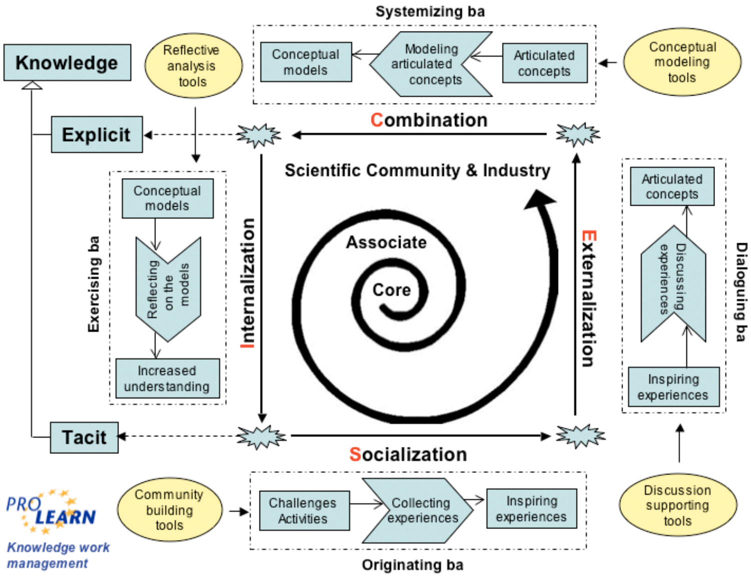

Figure 16. Applying the SECI process framework to *Knowledge work management* could give a classification framework for knowledge-creating types of workplace learning processes.

7.2. Future research issues

How should we design effective learning processes in the workplace? In the present study we have introduced several different types of knowledge. Göranzon's [20] four types of knowledge have been discussed, as well as Bloom's six levels of cognitive knowledge [8] (slightly revised by Anderson and Kratwohl [1]) ranging from simple remembering of facts at the lowest level through more complex and abstract mental levels to the highest one, classified as *Creation* in Figure 1. Moreover, Naeve [43] defines a new dimension of knowledge, namely *efficient fantasies*. We need here a synthesis of the different types or dimensions of knowledge, which could be tested by confirmatory factor analysis.

Also, knowledge *transmission* or *creation* and *pushing* and *pulling* concepts were presented as two important dimensions that distinguish *formal* and *informal* learning processes. These two types of learning could be tested by a comparative approach, which is one strong feature in the *LISREL* –method (LInear Structural RELationships [80]).

Another interesting comparison of knowledge-transmitting and knowledge-creating types of learning processes recognizes knowledge-simulating and knowledge-stimulating type of behaviour (Figure 3). Here the following question arises: how can we distinguish real and simulated knowledge? One possibility might be by means of the Bloom taxonomy – which has knowledge simulation (or imitation) as its lowest level. In the knowledge-creating learning process learners are trying to figure out the right questions. This corresponds with the revised concept of intelligence as specified by R. C. Schank ([11]). The easier is it to get information the lower is its value. But the value of good questions increases. In the future, intelligence will mean ability to reach the boundaries of the knowledge base.

The SECI knowledge creation process consisted of four different dimensions, namely ***Socialization, Externalization, Combination,*** and ***Internalization.*** It was also concluded that these four different types of knowledge creation processes take place in four different types of ***interaction spaces*** (ba). These spaces are of great interest especially for ***INTeL*** –project group (INTeractive e-Learning), which will be collecting the data to be analyzed. And the data collecting procedure should be carefully planned to cover all the processes and theoretical features, which are included in the measurement model

The main aim of the present study has been to theoretically investigate different types of knowledge, knowledge transmission or creation, knowledge creation processes, and different types of ***interaction spaces*** (ba).
In the previous chapters a hypothetical model of learning was advanced and compared with previous research. However, a major aim for the future is to test its validity when applied in online learning. The *INTeL* –project[19]

[19] Managed by the University of Oulu. which is one of the Prolearn associate partners.

will setup an empirical testing process for the present hypothetical model (see Figure 16Figure 16). The first aim should be to collect all the used concepts in the four stages in the hypothetical process model, which should cover the useful theoretical features in every stage to be used. A structural model will be the aim product. After that a measurement model will be advanced to be able to collect correct empirical data for testing purposes. The *LISREL*-method could be applied as an analysis method for the following purposes:
• a structural model can be tested,
• all the hypotheses can be confirmed in one model run,
• in *LISREL* a hypothetical model can also be modified manually or automatically, and
• a simultaneous comparative analysis in several populations can also be undertaken.

