A modelling approach to study learning processes with a focus on knowledge creation

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Abstract: In this paper, we present a modelling approach to study learning processes. We introduce the process/pedagogy/tools model and shown how its assembly-line style of process modelling can be used to describe which pedagogical aspects and which tools that support which parts of a specific learning process. We also review the SECI knowledge creation theory of Nonaka and combine it with process modelling to arrive at a SECI process framework for the study and analysis of knowledge-creating learning processes. Finally, we show that the different SECI modes of knowledge conversion are empirically supported by pedagogical research.

Keywords: learning process modelling; knowledge-creation; SECI process framework; LISREL method; validating web-based learning processes and tools.

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Pertti Yli-Luoma has a background in Mathematics, Computer Science, Statistics, Physics, Comparative Education, and Educational Psychology. He is presently Professor of Education with Applied IT at Oulu University, where he is Director of a LearningLab for web-based learning research. His research focuses on web-learning, learning styles and strategies, mathematics and physics learning, and research methods, and he has published 96 papers and 24 books within these fields. He has developed a web-based interactive learning tool (WebLI), and he is presently using WebLI in a project with two Chinese universities running a web-based Master's Degree programme on Information Technology.

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1 Introduction

1.1 Background and scope

In our emerging knowledge society, a firm understanding of the interplay between the management of knowledge and learning is of strategic importance to create and maintain effective learning processes in a large variety of non-traditional learning situations (Lytras et al., 2005a). For example, as described by Grace and Butler (2005), Zuboff (1988) 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 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, organisational learning has become an idea in good currency." (Argyris and Schön, 1996)

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 categorising knowledge-creating learning processes based on process modelling and Nonaka's (SECI spiral) theory of knowledge creation (Nonaka, 1991, 1994; Nonaka and Takeuchi, 1995; Nonaka et al., 2000). Our framework makes use of assembly-line-style process modelling (Eriksson and Penker, 2000) to show how different parts of a learning process are supported by different pedagogical aspects and tools. It also uses the Unified Language Modelling (ULM) technique (Naeve, 2006) to improve the conceptual overview and increase the visibility and clarity of the structures involved.

The bulk of the work presented here was undertaken within the PROLEARN Network of Excellence for professional learning and reported as PROLEARN Deliverable 5.3 (June 2005). Although it has not been published until now, it has been quite influential in raising the awareness of Nonaka's ideas within the TEL[2] community. We will return to this subject in Section 5.2.

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 (Naeve, 2005). In Section 3, we apply assembly-line process modelling (Eriksson and Penker, 2000) 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 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[3] at KTH as presented in Naeve et al. (2005a).

In Section 4, we review (part of) the unified model of dynamic knowledge creation as presented by Nonaka et al. (2000), and apply both process modelling and ULM-style conceptual modelling (Naeve, 2005) to it to construct an abstract model of the most important parts of the knowledge creation process described by Nonaka et al. (2000): 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 modelling (Section 3) with SECI knowledge conversion (Section 4) 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 has been 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.

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 et al. (2000), in traditional Western epistemology 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.

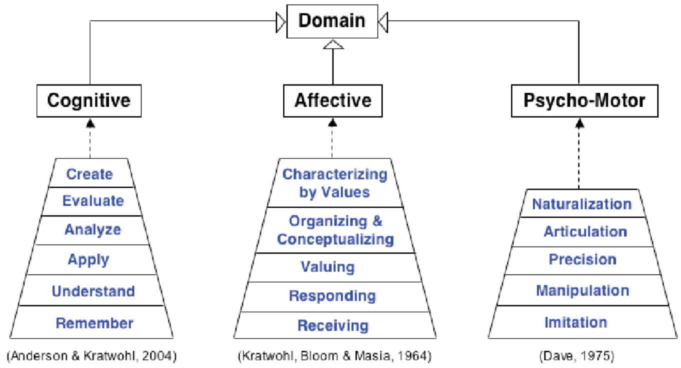
According to Sperber and Wilson (1995, p.45), "Human beings are efficient information-processing devices. This is their most obvious aspect as a species". This quote from one of the classics of cognitive psychology provides a good example of the Western emphasis on explicit knowledge, as opposed to *tacit knowledge*, a term which was introduced by Michel Polanyi in 1967. The term tacit knowledge refers to the implicit and silent (pre-logical) knowledge that we all carry within ourselves, and which Polanyi (1967, p.4) expressed as "we can know more than we can tell".

In his dialogue seminars, Göranzon (1990) 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 standardised 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 – can be explored with psychological methods.

In his famous taxonomy of learning, Bloom (1956) identifies six different levels of knowledge in the cognitive domain. They are shown in Figure 1 – slightly revised by Anderson and Kratwohl (2001). The truncated pyramid indicates that each level builds on the ones below it. A similar analysis for the effective domain[4] has been carried out by Kratwohl et al. (1964) and in the psycho-motor domain by Dave (1970). 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, effective and psycho-motor domains[5] (see online version for colours)

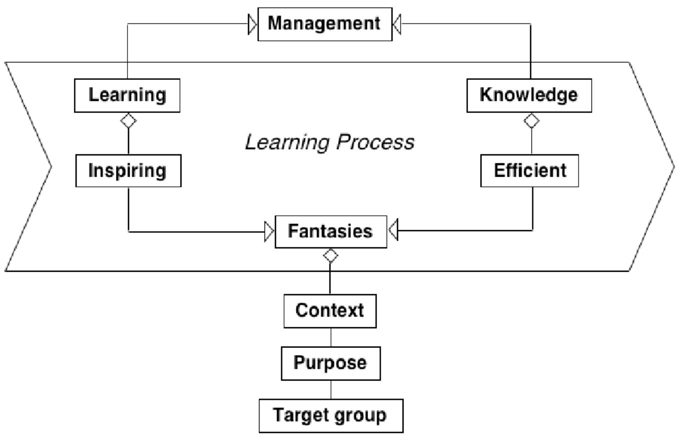


Source: Atherton (2004)

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.

