Lifelong Learning and Second Order Learning Objects

Heidrun Allert, Christoph Richter and Wolfgang Nejdl

Address for Correspondence: Heidrun Allert, Christoph Richter, Prof. Dr. techn. Wolfgang Nejdl, Learning Lab Lower Saxony [L3S], University of Hanover, Expo-Plaza 1, 30539 Hannover, Germany, Tel: +49 511 762 9754, email: allert@learninglab.de, richter@learninglab.de, nejdl@learninglab.de.

Abstract
Current cultural, social, and economic trends challenge traditional concepts of learning and lifelong learning. This paper draws on the twofold nature of learning in a knowledge society and explores options for technological support. The concept of Second-Order Learning Objects is introduced as a potential means to foster generative learning. Generative learning goes beyond that what is already known and extends or transforms the socially shared knowledge including its artefacts and practices. According to the notion of individual and social learning as a process of reflective action, the role of strategies and media for reflection and inquiry is stressed. This paper outlines the use of schematically represented strategies for learning and reflection and sketches important features of a pursuant modelling approach.

Introduction
Moving into the Knowledge Age is an acronym for being confronted with far-reaching changes in cultural, social, and economic life. In this context lifelong learning is an ongoing agenda in scientific and public discourse. The character of knowledge-based societies and lifelong learning is twofold: individuals, organisations, and societies are both reproductive and productive. On the one hand, living and working within a knowledge-based society requires continuous development of individuals and groups in order to adapt to ongoing change and to improve employability and adaptability (i.e., the reproductive character of learning). On the other hand individuals and groups form and create innovation and change, which again constitutes and characterises the knowledge-based society (i.e., the productive character of learning). Being able to contribute to and co-determine the complex cultural, social, and political spheres fosters active citizenship.

Whereas some current concepts of learning solely focus on aspects of reproduction of culture and on reconstruction of existing knowledge and thus on learning as qualification, other concepts broaden the scope beyond the learner-centred reproductive aspects towards societal-transformative and generative aspects of learning. Broadening the scope towards both aspects of learning raises crucial questions on the design, implementation, and use of technology to enhance learning. While there are divers endeavours to support productive and transformative processes of learning by technology (Scardamalia, 2004, Paavola, Lipponen, & Hakkarainen, 2002, Suthers, Weiner, Connelly, & Paolucci, 1995), the discussion about learning objects (LO) and Metadata for Learning Objects (LOM) have merely concentrated on the reproductive side of learning.

We state that this predisposition towards reproductive learning is at least partly due to the idea of learning objects as self-contained and decontextualised resources that convey the information that is to be aquired by the learner. This conceptualisation of learning objects separates the creation and design of learning objects from its use and hence restricts the learner's role to that of a consumer. The separation of design and accomplishment (run-time) of educational activities also characterises modelling approaches for learning activities such as IMS-learning design (IMS Global Learning Consortium, 2003).

The concept of pre-planned learning activities contradicts the character of innovative processes of production and transformation, which can not be predetermined. Accordingly, current modelling approaches are of limited value in this respect. In order to utilise the potential of metadata, modelling languages, and semantic technologies to support generative learning it is not sufficient to look for innovative and appropriate modelling languages, but to answer the question, what the purpose and the raison d'être of these approaches will be in the light of a more comprehensive concept of lifelong learning.

In this paper we present a notion of lifelong learning that goes beyond the reproductive aspects of learning and sketch how metadata and semantic technologies could be used to support generative learning processes. After a brief discussion of lifelong learning as an individual as well as organisational and social endeavour, we introduce the concept of Second-Order Learning Objects as a complement to content-driven learning objects. Subsequently we describe the use of Second-Order Learning Objects as mediating artefacts in processes of generative learning. We show how metadata and semantic technologies can be used as means for planning, structuring, reflection, and communication in productive learning processes. Finally we present cornerstones for a modelling approach for Second-Order Learning Objects and conclude with a discussion.

