Flexible instructional strategies for e-learning

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Abstract
This paper provides an overview on a German lighthouse research project called L3 in the area of e-learning systems that supply e-learning services via a virtual private network. More specifically this paper focuses on a new approach of meta-tagging learning elements to enable the flexible execution of courses depending on the individual learning style of the student. The notion of a content aggregation model is introduced and a set of tools and a first prototype of an associated run-time environment will be described. An extension to the existing standardization according to SCORM is given to project future developments in this area to allow more in-depth implementation of didactical knowledge into courseware systems. A basic ontology on instructional units is described and provides extensions to also allow advanced learning scenarios where group learning is supported in the design and implementation of the courseware. First results of the evaluation are provided, as the material becomes used in vocational training centers as part of the e-learning service.

Keywords
L3, e-learning, instructional design, web-based training, architecture, SCORM

1) Introduction
"L3: Lifelong Learning - Learning as a utility" is a lighthouse project sponsored by the German Federal Ministry for Education and Research. A consortium of 20 companies headed by the SAP’s Corporate Research Center, the CEC Karlsruhe (Campus-based Engineering Center) is developing and establishing a national backbone for advanced education and training.

L3 aims to make lifelong learning possible by implementing an organizational and technical infrastructure that can be used by everyone, for both professional and private education. Therefore, the project takes an interdisciplinary approach by engaging all those directly or indirectly involved in advanced education processes (i.e., teachers, students, educational consultants, experts, content developers, and technicians). This allows combining the areas of advanced education, new information and communication technologies as well as innovative training material into a uniform service infrastructure for cooperative web-based learning.

Learning Centers in advanced education institutions are the points of access for students in this service infrastructure. They are able to provide curriculum advice, expert support and on-site tutorial help. A Service Center as the heart of the infrastructure coordinates the offering of online content on behalf of the Learning Centers and provides all kinds of technical services to them. The overall development approach considers the following important aspects:

- Today’s practices and processes in advanced education institutions
- The technical infrastructures available in the near future
- Business models to run the established services
- New didactic concepts and tools for on-line learning material.

Starting with today’s practices and processes in advanced education institutions, evolutionary models have been developed and are executed in order to continuously increase the amount on-line learning available in today's curricula. This guarantees that traditional and effective forms of learning are complemented with or replaced by new forms that are possible due to modern information and communication technologies (virtual learning groups, remote tutoring, tele-learning, course flexibility).

The technical infrastructure is the means to bring together educational methods, services, new media, the Internet and globally available information pools such as media archives. L3 is putting advanced education institutions in a position to make use of the new technologies and hence expand their current offerings. Although the institutions are not generally
major investors, they are a natural place for access to and use of innovative technologies in advanced education to be made available. Further more, their educational offerings can be extended by inter-institutional computer-supported cooperation that promotes joint use of available resources. However, in order to be effective the technical infrastructure must planned in a way that assures all technology used will be available at the end of the project at a reasonable cost.

The project explores economically viable business models that include both the public and private sector in depth, considering both technological as well as educational aspects. This will guarantee continuous operation of the backbone in the mid-term and will create an online education marketplace in the long-term. This satisfies the basic need for lifelong education for both the individual and the business professional.

The new didactic concepts and tools in L³ focus on the development of flexible, high-quality on-line course material. This includes the integration of cooperative exercises and the possibility to adapt content according to different learning styles and histories. The remainder of this paper will focus on the adaptation of content.

2) L³ Course Model

One of the major goals in L³ is to provide a methodology and tools to structure learning material in a way that allows for both reusability and adaptive delivery.

In this section we first introduce the basic concepts used in L³ and then relate them to other approaches taken in the field of e-learning.

Content Aggregation Model

In L³, content is aggregated in four distinct structural levels where each higher level may contain instances of all lower levels. These levels are enumerated from bottom to top:

1. Knowledge items
2. Learning units
3. Sub courses
4. Courses

The lowest level of granularity is formed by knowledge items which represent the smallest indivisible element in a course.