Naeve (2005) defines (mental) *knowledge* as consisting of *efficient fantasies*[6] and describes (mental) *learning* as based on *inspiring fantasies (Figure 2)*. 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 or 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., Grace and Butler (2005) for a more thorough discussion on the attempts of modern learning management systems to bridge this traditional gap and accommodate both of these important perspectives.

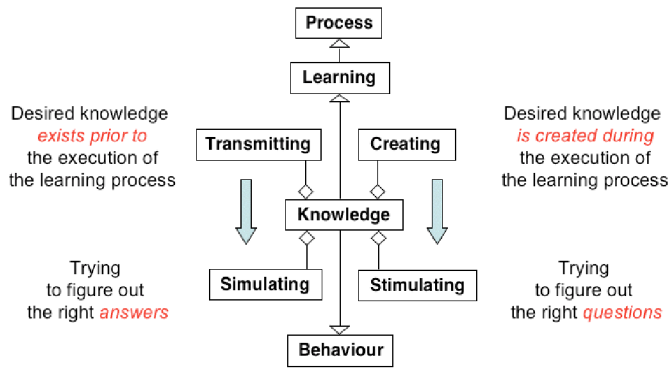
2.1 *Knowledge transmission vs. knowledge creation*

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[7]. 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,[8] since it is driven by a fixed curriculum, which exists prior to the course.

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 Naeve (1997, 1999) for further discussions on these matters.

Figure 3 Knowledge-transmitting vs. knowledge-creating learning processes (see online version for colours)



2.2 *Knowledge pushing vs. knowledge pulling*

Naeve (2005) discusses the demands for flexible and personalisable 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 to support more learner-centric, interest-oriented, and knowledge-pulling types of learning processes. In 0, it is demonstrated 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 modelling examples, we briefly introduce them here for the convenience of the reader.

Over the last years, members of the WGLN[9] and the PROLEARN[10] networks have made numerous contributions towards a *Public Knowledge and Learning Management Environment* based on open source, open ICT standards Semantic Web technology (Naeve et al., 2005a; Nejdl et al., 2001, 2002; Wolpers and Grohman, 2005). 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* (Naeve, 2001a, 2001b), 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. The PKLME also includes:

- *the Edutella infrastructure*: a democratic (peer-to-peer) network infrastructure for search and retrieval of information about learning resources (Nejdl et al., 2002; Nilsson et al., 2004)
- *the SCAM framework*: (*Standardised Contextualised Access to Metadata*): a framework that helps applications to store and share information about learning resources (Palmér et al., 2004)
- *the SHAME framework*[11] (*Standardised 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 (Nilsson et al., 2002)
- the *Formulator* (or *SHAMEditorEditor*): a tool for editing metadata editors that is built on top of the SHAME framework
- the *Confolio* network:[12] 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:[13] a knowledge management tool that supports the construction, navigation, annotation and presentation of the information in a knowledge manifold (Naeve, 2001b; Palmér and Naeve, 2005)
- *the VWE composer*: an environment for composing learning resources and building customised learning modules (Naeve et al., 2005a).

The knowledge roles of a Knowledge Manifold

The KM architecture supports the following seven different knowledge roles (Naeve, 2001a):

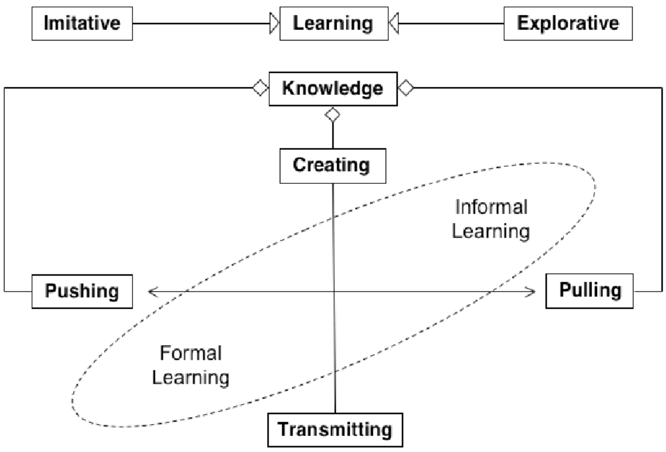
- the *knowledge cartographer*, who constructs and maintains context-maps
- the *knowledge librarian*, who fills context maps with content-components

- the *knowledge composer*, who constructs customised 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 vs. 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 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 vs. 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 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 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 (Nonaka, 1991, 1994) and the unified model of Nonaka et al. (2000). By combining this theory with process modelling, we will arrive at an abstract model that can serve as a basis for the analysis and classification of many professional learning processes.

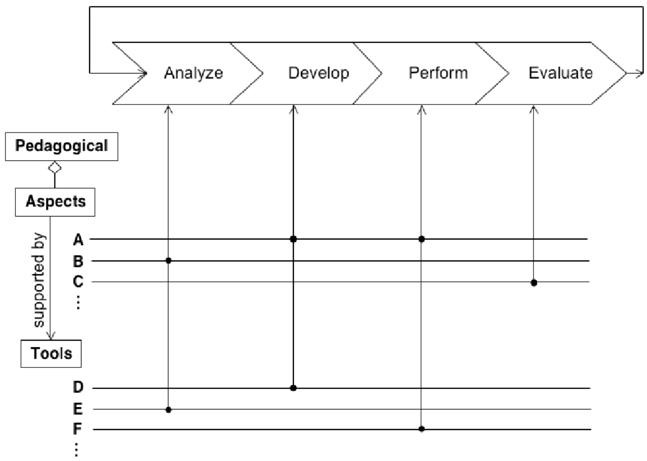
3 Assembly line modelling of the learning process

Process modelling presents powerful ways of describing dynamic interactions – ways that seem to have found little use for educational modelling within the TEL community (Rawlings et al., 2002).[14] Here, we will make use of a type of process modelling described e.g., in Eriksson and Penker (2000), where (horizontal) assembly lines and (vertical) support arrows indicate how the various parts of a process are supported by different kinds of resources.