Lifelong Learning
The notion of lifelong learning encompasses a hugh variety of meanings, ideas, and connotations. Before we pass over to technology enhanced forms of learning we sketch our understanding of lifelong learning. As mentioned in the introduction lifelong learning is not limited to reproductive forms of learning but also includes productive activities. From the perspective of an individual the twofold nature of lifelong learning means that he has to adapt to ongoing changes due to technological, social, and cultural transformations and at the same time has to make active contributions to these developments. Learning-on-demand, which predefines learning content and learning objectives according to demands resulting from job-specifications and current tasks, covers the reproductive aspects of learning, whereas generative learning focuses on the productive aspects of active citizenship, participation in innovation, knowledge creation, and ongoing change. Lifelong learning is not limited to professional development or vocational training but affects any aspect of life. Innovative technologies and business processes require the acquisition of new skills. Changing social structures and norms call for the creation of different types of relationships. Cultural transformation alters ones beliefs and attitudes. In contrast to concepts which solely focus on institutionalized and organized forms of education we stress a notion of learning as a core condition of human life.

The concept of learning which comprises both reproductive and productive aspects, also implies that learning does not only mean individual change but inevitably is a social process. Individual learning changes organisations, culture and the socially constructed objective world. Generative learning leads beyond what is already known and extends or transforms the socially shared knowledge including its artefacts and practices. The generation of new knowledge by means of scientific inquiry, artistic work, investigative journalism, personal experience, and even by accidential discovery brings about learning on the individual as well as social level. On the other hand, the increasing amount of innovative knowledge makes demands on the individual. Individual learning takes place in the context of organisational and societal development, calling for the adaptation of the individual. Figure 1 sketches the complex relationship between individual and social learning.

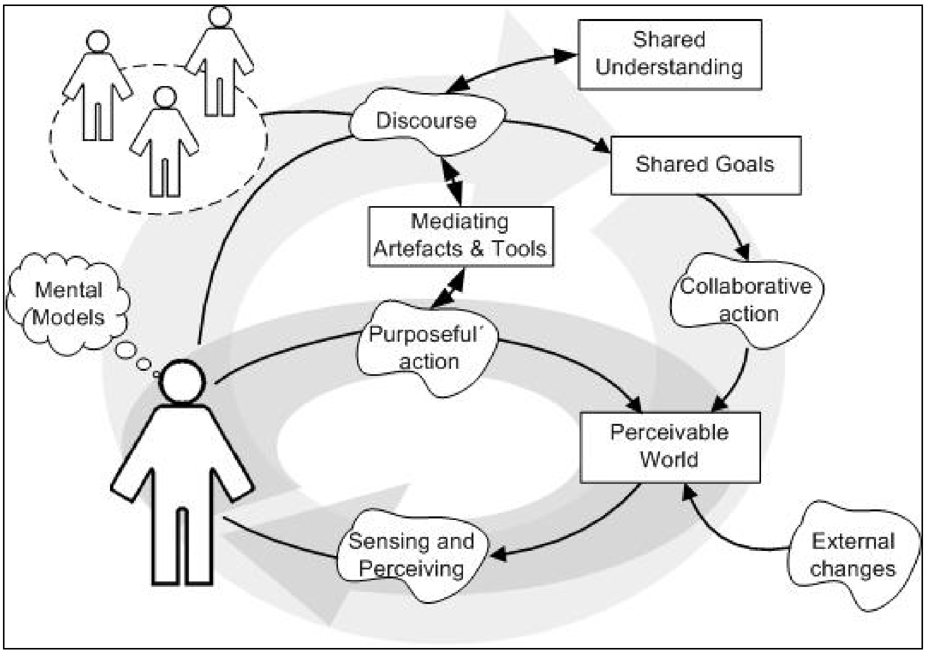

Figure 1: The relationship between individual and social learning

The notion of learning as a fundamentally social process has been acknowledged with regard to organizational learning as well as with learning in the context of culture. The change of organizational structures and the implementation of new practices does not only appeal on employees' skill and knowledge, but also results in improvements and innovations in work organisation, tools and products. Argyris' concept of double loop learning conceptualises the intertwined relationship between individual and organisational learning (eg Argyris & Schön, 1978). Beyond the organizational level, Oerter describes - referring to the cultural-historical activity theory (Leont'ev, 1978) - the mutual-dynamic adaptation of culture and the individual. By means of activity, the individual successively opens itself to the scope of options provided by culture. Culture, again, is created by individuals' activities. This mutual-dynamic process accounts for an isomorphism between culture as an objective structure and the individual as a subjective structure. While culture usually evolves slower than individuals, recent cultural trends indicate that even within one generation substantial cultural changes can occur. Rapid cultural change requires permanent learning (Oerter, 1994, 143). Both, the concept of single and double loop learning as well as the notion of isomorphism between the objective and subjective structure of the world by means of mediated action reflect the interrelationship of productive and reproductive learning.