8. ACKNOWLEDGEMENTS

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//////////////////////////// **APPENDIX** /////////////////////////////////

10. CONCEPTUAL MODELING

10.1. The concept 'concept'

Def: A *concept* is a representation of something that we have experienced or that we can imagine, and which we can apply to the objects that we are aware of.
Def: A description of the most important concepts - and their relations - within a specific problem domain is called a *conceptual model* of the domain.
Def: The *definition* of a concept describes its *intention*, i.e. what qualities it aims to express and delimit with respect to its surroundings.
Def: The *set of objects* that exemplify a concept is called its *extension*.
Def: Each *member element* of the extension-set is called an *example* = *object* = *instance* of the concept.
Def: The concept, whose extension consists of a set of instances, and whose intention describes their common structure, is called the *type* or the *class* of these examples.
Def: To identify a concept by observing similarities and differences within a group of examples is called to *classify* the examples.
Def: We say that a concept can be *applied* to a specific example, if this example fulfills the intention of the concept.[21]

10.2. Properties of the concept 'concept'

• A concept must always be defined by making use of other concepts.
• A concept can be denoted by one or several *names* (= *symbols*).
• A concept is always *idealized*, because it contains simplification that focus on some aspects and disregard others.
• The *definition of a concept* always *depends on the context* within which it will be used. The aim is always to disregard what is inessential and focus on what is essential within that context.

10.3. UML – a global modeling language

UML (*Unified Modeling Language*) [66], [109], is a language for specifying, visualizing and documenting conceptual models within many different domains.

UML was developed during 1993-1997 within the object-oriented software industry as an attempt to unify the 250 different modeling languages that were in use by the mid 1990s.It represents a collection of practically tested modeling techniques that have proven to be effective in the description of large and complex systems.

UML provides a "standardized visual language" where you can draw draw the most important concepts (and their relations) within a specific problem domain. You get a visible background against which you can discuss and where it is clear how you have been thinking up til now. This facilitates further development of the conceptual model and increases the possibilities to "calibrate the model" and reach consensus with respect to what should be regarded as important.

10.4. The Unified Language Modeling technique

Unified Language Modeling [39], [40] is a context-mapping technique, which has been developed by Ambjörn Naeve during the past decade. It is designed to visually represent a verbal description of a subject domain in a coherent way. Today, the ULM technique is based on the *Unified Modeling Language* [66], [109], which is a de facto industry standard for systems modeling.

[21] i.e. the conditions of its definition.

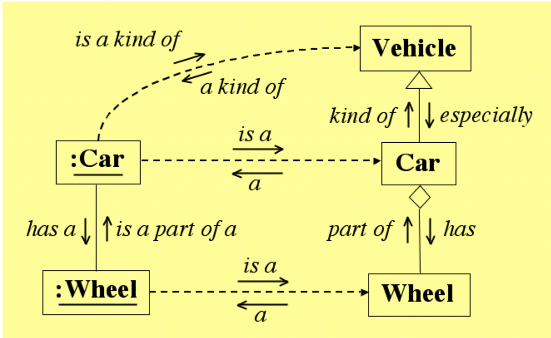

Figure 17. The basic verbal/visual correspondence of Unified Language Modeling.

In ULM the resulting context-maps have a clearly defined and verbally coherent visual semantics, which makes it easy to cognitively integrate the conceptual relations and achieve a clear overview of the context. Moreover, making the context visually explicit provides important support for the conceptual calibration activities that form an integral part of the learning process. The ULM verbal-to-visual contextual representation technique has a crucial advantage in comparison with similar techniques - such as *concept maps* [110] or *topic maps* [111] - which have to rely on purely verbal semantics in order to convey their conceptual relationships.

10.5. The modeling theory of David Hestenes

Here we will briefly describe the basic ideas that underlie the modeling theory of David Hestenes – a well-known physicist and physics education researcher. Although he has applied his modeling theory mainly to physics education [115] – and over the past two decades achieved striking results within this field - we share his belief that his theory is applicable to learning in general.

Hestenes uses the term "conceptual learning" for the type of learning that is the opposite of "rote learning". Here follows a brief presentation[22] of Hestenes' five general principles of conceptual learning that he has incorporated into his instructional theory and applied repeatedly in the design of instruction.

- *Conceptual learning is a creative act*. This is the crux of the so-called constructivist revolution in education, most succinctly captured in Piaget's maxim: "To understand is to invent!" Its meaning is best conveyed by an example: For a student to learn Newtonian physics is a creative act comparable to Newton's original invention. The main difference is that the student has stronger hints than Newton did.[23]

- *Conceptual learning is systemic*. This means that concepts derive their meaning from their place in a coherent conceptual system. For example, the Newtonian concept of force is a multidimensional concept that derives its meaning from the whole Newtonian system. Consequently, instruction that promotes coordinated use of Newton's laws should be more effective than a piecemeal approach that concentrates on teaching each of Newton's laws separately.