3.1 The process/pedagogy/tools abstract model

In Figure 5, the learning process has been divided into the sub-processes *Analyse*, *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

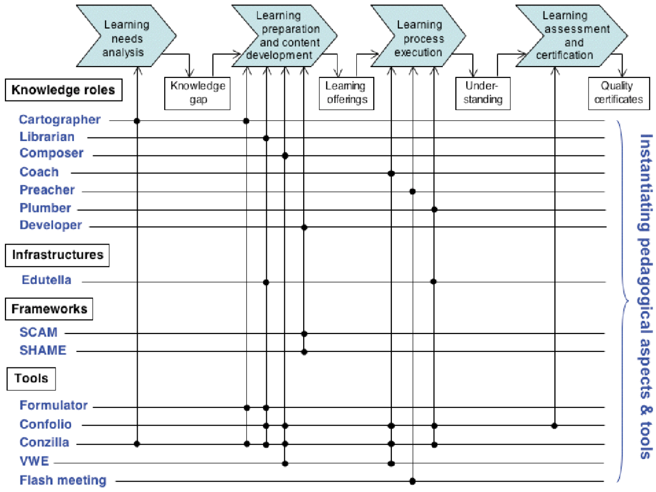


In Figure 5, the black dots indicate that the pedagogical aspect B and the tool E support the 'Analyse' part of the process, while the pedagogical aspect A and the tool D support the 'Develop' part of the process, etc. The arrow from 'Evaluate' back to 'Analyse' indicate a feedback loop that is characteristic for a never-ending (lifelong) 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[15] and tools.

Figure 6 Instantiated pedagogical aspects and tools for a knowledge manifold with flash meeting support (see online version for colours)



In Figure 6, the learning process is described as the following sequence of sub-processes:

- *learning needs analysis*, which produces a description of the *knowledge gap* (= the difference between present and desired knowledge)
- *learning preparation and content development*, which produces a set of learning offerings
- *learning process execution* (= LP-performance = LP-instantiation), which produces (some measure of) *understanding*
- *learning assessment and certification*, which produces quality certificates.

In Figure 6, below the description of the learning process there is listed the set of *knowledge roles* for a knowledge manifold educational architecture.[16] 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.[17]

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

- During the *learning needs analysis* stage, the *cartographer* makes use of:
  - *Conzilla* 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* to create context-maps of the relevant knowledge areas
  - *formulator* 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* to fill the context-maps created by the cartographer with information about content
  - *Edutella* to search for and locate information about this content on the Semantic Web
  - *Formulator* to create suitable metadata editors for the description of this information
  - *Confolio* to store this information (and sometimes also the content itself).
- During the *learning preparation and content development* stage, the *composer* makes use of:
  - *Conzilla* to locate relevant material for a certain learning module from the context-maps created by the cartographer
  - *Confolio* to locate relevant material for a certain learning module from the material gathered by the librarian
  - *VWE* to assemble the located material into a customised learning module.
- During the *learning preparation and content development* stage, the *developer* makes use of:
  - *SCAM* to develop relevant material in the form of computer programmes
  - *SHAME* to develop relevant material in the form of computer programmes.
- During the *learning process execution* stage, the *coach* makes use of:
  - *VWE* to run (execute) the learning process in the learning module created by the composer
  - *Conzilla* to let the learners map their own knowledge as it develops over time
  - *Confolio* 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* 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* to browse different context-maps looking for relevant preachers to answer a question
  - *Confolio* to browse different content archives looking for relevant preachers to answer a question
  - *Edutella* to search the Semantic Web looking for relevant preachers to answer a question.

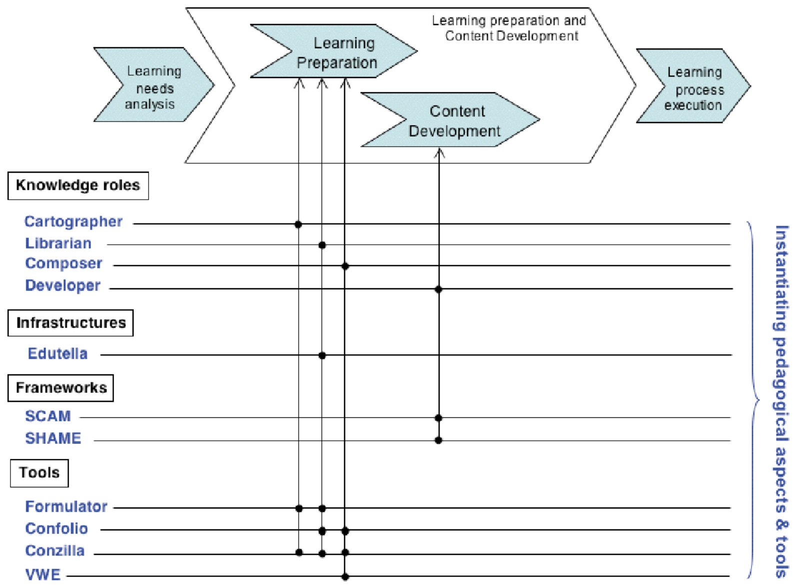
- During the *learning assessment and certification* stage, someone[18] makes use of:
  - *Confolio* to let the learners presents the knowledge they have gained during the learning process.

The scenario described above is related to *question-based learning* as described in Naeve (1997, 1999).

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 modelling 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 (see online version for colours)



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 modelling the way that different learning processes refine the abstract process model, we can in fact create an empirical basis for their classification.