Once we broaden the scope of lifelong learning and acknowledge productive learning as an important complement to reproductive learning processes a huge variety of additional activities of individual as well as collaborative learning comes to the fore. Endeavours such as change management and organizational learning, scientific inquiry, the creation of innovative technologies, the design and evaluation of social interventions and programs, and conflict resolution become part of a more comprehensive understanding of lifelong learning.

At this stage one may claim that we use the term learning in an inflationary manner as we go beyond reproductive learning and formal education towards informal and productive learning. While we argue for broadening the scope of educational technologies towards informal and productive learning we do not equate any activity with learning. Indeed not every process of change, generation, and innovation is a process of learning, as change does not always mean learning. But if these processes are made accessible to reflection they have the power to change and enhance understanding, knowledge, and skills. Not only learning theories (Scardamalia & Bereiter, 1996, Paavola, Lipponen, & Hakkarainen, 2002), but also pedagogical meta-models (Scheunpflug, 2002, Treml, 2000) integrate productive aspects as crucial structural elements of learning.
To extend the scope of educational technology, as we propose here, is also in line with the EC Memorandum on Lifelong Learning (Commission of the European Communities, 2000) which considers employability and active citizenship as equally important aims of lifelong learning.

Broadening the scope of lifelong learning towards productive aspects of learning, raises crucial questions on the design, implementation, and use of technology to support learning. In fact many applications that are useful to support productive learning have not been developed for learning purposes but for knowledge management, scientific visualization, and cooperative work. On the other hand, specifications for metadata to describe learning objects focus on reproductive learning. In the following sections we delineate the idea to use semantically rich descriptions, such as metadata and modelling languages, as mediating artefacts in processes of generative learning. We will sketch a type of educational resources designed to foster generative learning, reflection and active citizenship.

First and Second Order Learning Objects

The concept of learning objects has attracted a lot of reseach and discussion in the field of Educational Technology. Nevertheless, there is no general agreement on a definition of learning objects (Polsani, 2003, Wiley, 2003). While in principle, IEEE-LOM's definition of learning objects as „any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning" (IEEE-LTSC, 2002) is open to a wide variety of objects and conceptual ideas, discussions have addressed questions such as whether the concept of learning objects is restricted to digital resources, or whether it also includes non digital resources, whether learning objects are resources which were explicitly designed for learning purposes, entailing an inherent learning objective, or whether a learning object is any resource which is used in processes of learning. But with regard to the concept of lifelong learning, the relevant question is, whether the concept of learning objects is limited to reproductive aspect of learning, or whether it also addresses productive aspects of learning. We state, that current standards focus on the reproductive aspects of learning (Allert, Richter, Nejdl, 2003). In this section we broaden the scope to the use of learning objects in scenarios of generative learning, that is, the productive aspects of learning. To do so, we distinguish two types of learning objects which are structurally different and complementary. We differentiate between First-Order Learning Objects (FOLO) and Second-Order Learning Objects (SOLO).

First-Order Learning Objects are resources which are created or redesigned towards a specific learning objective. The learning objective is an integral part of the first-order learning object, no matter if it is explicitly stated or not. Usually FOLOs are designed to present information, which has to be acquired or re-constructed. Textbooks, lectures, educational movies, instructions are examples of First-Order Learning Objects.

Second-Order Learning Objects are resources which provide and reflect a strategy, such as generative strategies, learning strategies, problem-solving and decision making strategies, or a medium for planning, reflection, and inquiry. SOLOs are means to foster knowledge creation as they provide scaffolds, schemes, scripts, methods, and conceptual models. They represent a media of generative and reflexive activity as part of productive processes on the individual as well as social (and collaborative) level.

Defining different types of learning objects is based on current contributions in the field of educational metadata. For example, Wiley (2003) argues for a clear separation of instructional strategies and content: "[…] *learning objects should not contain content at all; rather, they should contain the educational equivalent of algorithms – instructional strategies (teaching techniques) for operating on separately available, structured content."*(p. 6). Also the Educational Modeling Language (EML, Koper, 2001) and IMS Learning Design (IMS Global Learning Consortium, 2003) separate the description of learning processes and activities from the description of learning resources.