- *Conceptual learning depends on context*. This includes social and intellectual context. It follows that a central problem in the design of instruction is to create a learning environment that optimizes the learner's opportunities for systemic learning of targeted concepts. The context for scientific research is equally important, and it is relevant to the organization and management of research teams and institutes.

- *The quality of learning depends on the conceptual tools*. The quality of learning is critically dependent on conceptual tools at the learner's command. The design of tools to optimize learning is therefore an important subject for educational research [20].

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[22] This presentation is condensed from [21].

[23] Hestenes attaches the following warning to this (Constructivist) Learning Principle: "There are many brands of constructivism, differing in the theoretical context afforded to the constructivist principle. An extreme brand called "radical constructivism" asserts that constructed knowledge is peculiar to an individual's experience, so it denies the possibility of objective knowledge. This has radicalized the constructivist revolution in many circles and drawn severe criticism from scientists. I see the crux of the issue in the fact that the constructivist principle does not specify *how* knowledge is constructed. When this gap is closed with the other learning principles and scientific standards for evidence and inference, we have a brand that I call *scientific constructivism*."

• *Expert learning requires critical feedback*. Expert learning requires deliberate practice with critical feedback. There is substantial evidence that practice does not significantly improve intellectual performance unless it is guided by critical feedback and *deliberate* attempts to improve. Students waste an enormous amount of time in rote study that does not satisfy this principle.

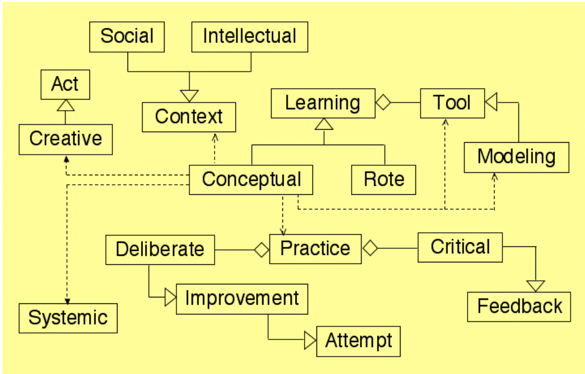


Figure 18. A ULM context-map of Hestenes' five learning principles.

The textual interpretation of Figure 18 is the following: Conceptual Learning *is a* Creative Act. Conceptual Learning *is* (*a*) Systemic. Conceptual Learning *depends on* Social Context and Intellectual Context. Conceptual Learning *depends on* Learning Tools, especially Modeling Tools. Conceptual Learning *depends on* Practice, which *consists of* (= *has*) Deliberate Improvement Attempts and Critical Feedback.

In his response [21] to the Oersted medal reward in 2002, Hestenes writes:

"I believe that all five principles are essential to effective learning and instructional design, though they are seldom invoked explicitly, and many efforts at educational reform founder because of insufficient attention to one or more of them."

"I see the five Learning Principles as equally applicable to the conduct of research and to the design of instruction. They support the popular goal of teaching the student to think like a scientist."

10.6. Educational Modeling Languages

In [65] an *Educational Modeling Language* (EML) is defined as: "A semantic information model and binding, describing the content and process within a 'unit of learning' from a pedagogical perspective in order to support reuse and interoperability."

According to [30], p. 5, the need for an EML is based on the fact that the prevailing learning object models (as expressed e.g. by *IMS Simple Sequencing* and *IMS Content Packaging*) express a common overall structure of objects within the context of a unit of study, but they do not provide a model to express the semantic relationship between the different types of objects in the context of use in an educational setting.

Several EMLs have been developed in order to remedy this deficiency [65]. Prominent among these is the OUNL-EML developed by the Open University of the Netherlands [23], [30], which now forms the basis for the standardization efforts of IMS Learning Design [105].

Although EMLs are important in several respects, they will not concern us much in this paper. This is mainly due to the follwing reason: An EML descibes a unit of study in a *formal* way, so that automatic processing becomes possible. This is an important general characteristic of *information modeling*, which aims to prepare for the construction of an automated information system that should support some ongoing human activities at a higher (*informal*) level.

In contrast, the models that are presented in this paper have no such aim. Instead they aim to facilitate effective communication at the human level by highlighting important concepts of the activities that humans are engaged in. Since our domain of interest is the management of the learning process, these activities involve the interplay of processes, human (pedagogical) roles and tools.