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*.[19]

Figure 8 Breaking *learning process execution* into smaller parts (sub-processes) (see online version for colours)

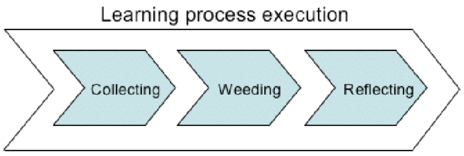
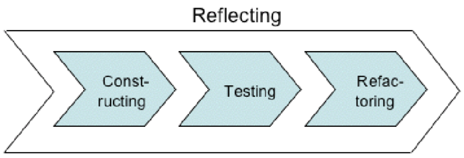


Figure 9 Breaking the *reflecting* process into smaller parts (sub-processes) (see online version for colours)



4 The SECI knowledge creation process

In their award-winning book *The Knowledge Creating Company*, Nonaka and Takeuchi (1995) refine and expand the SECI theory of organisational knowledge creation, first put forward by Nonaka (1991, 1994).

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 organisation as a mechanism for information processing. While this view has proven to be effective in explaining how an organisation functions, it does not really explain the concepts of innovation and knowledge creation. In the SECI 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.

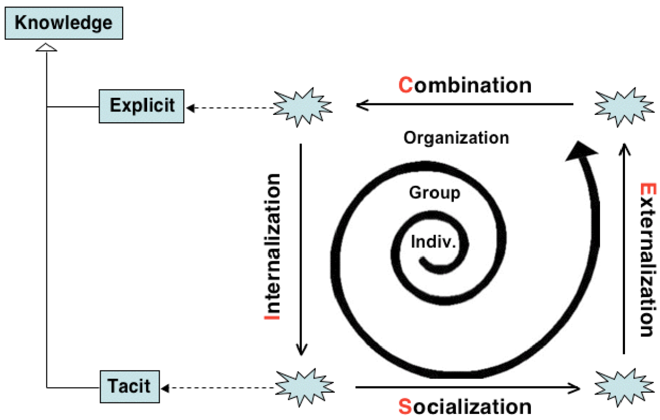
4.1 The SECI modes of knowledge conversion

According to Nonaka (1994), 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:

- *socialisation*, which is the process of sharing experiences (tacit knowledge), thereby creating new tacit knowledge
- *externalisation*, 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
- *internalisation*, which is the process of reflecting on and embodying explicit knowledge into tacit knowledge.

As illustrated in Figure 10, which is based on Naeve (2005), a knowledge-creating spiral occurs when these modes of interaction between tacit and explicit knowledge are elevated from the *individual*, to the *group* and *organisational* levels. Organisational knowledge creation, therefore, should be understood as a spiralling process that organisationally amplifies the knowledge created by individuals and crystallises it as a part of the knowledge network of the organisation. This process takes place within an expanding "community of interaction", which crosses intra- and inter-organisational levels and boundaries (Takeuchi and Nonaka, 2004, p.51).

Figure 10 The SECI spiral of knowledge creation (see online version for colours)



4.2 *Ba: A place for interactive knowledge creation*

Nonaka and Takeuchi emphasise that, on the organisational level, the spiral of knowledge creation is guided by dialectical thinking[20] and driven by organisational intention, i.e. an organisation'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 organisational context, it is the role of middle managers to maintain the necessary manifestations of such ba to support the knowledge creation spiral and make it efficient for the purposes of the organisation.

There are four types of ba that support the four different modes of knowledge conversion: *originating* ba, *dialoguing* ba, *systemising* ba and *exercising* ba (Nonaka et al., 2000). Each ba offers a context for a specific step in the knowledge-creating process. Building, maintaining and utilising ba is important to facilitate organisational knowledge creation.

- *Originating ba* provides a context for socialisation. 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 emerges 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.
- *Systemizing ba* provides a context for the combination of existing explicit knowledge into new forms. Information technology, through such things as online networks, groupware, electronic mailing lists, news groups, and databases, offers a virtual collaborative environment for the creation of systemising 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 programmes. 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 et al. (2000) define knowledge assets as "firm-specific resources that are indispensable to create values for the firm". According to them,

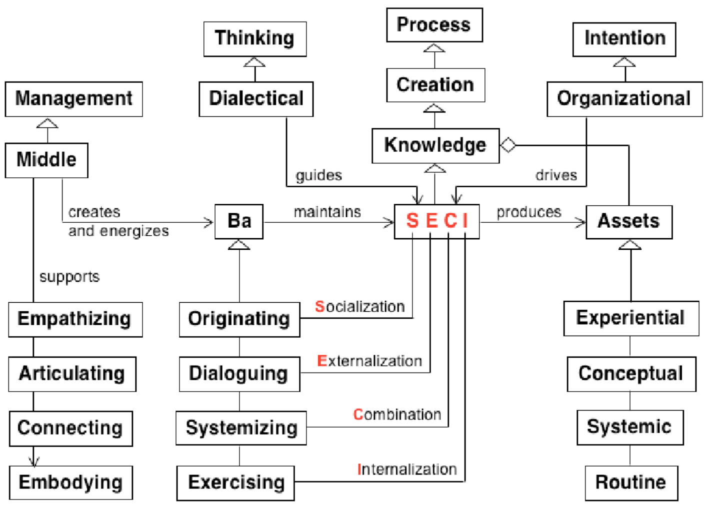
> "knowledge assets are the inputs, outputs and moderating factors of the knowledge-creating process. For example, trust amongst organizational members is created as an output of the knowledge-creating process, and at the same time it moderates how ba functions as a platform for the knowledge-creating process."

Knowledge assets must be built and used internally in order for their full value to be realised, as they cannot be readily bought and sold. To understand how knowledge assets are created, acquired and exploited, Nonaka et al. propose to categorise 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 characterisation of these four types (Nonaka et al., 2000, pp.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 organisation. Brand equity, which is perceived by customers, and concepts or designs, which are perceived by the members of the organisation, are examples of conceptual knowledge assets.
- *Systemic knowledge assets* consist of systematised 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 'routinised' and embedded in the actions and practices of the organisation. Know-how, organisational culture and organisational 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.