The concept of Second-Order Learning Objects changes the present notion of learning objects, as the learning strategy itself becomes a learning object. The distinction of First- and Second-Order Learning Objects refers to the distinction of first- and second-order learning environments introduced by Scardamalia and Bereiter (1996). While in a first-order learning environment learning can be seen as the adaptation to the environment and therefore is reproductive, learning processes facilitated by a second-order learning environment change the environment itself so that an ongoing process of change and readaptation evolves. Processes of knowledge, creation, including inquiry, reflection, and innovation, which take place in second-order learning environments are ill-structured generative processes. Processes of inquiry, reflection, and innovation are open with respect to their results. They don't succeed without planning but are insufficiently described by planning. In contrast to goal-oriented learning these processes can hardly be predetermined. Accordingly, Second-Order Learning Objects are no formal process models for learning but collaborative artefacts mediating processes such as planning, structuring, organizing, reflecting, and communicating knowledge generating endeavours.

Here we list some classes of generative strategies which constitute Second-Order Learning Objects:

- meta-cognitive strategies for individuals,
- creativity techniques for individuals and groups,
- methods that foster organisational development, including double-loop-learning,
- evaluation (reflection) on an organisational or public level,
- learning strategies,
- methods for conducting inquiries (how to make a survey etc.),
- approaches that help to organise and foster interaction and learning on a community level (Communities of Practice, virtual conferences, open space, etc.),
- methods of scientific inquiry,
- methods for strategic planning,
- problem-solving and decision making strategies.

SOLOs support the development of skills and competences, such as:

- Managing and structuring information,
- Decision making,
- Problem solving
- Mediating skills
- Planning skills
- Entrepreneurial skills
- Strategic management
- organizing team-oriented work,
- panning and coordinating projects
- self-directed learning

Besides productive learning, SOLOs support self-directed reproductive learning. According to Reiserer & Mandl (2002) lifelong learning is characterized by self-directed learning. "The notion of lifelong learning implies, that learning is largely planned, accomplished, controlled, assessed, and evaluated by the learner himself." (p. 924, translated by the authors of this paper). The learner decides about learning objectives as well as strategies (cognitive, meta-cognitive, and resource-oriented strategies). Examples of SOLOs supporting reproductive learning are SOLOs such as 'Become Acquainted with a new Topic', 'Preparing for a Presentation', or 'Embedding Learning into your Workflow'. Whereas SOLOs provide support for solving complex problems by making aware strategies, FOLOs provide support by making available learning content.

Gelöscht: 1997

Learning processes, which address meta-cognitive skills, need explicit support. Due to their inherent character, these competences can not form learning objectives which can be achieved and reached finitely. Learners do not asymptotically approximate these learning objectives. There are no fixed criteria and benchmarks. Achieving these competences is an ongiong and dynamic process. Just as someone who is competent in strategic management, has to adjust his strategic competences within any unforeseen situation in a project, learners have to develop these competences anew within any new situation and project. These competences may not be gained in an abstract manner. A student of software engineering gains strategic competences within a project of software engineering. But she or he does not gain it ad hoc and by chance, but strategic management and planning must be explicitly supported.

Generative Learning as Situated Action

Generative learning is situated in activities and processes, such as work, innovation, organisational, and societal change. Processes of generative learning are integrated and embedded in their context, and intertwined with local conditions rather than isolated. Thus, situatedness is a basic constituent of generative learning. In this section we describe the use of SOLOs as mediating artefacts in processes of generative learning and provide three examples of use. We show how metadata and semantic-based techniques can be used as means for planning, structuring, reflection, and collaboration in productive learning processes.

Second-Order Learning Objects as Means to Plan and Organise Activities

Plans are artefacts which outline the relation between intentions, activities, resources, and outcomes. As plans and generative scripts play a prominent role in processes of generative learning they are an important kind of Second-Order Learning Objects. As processes of generative learning are bound to specific situations, the creation and adoption of plans cannot be separated from the context and learning activity itself, but has to be tied to the concrete situation. Consequently, plans can and usually have to be modified or changed in the course of the activity. Plans enable to structure activities and processes and to reflect routines, procedures etc.. SOLOs support learners to make plans. Thus planning, structuring and reflecting is an explicit and integral part of generative learning. SOLOs are modelled accordning to divers methods, which guide the creation of plans. In order to explain the concept of SOLOs, we outline an example, which will be taken up throughout the next sections of the paper: The SOLO "Program Logic Mapping (PLM)" represents a model of a planning-method, called *Program Logic Map*. This SOLO was used and instantiated by a group of students in the 4th year at a University of Applied Sciences. In the 4th year, students usually are responsible for a project, such as the "Compter-Supported Clinical Record Management". With support of the SOLO, the students planned the program they had to implement. Figure 2 is a graphical representation of the Program Logic Map. According to the notation chosen, clouds represent the context of a project, rectangles the available input and resources, rounded rectangles the intermediate goals, and elipses the ultimate goal.