Moreover, the EMLs presented and compared in [65] do not contain any support for dynamic (e.g. process or activity) modeling[24]. They introduce dynamic concepts (such as e.g., Learning Activity), but these concepts are described only in terms of static UML models (class diagrams). This makes EMLs unsuitable for expressing the kinds of process-related concepts that we are interested in exploring here.

11. PROCESS MODELING: THE GOAP APPROACH

Here we will briefly describe the GOAP (Goal, Obstacles, Actions, Prerequisites) approach to process modeling. It is often used in connection with business modeling[25], but since our present 'business' is the learning process, we can just as well apply it to the modeling of learning processes. This approach was not explicitly followed in the CFL modeling work described above, but will be applied by CFL in the future in order to validate its course development process model.

The GOAP approach starts out by modeling the goals of the business or organization. A specific goal in the business is described as an object of a goal type. Goals can be *quantitative* or *qualitative*, and both of these goal types have a goal *description* as an *attribute*. A quantitative goal also has a goal *value*.

The relationships between goals are *dependencies* and *associations*. A dependency is represented in UML by a dashed line from the larger (dependent) goal to the smaller (partial) goal ending with an open arrow. The dependency should be interpreted as stating that the fulfillment of the smaller (partial) goal contributes towards the fulfillment of the larger (dependent) goal. If a larger goal can be completely broken down into smaller (partial) goals, a dashed line is drawn across the dependencies and a constraint is written next to the line in this form: {*complete*}. If the goal cannot be completely broken down into partial goals, {*incomplete*} is written (this is also the default if nothing at all is written).

A goal that has been completely broken down into partial goals indicates that the goal will automatically be fulfilled if all of the partial goals are met. This is what could be seen as a logical AND condition between the partial goals. The <<*contradictory*>> stereotype can be used to denote *mutually exclusive goals*. Typical examples of contradictory goals are "high quality" and "low cost". Contradictory goals normally cannot both be fulfilled, but must both be taken into consideration.

In connection with describing the goals we also describe the *obstacles* that stand in their way. An obstacle is a problem that hinders the achievement of a goal. By finding the problem, new goals or partial goals are discovered that attempt to eliminate the problem. An obstacle is therefore always linked to a goal. Similar to a goal, an obstacle can also be broken down into partial obstacles. By modeling the connections between the goals and the obstacles, we construct a *goal/obstacle model*, which can be expressed in a *goal/obstacle diagram*.

An obstacle can be informally specified in a note with the stereotype <<*problem*>> attached to its goal object. An obstacle can be a *temporary* problem that can be solved once and for all, or it can be a *continuous* problem that requires continuous action in order to prevent the problem from reoccurring.

Obstacles are eliminated (overcome) by *actions*. An *action plan* can be formulated from the goal/obstacle model, where temporary obstacles are resolved as soon as possible, and the goals linked to the continuous obstacles are allocated to processes in the business.

The action plan should contain:
1) a list of the obstacles,
2) the cause of each obstacle,
3) the appropriate action for each obstacle,
4) the prerequisites for each action, and finally,
5) the resource or process responsible for overcoming it.

This can also be shown visually in the goal/obstacle model through the use of stereotyped notes. The stereotypes <<*problem*>>, <<*cause*>>, <<*action*>>, and <<*prerequisite*>> specify the purpose of the note. In UML all of these optional concepts are defined through the use of informal notes, because they are normally described in

[24] as described e.g. in [14].

[25] A more detailed description of this use can be found e.g. in [14].

simple text and cannot be formally defined. The problem-note is attached to the goal, the cause note to the problem-note and so on. The example presented in the figure below is taken from [14]:

As described in [14], a technique for identifying goals is to ask these questions:

• *Why* should we achieve this goal?
• *How* should we achieve this goal?

The answers to the why question will identify higher goals (goals to which the current goal is a partial goal), and the answers to the how question will identify partial goals. Answering these two questions makes it possible to identify new goals from existing goals, and to reveal additional goals that might not have been discovered by the people in the business.

All the primary goals of the business can be summarized in a diagram of their own, where any conflicts between the goals (contradictory goals) are shown. Each of the primary goals can then be described in a diagram of its own, with its corresponding partial goals. It is important to realize that the goal/obstacle diagram should not be over-formalized or described in too computational terms. The purpose of the goal/obstacle diagram is to identify and structure the different goals of the business and to break down the goal descriptions to a level at which the corresponding goals can be allocated to individual processes.