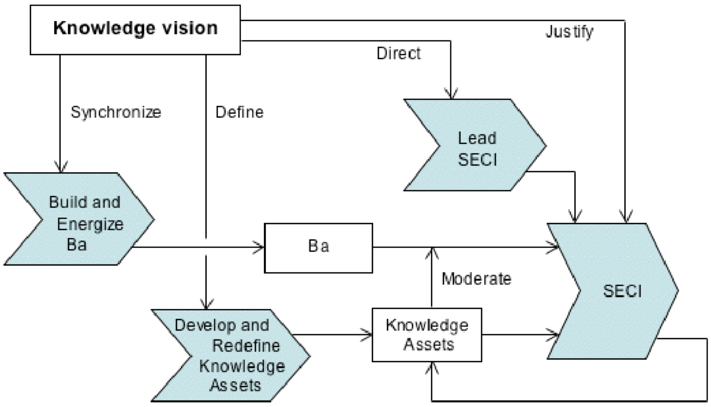
Figure 11 A conceptual model of the SECI knowledge creation process (see online version for colours)



4.4 Managing 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 et al. (2000), the SECI process cannot be managed in the traditional sense of management, which centres 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[21] of the knowledge-creating process. Leaders provide the knowledge vision, develop and promote the sharing of knowledge assets, create and energise ba, and enable and promote the continuous spiral of knowledge creation. This overall organisational knowledge creation process is modelled in Figure 12.[22]

Figure 12 The overall organisational knowledge creation process (see online version for colours)



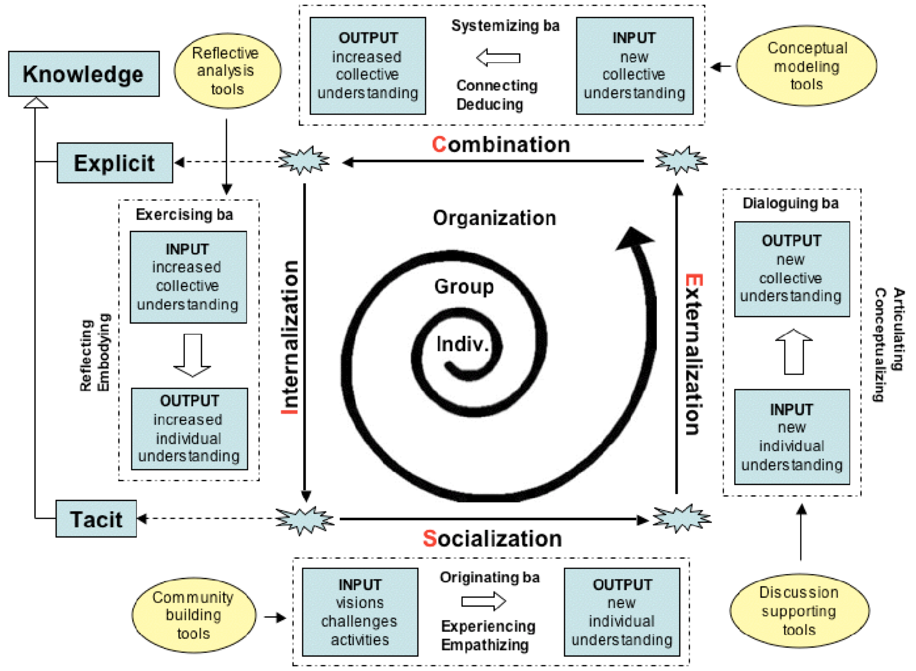
Especially, crucial to the SECI process is the role of knowledge producers, i.e. middle managers who actively interact with others to create knowledge by participating in and leading ba. Nonaka et al. emphasise that to create knowledge dynamically and continuously, an organisation needs a vision that synchronises 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 organisation 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.

5 The SECI process framework

5.1 Combining the SECI theory with process modelling

By combining learning process modelling (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. *Socialisation* occurs in *originating ba*, where *experiencing* and *empathising* activities are supported by *community building tools*. *Externalisation* occurs in *dialoguing ba*, where *articulating* and *conceptualising* activities are promoted by *discussion supporting tools*. *Combination* occurs in *systemising ba*, where *connecting* and *deducing* activities are supported by *conceptual modelling tools*. *Internalisation* occurs in *exercising ba*, where *reflecting* and *embodying* activities are supported by *reflective analysis tools*.

Figure 13 The SECI process framework: increasing understanding through experiencing, articulating, deducing and reflecting (see online version for colours)

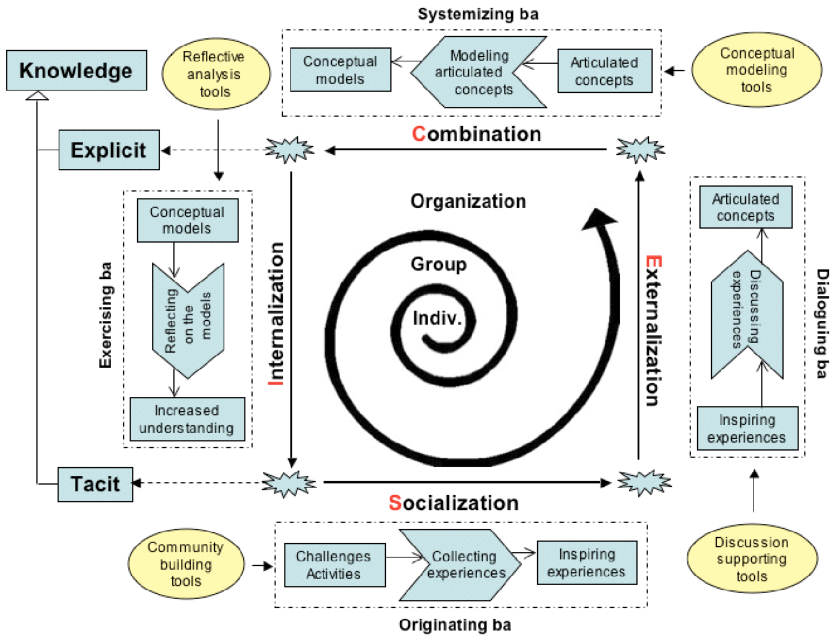


In each of the four SECI knowledge conversion stages a learning process takes place. As shown in Figure 13, sharing experiences in the socialisation process, with input from *visions*, *challenges* and *activities*, produces *new individual understanding* of the issues at stake. This new individual understanding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