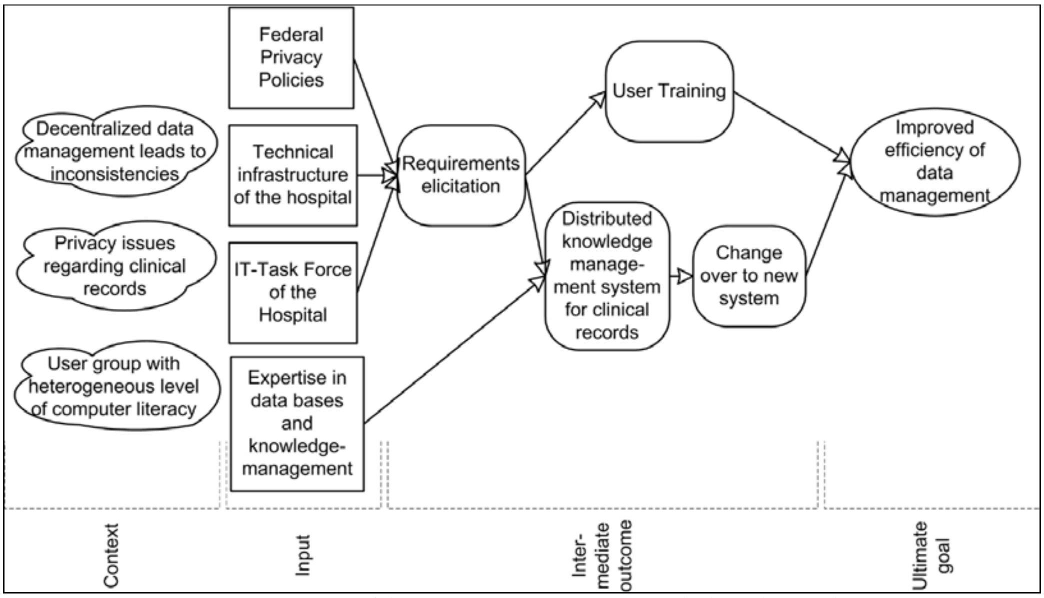

Figure 2: Program Logic Map of the project: "Compter-Supported Clinical Record Management"

The use of SOLOs as representation of planned activities is different from that of formally specified learning designs. In the latter case the description of learning activities is seen as self-contained, represented in a formal process model. SOLOs do not automatically control the flow of activities but assign the creation of plans to the learning activity. This includes the possibility to modify and change plans and schemata during the course of the activity. For example the creation and modification of a Program Logic Map is a very important process throughout the lifecycle of a project. Thereby, changes and alterations are of great importance, because as Bardram (1997) states: *"Deviating from a plan is a breakdown and therefore a potential learning situation"*. Deviations motivate and require to readjust and modify existing plans and to create entirely new ones (Volpert, 1999). Activities are not fixed but are the product of interacting with an environment.

Second-Order Learning Objects as Means to Structure Information and Modelling
Second-Order Learning Objects are not restricted to the description of activities but can also provide means to structure information or model certain aspects of the world. In this sense they represent sets of interrelated concepts that can be used to describe the domain of interest. Accordingly, different Second-Order Learning Objects represent different approaches of structuring, each based on different assumptions and each providing a different view. Second-Order Learning Objects represent models in order to structure information and to annotate this information with meaning. The use of different Second-Order Learning Objects thereby allows to look at a system form different angles. For example to provides two perspectives on an organisation: an organisational and a social perspective. Again, Second-Order Learning Objects are no fixed entities, but are open to change, modification and enhancement.

Second-OrderLearning Objects as Collaborative Artefacts
Within collaborative settings SOLOs provide facilities for meta-communication in order to plan, structure and reflect the actual course of activities and the status of a project. Schemes work as mediating artefacts of meta-communication, which are shared and modified within groups. Shared schemes can be used to coordinate activities of different stakeholders and to organise projects and work.