Figure 1 Content Aggregation Model

Each knowledge item shall contain material that illustrates, explains, practices or tests a certain aspect in one thematic area and thus refers to actual learning content. Several related knowledge items are typically assembled into one learning unit, which is the logical representation of a distinct, thematically coherent unit. Learning units are still considered small in terms of “size” (i.e. duration) and are further grouped into larger structural units, so-called sub courses. Sub courses may also be used to build an arbitrarily deep nested structure by including other sub courses. At the highest structural level sub courses, learning units and knowledge items are contained in a course (see Figure 1).

To foster maximum reuse, all structural elements are supposed to be self-contained and (ideally) context free. This implies that higher level elements do not actually contain but merely refer to lower level elements.

Meta data

Besides structural composition, course material in L³ can be tagged with additional meta data that further improves the support for adaptive delivery, reusability, and the search and retrieval of existing material.

The meta data set used in L³ can be divided into four categories:

Instructional meta data

This is essentially the Learning Object Meta data (LOM) set defined by the IEEE Learning Object Meta data Working Group [IMS, 2001]. The L³ authoring tool allows authors to attach the full LOM set to individual course elements.
Knowledge types
Receptive knowledge items can be categorized using a didactical ontology defined in [Meder, 1999]:

- **Orientation knowledge** helps a learner to find her way through a topic without being able to act in a topic-specific manner ("know what").
- **Action knowledge** helps a learner to acquire topic related methods, techniques, or strategies ("skills", "know how").
- **Explanation knowledge** provides a learner with arguments that explain why something is the way it is ("know why").
- **Reference knowledge** teaches a learner where to find additional information on a specific topic ("know where").

These four basic types are further sub-divided into a fine grained ontology shown in Figure 2.

![Figure 2 Knowledge types ontology](image)

Furthermore, knowledge items can represent some sort of (performance) test which may have implications on the competencies a learner has mastered (see below). Finally, a knowledge item can be a placeholder for a collaborative scenario that has been designed into the course by the author and that forms an integral part when taking a course (as opposed to spontaneous collaborations scenarios that occur in tutoring or requesting help situations).

**Relations**
While assembling the higher level building blocks of an L3 course, an author may describe dependencies between structural elements by specifying **matter of facts** or **subject-related** relations. These relations, again, are categorized into two groups, namely the **association** and **hierarchical** relation types, where each group is further sub-divided into a fine-grained net of sub-relations [Meder, 1999]. Examples for sub-relations are: **analogy**, **side by side**, or **similarity**.

Matter of fact relations are not used within a learning unit. Since all knowledge items in that unit already belong to the same "matter", there is no need to describe further subject-related dependencies. Here, it might be desirable to order items according to **didactical** relations (e.g. item 1 is a **prerequisite** of item 2).

**Competencies**
Performance evaluation is an integral part of the L3 learning platform. Thus, course authors can assign competencies (or skills) to learning material and can provide test procedures that evaluate the individual learner’s performance. A competence classification scheme has been introduced to tag an individual competence as either being **cognitive**, **emotional**, **sensoro-motorical**, or **social** skill.

**Strategies**
So far, we have not made any assumptions concerning how sequencing happens between units in an L3 course. This is deliberately omitted from our
content aggregation model, thus allowing different sequencing rules to be applied to the same course material: One strategy might start at the bottom moving up to the more general concepts which resemble an *inductive* strategy. At the opposite end, another strategy may lead the learner from the general concepts to the specific ones, thus implementing a *deductive* approach.

Ideally, no dependencies between macro and micro strategies exist, thus, any combination of macro and micro strategies can be used when taking a course.

No matter what strategy set is chosen, they are chosen at run time, not at design time. Authors are relieved from the burden of thinking in sequenced order and can concentrate on structuring and annotating the material. This eventually leads to better courses in terms of reusability and adaptation.

**Related Work**

The *Sharable Content Object Reference Model (SCORM)* [ADL1, 2001] imposes a similar content aggregation approach. Here, reusable units, so-called *sharable content objects (SCO)*, are assembled into higher level units, so-called *blocks*. As opposed to the content aggregation model in L3, these blocks are not reusable. Furthermore, the current version (1.1) of the SCORM specification provides only limited support for adaptive course strategies. Sequencing is merely controlled by scriptable prerequisites where didactical dependencies are captured in Boolean predicates. This is not very flexible and tends to be error-prone. Recently, a proposal has been submitted to the Advanced Distributed Learning Initiative that outlines a new, more flexible approach [Oysten, 2001].