In Figure 14, the different knowledge conversions have been modelled as processes. During the socialisation process, we respond to *challenges* and *activities* by collecting *inspiring experiences*. During the externalisation 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 internalisation process, these conceptual models are reflected upon, which results in 222 *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[23], a double-click on the top diagram within each ba would open up the corresponding process/pedagogy/tools abstract model. To describe a concrete professional learning process, we can then perform a '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 and how to best support them with various tools. A first attempt at such a classification – based on the SECI process framework – has been carried out by Yli-Luoma and Naeve (2006).

Figure 14 The SECI process framework with a process model within each ba (see online version for colours)



5.2 *The application of SECI within the TEL community*

As mentioned in the introduction, the bulk of the work presented in this paper has been carried out within the PROLEARN NoE[24] and reported in June 2005 as PROLEARN Deliverable 5.3 (Naeve et al., 2005b). In October 2005, this deliverable was singled out for excellence by the reviewers of PROLEARN, and it has had a profound influence on the later work within PROLEARN. For example, the SECI process framework has been used as the methodological backbone of the PROLEARN Roadmapping Process for Technology Enhanced Professional Learning (Kamtsiou et al., 2006a, 2006b, 2007, 2008), it has been used to describe Web 2.0 style learning processes (Chatti et al., 2007), it has been applied to the analysis of business models for TEPL (Lefrère et al., 2008), to the architecture of TEL (Martin et al., 2007), as well as to process-based knowledge work management (Zimmermann et al., 2007).

A modified version of the SECI process framework has been used as a basis for constructing a Professional Learning Process Framework (Naeve et al., 2007). This modified SECI model addresses the sequence problem of SECI (the fact that the SECI knowledge conversions do not occur in a linear sequence), and introduces a model where the Combination and Socialisation conversions occur ‘in parallel’ (on the explicit, respectively, the tacit knowledge levels) supported by the ever-ongoing Externalisation and Internalisation 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. The corresponding learning model involves four latent variables, namely ***Socialisation, Externalisation, Combination,*** and ***Internalisation***, which will be reviewed from a pedagogical perspective. These latent variables consist of the measurable processes: ***Collecting experiences, Discussing experiences, Modelling 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 ***Socialisation*** 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 ***Socialisation,*** is activated. This part has been empirically tested by Yli-Luoma (1996a, p.211; 2003, pp.15–28) using the LInear Structural RELationships (*LISREL*) method (Jöreskog and Sörbom, 1993).

The *LISREL* method can be applied as an analysis method for the following purposes:

- a structural model can be tested
- all hypotheses involved can be confirmed in one model run
- a hypothetical model can also be modified manually or automatically
- a simultaneous comparative analysis in several populations can also be undertaken.

Making use of the LISREL method, Yli-Luoma (1995, p.106, 1996a, p.211) has shown that the *Collecting experiences* process is both emotionally and socially loaded (Vygotsky, 1986, p.163). 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 ***Externalisation*** phase, the *Discussing experiences* process is still emotional. However, cognitive dimensions are needed (Honey and Mumford, 1982, p.114), where creativity is also activated (Bransford et al., 2002, p.152). Kolb (1984) argues further that this process becomes effective in the form of teamwork.

When the Externalisation phase goes over to the ***Combination*** phase, the *Modelling* process is activated, and *Hypothetical-Deductive* thinking abilities are needed for the modelling approach (Kaplan, 1997, p.209; Keeves, 1997, pp.388–390, 2002, p.117;

Grace and Butler, 2005, p.175). It should be observed here that the *Constructivist* learning process only covers the *Socialisation* and *Externalisation* phases of the learning process (Keeves, 2002, p.175). In any type of learning that involves deductive or abductive reasoning, such as e.g. the learning of science and mathematics, a modelling approach is needed (Evers, 2000, p.1; Hestenes, 1995).

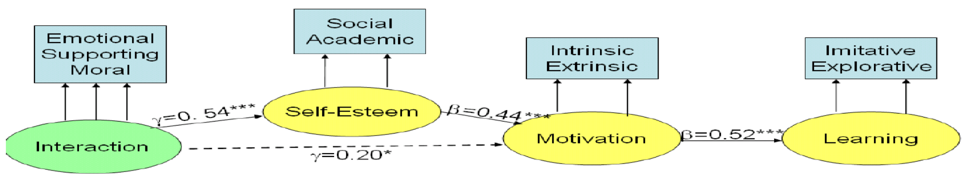
The learning process requires further that students engage in seeking to understand and explain the conceptual models developed in the Combination process (Yli-Luoma, 1992, pp.92, 93; Penner, 2001, p.1), which means that the process of ***Internalisation*** is activated. This is a process, where learners reflect on the new structures (models) by using critical thinking abilities when testing or applying them.

6.2 Socialisation process

In the Socialisation process, the social interaction between students and their teachers is included. Yli-Luoma (1996a, p.175; 2003, 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 to activate their learning processes. Bowlby (1987, 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 has been tested empirically by using a *LISREL* model (Yli-Luoma, 1990, 1996b). 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.

Figure 15 The *LISREL* model of the interaction process (see online version for colours)



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. (1976, 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*.