SOLOs are Shared Schemes
SOLOs support the creation of mediating artefacts. The Program Logic Map of the project: "Compter-Supported Clinical Record Management", shown in figure 2 is a mediating artefact, which instantiates the SOLO "Program Logic Mapping (PLM)". The SOLO provides a scheme, which allows to organise and structure the field of activities. The scheme is specified according to a specific method (the method of Program Logic Maps). A group of learners searches for a suitable SOLO, finds one and instantiates it. During the course of their learning process they do not only create, modify and change the instance of the SOLO, but eventually also modify, and change the SOLO (the scheme) itself as they adapt the SOLO to the specific situation they face. They make available the new SOLO again.

Schemes reflect certain practices which are common within a community. Knowing how things are usually done is an important prerequisite for being integrated in a community as well as for improving such practices and extending the set of available strategies - and therefore for innovation and change. New strategies are created in the course of activities and reflected in schematic representations in order to establish new routines and to extend the set of available strategies.

Modelling Second Order Learning Objects
In this section we present cornerstones of a modeling approach for SOLOs. The character of situated activities defines some requirements regarding the modelling approach:

- SOLOs have an intended purpose and a theoretical foundation (e.g. a method)
- SOLOs must be open to change (as a consequence of situatedness of generative processes)
- SOLOs represent a strategy abstracted from concrete content
- In order to enable collaboration, SOLOs must encode a shared and explicitly defined meaning.

Intended purpose: SOLOs represent a description of strategies, abstracted from a concrete activity. Besides a description of activities, they include the intended purpose of activities. This is crucial as a learner must be able to change the plan according to the situation he is confronted with. Changing a SOLO is a consequence of situated action. SOLOs must allow reflection and change, as design and execution (plan and performance) of a learning activity can not be separated from each other. Thus, plans must be adapted to the actual situation. Only if an actor knows the intended purpose of an activity, he is able to reflect whether a plan is suitable according to the situation he is confronted with. Knowing the intended purpose allows to adapt the plan to the actual situation, to deviate from the plan, and to change the plan. A SOLO (generative script) must explain why an activity is relevant, rather than just sequencing activities. For example: A test or exam can serve different purposes, such as selection or constructive feedback. The question is, what function the test has to fulfil. On the other hand, there are functional equivalences: an oral exam at the end of a term might be equivalent to continuous feedback during the entire term. Another example: A discussion might proceed entirely differently and might produce different outcomes depending on the intention, (organisational) culture, and prior experience in the group. SOLOs do not control activities, but are means for reflection.

Changing plans: SOLOs must be open to change. SOLOs and tools, which integrate SOLOs, must allow non-linear procedures such as iterations and recursions. Learners must be able to integrate activities which are not described by the SOLO. Learners must be allowed to combine and mix different SOLOs. According to the concept of learning objects, modified SOLOs can be exchanged again.

Roles and Types
In order to model SOLOs we distinguish the formal concept '*type*' from '*role*'. The concept of *roles* we use is taken from the field of semantics and formal languages (see Steimann 2000a,b). Steimann recommends the introduction of the concept of roles into object-oriented modelling in order to make dynamic modelling approaches possible. He distinguishes natural-type and class-type from roles-type (table 1). Roles are not semantically rigid but founded (Guarino 1992). Instances of natural types can fill, adopt and leave a role without losing their identity. The concept of role-based modelling in the context of metadata for learning objects is described by Allert, Richter & Nejdl (2003). Within the following diagrams a rectangle indicates a *natural-type*, a circle indicates a *role-type*.

Natural-Type/Class-Type	Role-Type
•Static	•Dynamic (Dynamic classifying)
•An instance of a class once and forever belongs to that class. It cannot change class without losing its identity	•Founded (has context and relations) •Not semantically rigid – an instance does not lose its identity when leaving the role [Guarino 1992]

Table 1: Distinguishing natural-types and class-types from role-types

SOLOs are consistent systems of interrelated roles. Roles represent the function a type can fulfill. Types can fill a role and a type can fill different roles. Basic terms of this modelling approach are: schema, system, role, and type.

Roles model which role a resource can fill in a learning process. We explain this with a scenario which comprises the use of a SOLO ('Program Logic Mapping'). The resources referred to in the model (instances of types) can among other objects include First-Order Learning Objects (FOLOs) and further SOLOs.