12. THE ONSCAIL NETWORK

The ONSCAIL network involves a number of stakeholders (shown in the figure below) that have teamed up and are now jointly contributing to a *Public e-Learning Platform* (PeLP)[26]. These stakeholders include the *Swedish Educational Broadcasting Company* (UR), the *Swedish National Agency for School Improvement* (MSU), the *Swedish National Agency for Education* (SV), the *Swedish National Centre for Flexible Learning* (CFL), the Swedish Terminology Centre (TNC), the *Swedish Museum Window* (SMW), and the *Stockholm Public Education Management Agency* (UTBF). The Soft infrastructure for IT in education project of MSU [101], the Digital Media Library of UR [102], and the Learning Resource Centre of CFL [103] are three of the important stakeholders projects in the PeLP.

The present stakeholder roles of the ONSCAIL network are listed below, together with the organizations that are implementing these roles:

• *Content provider*: UR, SV, UTBF, Museum Window
• *Service provider*: MSU, UR, Ateles.
• Course developer: CFL.
• Terminology integrator: TNC
• *Technology Integrator*: DataDoktorn, Uppsala Learning Lab, Uppsala Database Laboratory, Swedish Netuniversity.

The overall idea of the ONSCAIL network is that each participating organization should work out a conceptual model (ontology) that describes its corresponding role(s). This will create a set of open role-interfaces that describe how to play each one of the roles within the network. In this way, any organization that wants to participate, will be provided with an explicit interface for the role that it wants to play, and by implementing this interface, the organization can take on the corresponding role and interoperate with the other stakeholders of the network.

12.1. Enabling semantic cooperation among content providers

Here we will describe a *metadata interoperability modeling effort,* which has been performed within the ONSCAIL network in order to lay the foundations for future *semantic collaboration among content providers*. This modeling work was carried out within a Swedish standardization group for learning technology called

[26] By an *e-learning platform* we mean a system that contains the functionalities of an LMS (Learning Management System) and/or an LCMS (Learning Content Management System). An LMS typically contain features for administration, assessment, course management, possibly content management and authoring. An LCMS typically emphasizes content management/authoring and includes many features of an LMS. In generic terms, we will describe an e-learning platform in terms of its *infrastructures*, *architectures*, *frameworks* and *tools*.

TK450, which is part of ISO-JEC/SC36. During the spring of 2004, Ambjörn Naeve mediated a series of modeling sessions involving UR, SV, CFL, and MF, who were represented by their respective metadata experts.

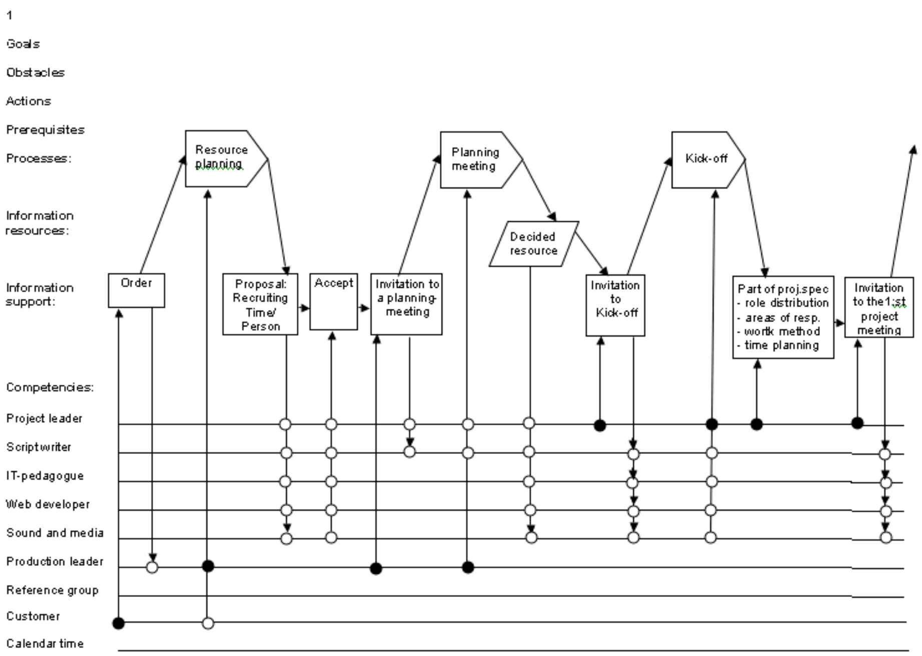
The aim was to find out the similarities and differences of the respective description structures that were used among them, as well as to decide on some common terms for things that were perceived (thought of) in the same way. The documentation of this modeling process is available (in Swedish) at http://knowgate.nada.kth.se:8080/portfolio/main?cmd=open&manifest=amb&uri=scam%3A%2F%2Famb%2F1776c