Vygotsky (1978; 1986) 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 using their thinking abilities. This type of approach has made a contribution to social constructivism, which was developed by Berger and Luckman (1969).

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 (Shedroff, 1999).

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 (Sears et al., 1991). 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 also 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 *Socialisation* knowledge conversion process, which (as mentioned above) is emotionally or effectively loaded. If the learner does not like the subject, she or he would not be interested to collect any new information or experiences either. The Kolbian approach replaces these two aspects together (Kolb, 1984; Honey and Mumford, 1982). Moreover, brain research has demonstrated that ***learning is based on collecting experiences*** (Bowlby, 1987). In his study of Kolbian learning styles, Yli-Luoma (2005) 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 weak. It would further seem to have 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 Externalisation process

The Socialisation process is needed to activate a collaborative discussing phase between the online learners (Honey and Mumford, 1982; Kolb, 1984). Ravenscroft (2002) argues further that a socio-cultural framework is needed for cognitive change. According to the argumentation of Vygotsky (1978), the higher cognitive processes provide a basis and motivation for collaborative, argumentative and reflective discourse.

Bransford et al. (2002) suggest further that the collaborative discussing phase includes *creativity*. Zohar (1997) 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 (2002), 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 modelling theory of Hestenes (see Naeve et al., 2005a, pp.355, 356), which he has applied to the education of high-school physics teachers for almost two decades (Hestenes, 1995).

Sweller (1999) questions strongly the efficacy of the 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 modelling process (or the Combination process as it is called in this study).

We stress the relevancy of cognitivism in the Externalisation phase. One of the learning strategies that support cognitivism is *concept mapping* (Novak, 1990, 1991), which is a technique for the expression and visualisation of domain concepts and their relationships. Concept maps are tools for organising 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 and Cañas, 2006). 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 Modelling approach (modelling articulated concepts) takes place in *Systemising ba* after Externalisation (Figure 14). Here, the learners need *Conceptual modelling tools* to advance the articulated concepts towards forming *Conceptual models*. For these kinds of processes, higher thinking abilities with advanced modelling tools are needed. The Piagetian Formal Operations Stage would seem to fulfil 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 (1997, p.117) argues that the term ‘model’ is useful when the symbolic system referring 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 (2000) has presented a connectionist model of artificial neural networks in an educational situation. The paper of Penner (2001), titled ‘Cognition, Computers, and

Synthetic Science: Building Knowledge and Meaning through Modelling', laid the foundations for a shift towards what he recognises to be a modelling approach. However, Penner fails to recognise 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 modelling approach. Keeves (2002), however, argues very clearly for a modelling 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
- 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
- *causal* models.

These modelling 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 'modelling' could be adopted. In the present learning model, the term *Combination* (Figure 14) is also used for this process. The Combination process in this study is closely related to the *Kolbian Learning Style* of the *Theorist*. Its predictive value in the academic learning process is the highest possible (Yli-Luoma, 2005). In the very same comparative study of Kolbian learning styles, which uses a new measurement model advanced by Yli-Luoma, it is shown that the Kolbian theorist (closely related to our *Systemising 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 modelling approach has already been used in Bloom's taxonomy (Bloom, 1956). 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 *Analyse* level, the learner should be able to make a flowchart to show the critical stages of knowledge or construct a graph to illustrate the selected information. Moreover, Novak (1990) has turned modelling into a real cognitive tool in his conceptual mapping procedure. While constructing good concept maps, the learner is modelling e.g., a laboratory activity, or a particular problem or question that she/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, 1993). 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 when they are needed.

6.5 Internalisation process

The *Internalisation 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., to test the conceptual models they have developed. This process should increase their understanding.

Yli-Luoma's comparative study (Yli-Luoma, 1992, p.92) on the learning among pre-university students of physics 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. In 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 to $t = 36.9$, $p < 0.001$. 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.

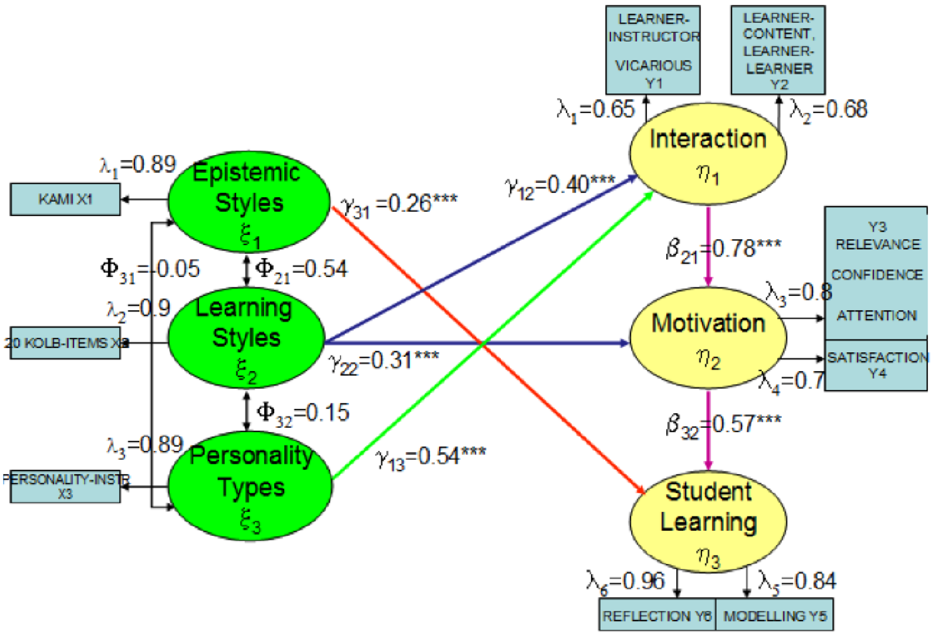
How is the experimental learning process implemented in online learning? Simulations might be useful as laboration tools in an experimental approach. Nakajima (2002) tested it in physics-learning, using chat forum as a reflection tool. His experiment would seem to confirm the benefits of using simulations as a part of the experimental approach.