Early learning environments were based on hypermedia systems in which the content is statically linked together. They did not provide adaptive navigation strategies, but achieved guidance for the learner by annotating the hyperlinks between different knowledge items (e.g. [Cleary 1996]).

Research about intelligent tutoring systems (e.g. [Brusilovsky et al. 1996], [Weber et al. 1997]) and adaptive hypermedia systems (e.g. [Henze 2000]) is often based on a special domain model that has to be defined prior to the creation of the content. A typical model consists of a conceptual graph build upon the main concepts of the problem area. Prerequisite relations link single concepts and documents need to be indexed according to the domain model. User modeling and user guidance are also based on the domain model by estimating which concepts the learner knows to which degree of expertise. The main differences in the L3 approach are: (1) An explicit a priori domain model is not required; instead, our domain model is implicitly constructed during the course construction by structuring the course into sub courses, learning units etc. (2) In addition to prerequisite relations, we heavily exploit matter of facts relations which allows the traversal of course material according to different learning strategies.

[Ranwez et al. 2000] presented a system that guides users not only based on domain knowledge but also by considering teaching strategies, learning goals and the learner’s state. All of these were modeled using conceptual graphs and an inference engine to answer queries about these graphs. Though this approach is very flexible, it suffers from a complexity that is hardly manageable by ordinary course authors. In contrast to this general approach, we developed the concepts of macro and micro strategies, which can be easily understood by authors and can be applied to arbitrary course material. In addition, the hierarchical structure of L3 courses allow the reuse of components as well as the forecasting of learning strategies’ effects.

L3 searches for a “practical” solution that is easy to use for both authors and learners and offers sophisticated guidance at minimal cost. This goal is achieved by using a minimal set of meta information. The author only needs to concentrate on the structuring of the content and receives (nontrivial, useful and didactically motivated) adaptive learning strategies for free.

**3a) A formal approach**

The implementation of the approach described above is based upon the following formal model:

**Course graphs**

In L3, a course is essentially a set of graphs. A *node* represents a structural unit of a course and node attributes are used to carry the meta data attached to the corresponding unit. An *edge*, in turn, represents a relation between two structural components.

The following example illustrates this:
Figure 3 Example course: “Course authoring in L3”

The author has divided a course about “Course authoring in L3” into three sub courses and one learning unit. She has also decided that the concepts explained in the learning unit provide the context for the concepts covered in the three sub courses (see Figure 3).

Figure 4 Sub course "Knowledge structure"

The sub course “Knowledge structure” is further subdivided into a learning unit on “Relations”, and two sub courses that cover the topics “Methods” and “Knowledge objects”, respectively. Here, the author expressed the fact that the methods “determine” which relations and knowledge objects can be used (see Figure 4). The learning unit “Relations” introduces the different relation types, gives examples for these different types, provides further explanations on “non-subject taxonomic” relations, and finally contains a “Test on relations”.

Figure 5 Learning Unit "Relations"

In this unit, the author has decided to declare the first example about “Associative relations” as a prerequisite for the second example (see Figure 5).

Computational Model

The main purpose of the course macro and micro strategies is to help generate a path through a set of course-related graphs that is simply an ordered list of nodes. To accomplish this, graphs and strategies “interact” in the following ways:

1. A strategy implements a set of Boolean predicates that can be applied to graph nodes. Example: isCompleted(node).
2. A strategy will get informed by an event that some sort of action has been performed on a graph node. Example: navigated(node).
3. A strategy provides functions (in a mathematical sense) that can be used to compute new node sets for a given node. Example: NavigationNodes(node).
4. A strategy provides an ordering function that turns node sets computed via 3. into ordered lists.
5. A strategy may decide to alter certain strategy-related node attributes. Example: node.setVisited(true).

Note that the last point is necessary because we do not want that the strategy itself to keep an internal state. Instead, any strategy-related information is stored in a graph nodes’ attributes which allow strategies to be changed “on the fly” during graph traversal.