12.2. Modeling the CFL course development process

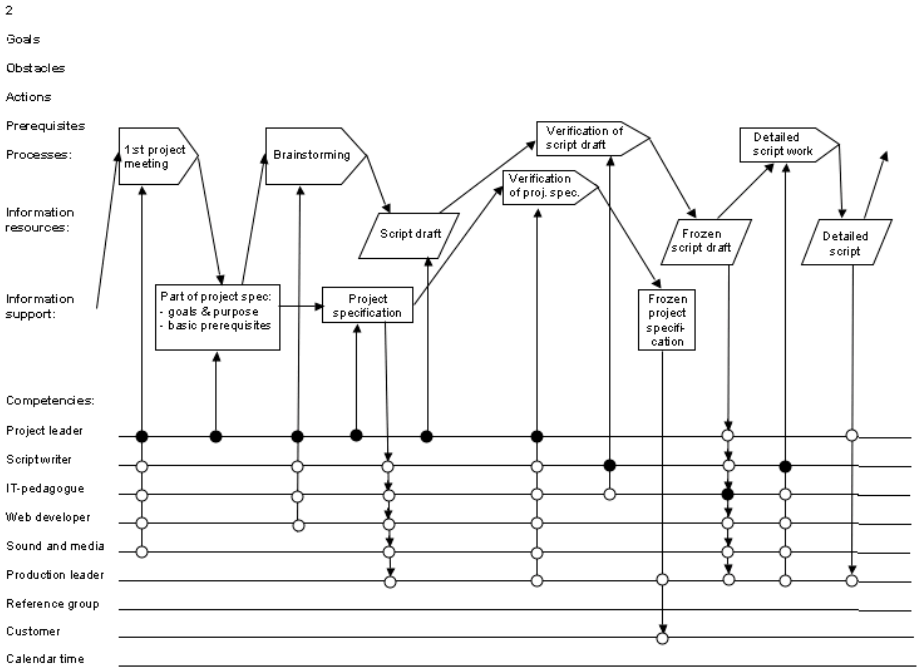
During the spring of 2004, Ambjörn Naeve conducted a distance course in conceptual modeling with participators from CFL, which is located in two different Swedish cities, Norrköping and Härnösand. The process modeling part of the course worked with the example of modeling the CFL course development process – as described in a number of internal text documents. As the modeling processed, several discrepancies and inconsistencies of these textual descriptions were uncovered, and the participants became enthusiastic about the conceptual clarity that grew out of the visual models. This kind of process modeling is gaining increased attention within CFL and is rapidly becoming established as a working method within the departments of CFL that participated in the course.

Although the modeling was carried out in Swedish, the resulting CFL course development process model has been translated into English and uploaded to the CFL confolio[27] at http://knowgate.nada.kth.se:8080/portfolio/main?cmd=open&manifest=CFL&uri=urn%3Ax-smac.nada.kth.se%3ACFL%3A12

Screenshots of the model have been included below, but in order to be able to read the text properly, the online slides at the URL above are recommended.