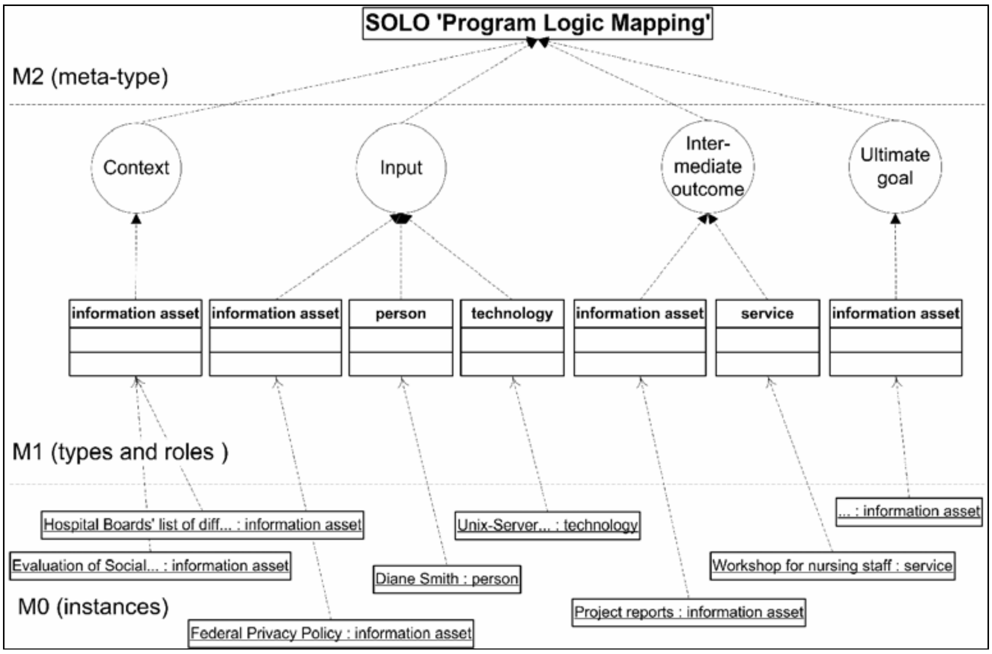

Figure 3: Modelling a Program Logic Map scenario

According to figure 3, *Program Logic Mapping* comprises the roles '*context'*, '*input'*, '*intermediate outcome'*, and '*ultimative goal'*. According to the SOLO 'Program Locig Mapping', these aspects are relevant structural elements of the strategy Program Logic Mapping. Information assets, persons, services, technologies, and activities are types which can fill the roles. The '*Federal Privace Policy*' in an instance of the type '*information asset*' which fills the role '*input'*. Thus, resources can fill roles which are specified by the SOLO. According to the modelling approach, a SOLO is a set of roles, representing a coherent system. A SOLO within the Semantic Web is a scheme, which is shared. A SOLO which is instanciated by a group of learners is an shared artefact, which supports collaborative work and learning.

Comparable to a Learning Management System, which integrates learning objects (FOLOs), there are tools which integrate SOLOs. We give an example of how such a tool might look like and how it might be used: A group of learners plans to conduct a session of Program Logic Mapping. They search for a suitable SOLO and integrate it into their tool. Within the tool, the SOLO is represented as a palette – the structural elements (roles) are represented as icons in the palette. A double-click onto an icon shows the description and intended purpose of this structural element. The group can drag&drop any icon onto the action pad (the shared stage). During runtime they reference resources (which can be uploaded to the library or found in the internet) they use and produce within the session. These resources fill the roles specified by the SOLO. Resources are instances such as html-files (presenting a problem statement, etc.), text-files, FOLOs (presenting background knowledge) and so on. At any time the group of learners can integrate a new structural element (role) into the SOLO which actually means integrating an activity within the process which was not specified in the SOLO. To do so, they generate a new icon and describe it. The SOLO is now modified and can again be exchanged. But also the process model of the actual session as visualized on the action pad can be saved as file, containing all references to any of the resources and instances used within the session. It is the mediating artefact, shared by the group.