What set of nodes are of interest when generating a path through a course? First of all, the set of “navigation nodes” includes all nodes that the strategy identifies as immediately “reachable” from the current node. In other words, they represent
potential direct successors. A second important set contains the “start nodes”, which are potential starting points for entering a new unit. The more elements this set contains, the more choices a learner has when entering the unit. As a consequence, any strategy must implement at least two functions that can compute the sets we just described and the ordering function that transforms those sets into ordered lists. In order to illustrate these concepts, it is necessary to take a look back at the example above. To conserve space it is assumed that the ordering is done implicitly when calculating the sets:

For the top-level graph (the whole course) in Figure 3 one macro strategy may take associative relations into account, thus computing the list of start nodes for this graph as follows:

StartNodes("authoring") := ("Basic concepts")

Opposed to this, another macro strategy ignores any relation whatsoever, thus returning:

StartNodes("authoring") := ("Basic concepts", "Knowledge structure", "Learning environment", "Tools")

The “navigation nodes” list is empty in both cases, since there’s no current node yet.

When entering the “Knowledge structure” subcourse (Figure 4), the first macro strategy computes the following lists:

StartNodes("Knowledge structure") := ("Methods")

NavigationNodes("Knowledge structure") := ("Relations", "Knowledge objects")

For the same node, the second macro strategy returns:

StartNodes("Knowledge structure") := ("Methods", "Relations", "Knowledge objects")

"Relations", "Knowledge objects")

In opposition to that example, an “overview” type of micro strategy may limit the choices to:

StartNodes("Relations") := ("The different relations")

NavigationNodes("Relations") := ()

Micro strategies, in turn, may want include the knowledge type meta data attached to the knowledge items of the learning unit. For example, an “action oriented” micro strategy will generate lists for the learning unit “Relations” as follows:

StartNodes("Relations") := ("Test on relations")

NavigationNodes("Relations") := ("Associative relations (1)", "Associative relations (2)", "The different relations", "Hierarchical relations", "Non subject-taxonomic relations")

In opposition to that example, a “navigation support” may want include the knowledge type meta data attached to the knowledge items of the learning unit. For example, an “action oriented” micro strategy will generate lists for the learning unit “Relations” as follows:

StartNodes("Relations") := ("The different relations")

NavigationNodes("Relations") := ()

Navigation support

We have seen that different strategies may result in completely different paths. The examples also show that even one fixed combination of a macro and micro strategy can produce more than one alternative.

L3is currently experimenting with different ways the system can support learners as they are making their way through the learning material. At one end, learners can opt for “complete guidance” in which they rely on the system to automatically find the most appropriate path. In this case, learners simply tell the system to navigate them to the “next” item in the course. Conversely, learners may choose to explore the material as they see fit without following the suggestions made by the system. Learners may also switch between the two modes whenever they like (see Figure 6).

Figure 6 Navigation modes

To support these different options the system dynamically generates a navigation view that helps learners determine:

- where they are in a course,
- where they have been already, and
- which route(s) they can follow.
The navigation view, as depicted in Figure 6, is a combination of the navigation history and new navigation suggestions. In this example, the navigation history consists of the first two columns, where “+” Knowledge objects” denotes the current node. The other entries in the history columns have been “gathered up” during previous navigation steps; they were listed in the corresponding node lists that have been computed by the macro and micro strategy. The navigation suggestions in the right-most column contain nodes from the start node and navigation node lists for the current node: To avoid duplicates entries that are already part of the history view are omitted from this column.

This structural information is further augmented by visual clues that are either generated using the Boolean predicates implemented by strategies (e.g. isDone, isSuggested), or are deduced from node attributes (e.g. node type, knowledge type) or context information (e.g. node lies on the learner’s path). The example uses a color coding scheme to give hints concerning nodes is the current unit (“orange”), whether units have been completely visited (“gray”), which next steps are suggested (“dark green”), or whether a node contains additional material not yet visited (“light green”). Other colors are used to mark a unit as not yet suggested (“light red”), or identify a test (“dark red”) (see Figure 6). Additionally, a “+” sign is used to indicate that a node represents a higher level unit that contains sub units or items.