6.6 Results from the INTeL project

Yli-Luoma and Naeve (2006) apply the SECI process framework to the classification and assessment of various tools that support online learning. The results indicate that four different types of interaction tools should be developed and used in web-learning process. The interactive web classroom (*WebLI*) has been developed (Yli-Luoma, 2006a, pp.7–26; 2006b, pp.7–42) by the Oulu University LearningLab. For the moment, it only has two tools covering the SECI dimensions ***Socialisation ba,*** and ***Externalisation ba.*** The next two would be ***Combination ba*** and ***Internalisation ba,*** which will developed during the present year.

These spaces are of great interest especially for the ***INTeL*** project[25] (INTeractive e-Learning), which has set up an empirical testing process for the present hypothetical model, collecting and analysing empirical data on web-based interactive learning using the LISREL method (Yli-Luoma, 1990, 1996b; Jöreskog and Sörbom, 1993). The data collecting procedure has been carefully planned to cover all the processes and theoretical features, which are included in the measurement model. Within the context of the INTeL project, Pirilä (2008, p.65) has used the LearningLab to collect data for studying with *WebLI* – using online (synchronous) *WebLI* – users*,* streamed (asynchronous) *WebLI* – users, and a control group of (traditional) face-to-face students. All these three groups were studying quantitative research methods taught by the same teacher. Her main results are given in Figure 16.

Figure 16 The *LISREL* model of the *WebLI* – users (Pirilä, 2008, p.159) (see online version for colours)



The significant relationships between the variables among all students in this study are presented in Figure 16. In this study, this *LISREL* model with all students is referred to as a main model. The values presented in Figure 16 are standardised λ-, γ- and β-values. The *LISREL* programme computes the direct, indirect and total causal effects. The standard errors for these effects are calculated and in the results of the estimation process the insignificant relationships were excluded when re-estimating the model. (Pirilä, 2008, p.159.)

The path: *Interaction* → *Motivation* → *Student Learning* would seem to be a very strong and statistically very significant path ($p < 0.001$). The causal impact of *Interaction* on *Motivation* is strong, and the *Motivation* has also a strong impact on *Student Learning*. That would seem to give us the possibilities to conclude that the *WebLI* tool is working and supports the students with an interactive learning environment. A closer look at the different groups would tell us that the face-to-face group would seem to be the best one, but the difference is not statistically significant (Table 1) when the groups were tested with OneWayANOVA (Pirilä, 2008, p.141).

Table 1 Scores in the critical ability and final examinations in three different learning groups (maximum points5; all students: final exams *mean* 2.47. *std. dev.* 1.15; critical thinking *mean* 2.43, *std. dev.* 1.99)

	Face-to-face	*Synchronous*	*Asynchronous*	*Significance*
Scores in exams	*mean* 2.92 *std. dev.* 1.16	*mean* 2.33 *std. dev.* 1.05	*mean* 2.38 *std. dev.* 1.18	$F = 1.12$ $p = 0.34$ *n.s.*
Critical thinking	*mean* 3.08 *std. dev.* 1.97	*mean* 2.60 *std. dev.* 1.92	*mean* 2.03 *std. dev.* 2.03	$F = 1.12$ $p = 0.33$ *n.s.*

This means that the web-learning approach according to this study would seem to give about the same quality of learning outcomes as the face-to-face teaching method. Hence, the results of Pirilä's (2008) study should be considered as a promising result for the future approach to use of web environments (as well as the WebLI tool) for learning.

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 modelling 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 to a large extent separates formal learning from informal learning, as well as (traditional) courses from research. We have reviewed the SECI knowledge creation theory of Nonaka and 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. Finally, we have presented empirical pedagogical research that indicates how to effectively and efficiently apply the SECI knowledge creation process by connecting it to several important psychological and social motivators for learning.

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 3–5 years (Moe and Blodgett, 2000), 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 situations. On the other hand, companies also need to collect and analyse 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, this paper has focused 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 Future research issues

How should we design effective learning processes in the workplace? In this study, we have introduced several different types of knowledge. Göranzon's (1990) four types of knowledge have been discussed, as well as Bloom's six levels of cognitive knowledge (Bloom, 1956), slightly revised by Anderson and Kratwohl (2001), 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 (2005) 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 have been discussed above 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.

Another interesting comparison of knowledge-transmitting and knowledge-creating types of learning processes recognises 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 Schank in Brockman (2002). 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 the ability to reach the boundaries of the knowledge base.

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Notes

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

[2]Technology Enhanced Learning.

[3]http://kmr.nada.kth.se

[4]Which is concerned with the perception of value issues.

[5]The figure is based on Atherton (2004).

[6]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.

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

[8]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.

[9]www.wgln.org

[10]www.prolearn-project.org

[11]http://kmr.nada.kth.se/shame

[12]http://www.confolio.org

[13]http://www.conzilla.org

[14]For example, IMS Learning Design (http://www.imsglobal.org/learningdesign/index.cfm), a leading international standardisation effort that deals with the description of learning processes, does not seem to make use of process modelling in a systematic way.

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

[16]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.

[17]Flash meeting is developed by the Knowledge Media Institute (KMI) of the Open University under the coordination of Peter Scott.

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

[19]Naturally, in Figures 4–6 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.

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

[21]SECI, ba and knowledge assets.

[22]Which is a process model version of Figure 8 from Nonaka et al. (2000).

[23]A Conzilla-based model of the PROLEARN Roadmapping process is available at http://www.conzilla.org/projects/roadmapping/presentation/CM#15a94f1105ee8e827

[24]www.prolearn-project.org

[25]Managed by the University of Oulu.

[26]All listed URLs have been accessed on 2008-07-24.

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