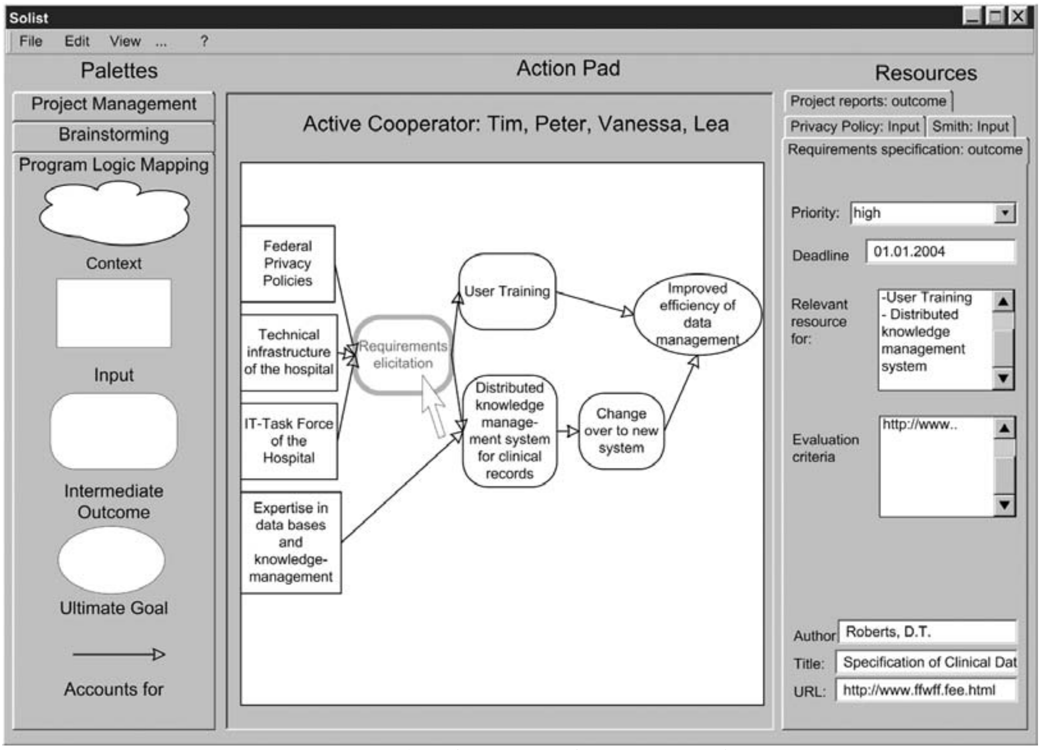

Figure 4: Screenshot of a user-interface prototype of SOLIST

Palette: visualises the SOLO and its roles as icons.
Symbols: visualising roles as icons
Action pad: a shared stage.
Library: resources, which are referenced as soon as they fill roles.

Discussion
In this article we outlined the concept of generative learning as an important component of lifelong learning and introduced the idea of Second-Order Learning Objects as means to foster knowledge generation.

We started with exploring the notion of lifelong learning including productive as well as reproductive aspects and covering individual learning as well as social development. We argued, that recent discussions on learning objects and metadata for educational resources focus on the reproductive aspects of learning and proposed the concept of strategy-oriented Second-Order Learning Objects as a complement to content-oriented First-Order Learning Objects. In order to specify core requirements of Seocond-Order Learning Objects we drew on the situatedness of generative learning processes and described their use for planning and organizing activities, structuring information as well as collaboration. Furthermore, we argued that Second-Order Learning Objects provide shared schemes which allow to structure information in a meaningful way. The notion of SOLOS as shared schemes has extensive consequences on the use of metadata for educational purposes. While so far metadata have been used to ensure the interoperability and reusability of learning objects, now the use of metadata and metadata schemes becomes an important aspect of learning itself. We also showed that the use of a role-based modelling approach would allow to use multiple schemes and to overcome the need for unifying schemes.

Neither the idea of generative learning nor the development of means to foster generative learning and knowledge creation is genuinely new. Accordingly, the design of Second-Order Learning Objects and the development of technical support applications can draw on a lot of prior work and ongoing research. Regarding the design of Second-Order Learning Objects input might stem from research regarding the use of external represenations for individudal and collaborative learning (eg Suthers, 2001), the use of scripts and scaffolds for problem-solving, the development of modelling languages for design purposes, as well as techniques for knowledge management. Additionally, Semantic Web technologies provide important means to create powerful technical applications.

While this article aimed to raise an awareness for the significance of generative learning and to clarify important concepts there are several directions for future research and development: Up to now there are no computer tools that allow to use arbitrary Second-Order Learning Objects. If tools are build in order to foster generative learning (e.g. the knowledge forum CSILE) the learning strategy is often part of the tool and cannot be exchanged or modified by the user. A second challenge arises from the fact, that generative learning often takes place in informal educational settings like work situations. Therefore, the use of SOLOs must fit into other work practices including the computer tools used. Finally, we have to learn more about adequate ways to represent SOLOs and mediating artefacts, created and shared by learners.

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