[27] To view the slides properly, press "PP-view" (= PowerPoint view), which lets you go through the slides without "jumping in and out" of the portfolio folder.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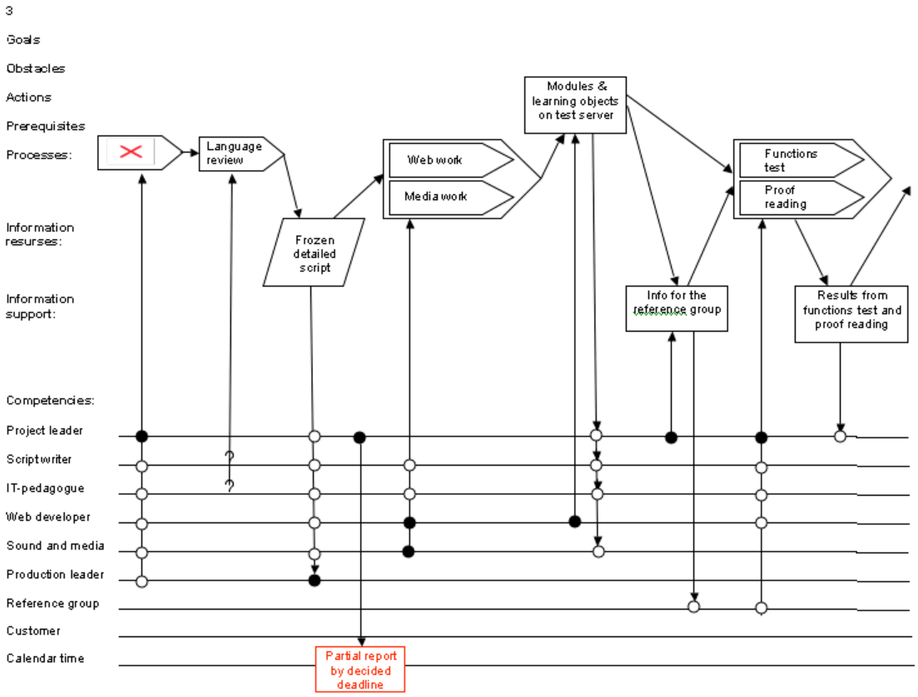
Goals
Obstacles
Actions
Prerequisites
Processes:
Information resources:
Information support:
Competencies:
Project leader
Scriptwriter
IT-pedagogue
Web developer
Sound and media
Production leader
Reference group
Customer
Calendar time
1:st project meeting
Brainstorming
Part of project spec:
- goals & purpose
- basic prerequisites
Project specification
Script draft
Verification of proj. spec.
Verification of script draft
Frozen project specifi-cation
Frozen script draft
Detailed script work
Detailed script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Goals
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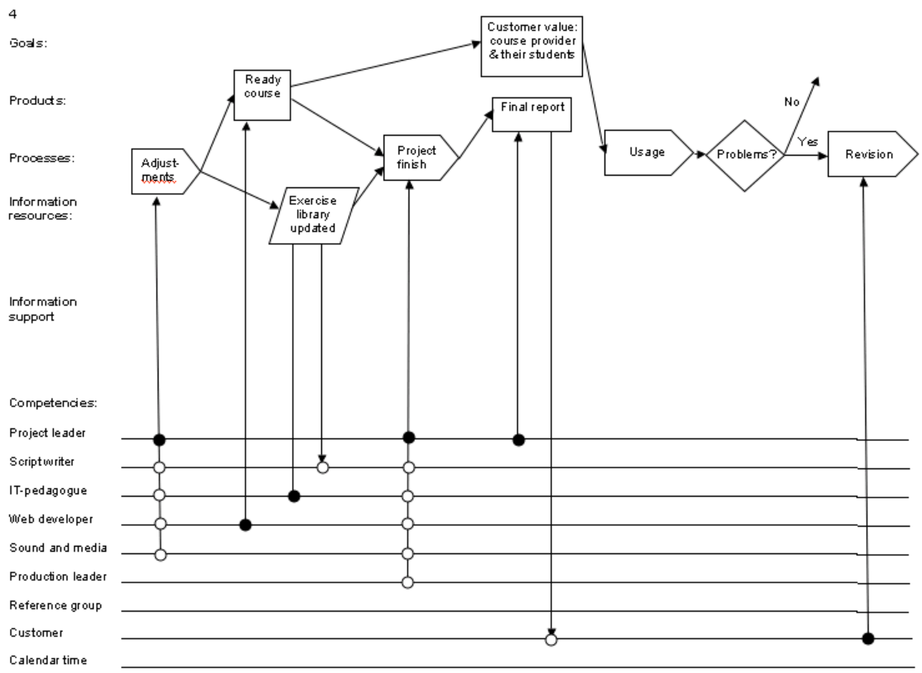
Information support:
Competencies:
Project leader
Scriptwriter
IT-pedagogue
Web developer
Sound and media
Production leader
Reference group
Customer
Calendar time
Language review
Frozen detailed script
Web work
Media work
Modules & learning objects on test server
Info for the reference group
Functions test
Proof reading
Results from functions test and proof reading
Partial report by decided deadline



A notational novelty in these process diagrams is the introduction of a ‘musical-note’ inspired system for describing the participation of different competencies (competency roles) in the various parts of the process. An unfilled note denotes participation, and a filled note denotes participation and responsibility. More precisely, if the corresponding vertical arrow (connecting the competencies with the information objects and the sub-processes) is pointing *upwards*, then the filled note means that the corresponding competency role is responsible for *initiating* the info object or the sub-process, and if the vertical arrow is pointing *downwards*, the filled note means that the corresponding competency role is responsible for *approving* the info object or the results of the sub-process.

13. THE OPEN-LMS ASSESSMENT PROJECT

The *openLMS assessment project* of open source based L(C)MSes is carried out for the Swedish Netuniversity under the coordination of Uppsala Learning Lab [99].

13.1. Objectives

The openLMS project is performing a survey-style assessment of open source based systems for technology-enhanced learning (here collectively referred to as Learning Management Systems). The overall objective of the project is to facilitate the exchange of experiences of such systems in order to enable cost-effective and quality-enhancing collaborative development of such systems and promote their use within Swedish universities and university colleges. Hence the survey focuses on assessing the “potential for interoperability” of open source based LMSes from a technical perspective.

13.2. Scope

The study focuses exclusively on open source LMS projects where the software technology and the development framework used is founded on open source code, open standards, open development tools and open operating systems with no limitations on distribution and use – e.g. GPL, LGPL type of license. Consequently commercial products are explicitly excluded from the assessment. For a LMS project to be considered for this evaluation, it must show results in the form of code, functional LMS application(s) and documentation. Also, the project must be focused on learning management – and not just content management.

13.3. Process and method

The study has been carried out in accordance with the following process:
• Find the initial technology candidates that fit the defined scope.

• Identify criteria/metrics and use cases useful in evaluating open source LMSes.
• Assess the selected technology candidates using software technology criteria.
• Select the top third of these candidates as quality candidates for quality evaluation.
• Further assess these candidates using ISO9126 software quality criteria.
• Select the top third of these candidates as UC candidates for testing based on Use Cases.

13.4. Practical user testing

The UC candidates were hands-on tested through demo installations available on the respective project's web site and building, installing and configuring the software from open source code repositories. User accounts with admin/teacher and student roles were created, inspection of the online help, user and instructor documentation, and commentary of the user community were preformed in order to assess the UC candidates.

A group of teachers and students then tested the basic functionality of the UC candidates and answered a set of questions based on groups of use cases. The questions were organized in a "question repository" consisting of seven different groups - based on use cases that reflect the basic functionalities of an LMS. These groups were Registration, Scheduling, Delivery, Tracking, Assessment, Content handling, and Activity handling. From this question repository, two different questionnaires were constructed, one for administrators/teachers and one for students. The questions were constructed around a common template formulated as "It is easy to carry out X", where X refers to some functionality of an LMS. The answers were given in the form of check-boxed "percentage of agreement": I agree to 0%, 20%, 40%, 60%, 80%, 100% and "not applicable". The testers were also encouraged to write down their qualitative impressions in the form of test-notes. At the time of writing these user tests are still being evaluated.

System	Functionality	Maintainablility	Reliability	Sakai
Operating	Linux Windows			32 / 64 bit
Network	HTTP (TCP)			Internet protocol
Development	Java / Eclipse CVS		Java / Eclipse CVS	Lang. / Dev. Env. Version handling
Storage	Hibernate Hypersonic	Hibernate Hypersonic	Hibernate Hypersonic	File system / Object Database handling
Application	Spring Tomcat	Spring Tomcat	Spring Tomcat	Framework Server
Web	Mozilla, Explorer Apache	Mozilla, Explorer Apache	Mozilla, Explorer Apache	Client Server
Portal	Pluto / Sakai OSPI / Velocity	Pluto / Sakai OSPI / Velocity	Pluto / Sakai OSPI / Velocity	Framework / Forum Portfolio / Content
Broker	Webservices SOAP			Interface Protocol
Metadata	LOM, IMS SCORM			Standards Reference impl.
Security	Acegi CAS	Acegi CAS	Acegi CAS	Framework Server
Peer to Peer				Framework Service

Figure 19. The Sakai LMS technical profile

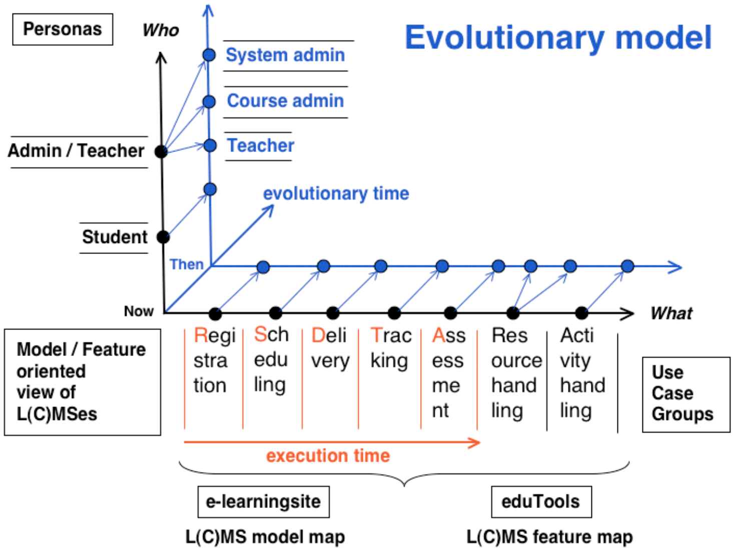


Figure 20. An evolutionary model for user-centered query shaping of LMS tests.