Implemented strategies
In the current version the following set of strategies has been implemented:

Macro strategies:

- Goal based top down: Follows a deductive approach. Structural hierarchies are traversed from top to bottom. Relations within one unit are ignored if they do not specify a hierarchical dependency which means that most nodes become start nodes and are not considered navigation nodes.
- Goal based bottom up: Follows an inductive approach by doing a depth first traversal. On its way down to the leaves (using hierarchical relations) it picks up orientation knowledge at each intermediate level using an “orientation only” micro strategy. Within a leaf node the chosen micro strategy is applied
- “Table of contents”: Simply enumerates all nodes within a container using the order given in the storage format of the course structure. All relations are ignored.

These macro strategies also exist in a “linear” variant; the navigation view will be flattened and all columns will contain only one item (see Figure 7) leading to a presentation-like navigation mode.

Micro strategies:

- Orientation only: Ignores all knowledge items, which are not classified as orientation knowledge. Best suited to implement a “management overview”.
- Action oriented: Picks knowledge items first that are classified as action knowledge. All other knowledge items are sorted in their “natural order” (i.e. as they appear in the storage format of the learning unit).
- Explanation oriented: Similar to action oriented with a focus on explanation knowledge.

4) Evaluation of the environment

Overview
The evaluation of a complex system like the L3 platform needs different viewpoints to allow a comprehensive experience about what works and what does not. The major focus will be on the
benefits for the learner, but we will also need to investigate other topics such as the following:

- the authoring support (methods and tools),
- scalability and reliability of the service,
- sustainability (business and organization)
- quality and quantity analysis of user (learner, tutor and author)

As the project is in its implementation and deployment phase in the pilot environment, L3 can only address a couple of aspects with regard to the different target audiences in the user community.

**Authoring**

A whole set of authors inside the L3 consortium have been addressed and L3 has also received feedback from SAP internal groups as well as usability tests according to the engineering organization. In general three major conclusions have been formed:

1. The structuring and tagging of instructional units is a **highly complex task** and content creators need support to introduce this to their organization and to deal with the methodology. A two day introduction with hands-on sessions have been developed and result in a reasonably fast learning curve enabling authors to create and/or reengineer first domain fragments. More specifically, they must abandon the “traditional” way of “hard-wiring” courses and design self-contained learning units to allow flexible assignment and reusability. The overhead introduced through the initial creating process has been measured to be approximately 5-10% depending on the experience of the author. In general, authors adjust to the method quickly and an in-depth trial has shown that a complex set of courses inside SAP on 7 major topics (100 hours of material) could be implemented as 400 learning modules within 20 weeks by one person which also allows a very flexible combination for new target audiences.

2. Authoring in the large needs massive support for versioning and the creation of variants (e.g. languages) and domains (e.g. different business units) to support a larger set of content topics. The standardization of processes and models support enabled through the structuring support tools is important but also requires support from the underlying web content repositories that store the content and structures. The current implementation is sufficient for standard hierarchical file systems are for small amounts of data (no size but complexity). L3 requires an authoring environment with the capabilities of large document or software engineering systems.

3. The usability tests have proven that a structuring and meta tagging tool like the Instructional design Editor that users have experience with CAD systems or other complex media editors. It is for advanced users not the casual user. Problems encountered included:
   - Lack of automated conformance checks,
   - Lack of Templates

These issues need to be addressed in order to increase the productivity regarding e-learning material generation. The current user base is chosen from five content companies inside the L3 consortia as well as a set of 10 associated partners using the tools. A whole set of courses ranging from basic language instruction to MS-office products have been created.

**Learning**

First course modules have been delivered to the L3-Service network as a set of first self-paced courses at various centers for vocational training in Germany. Typically most of the learners use self-paced e-learning material for the first time during their vocational education period. The groups first required IT-competencies concerning use of networked multimedia PCs. People took advantage of the available courses and started using their spare time after the official learning hours at the learning centers where they were supported by on-line tutors as well as on-site tutors. The first feedback has shown that about 85% of the students would like to have more courses available and would spending more time in addition to standard classroom hours. Many students (90%) used e-learning for their first time and their feedback is very encouraging as only 5% do not see any advantage in taking courses in the e-learning environment. The browser interface is widely accepted and the personalization is seen as a competitive advantage compared to existing systems.

As more classes will start their work after this paper is finished during the fall season, more feedback is expected next year. The results will be split according to the subject matter, the student level, and overall performance of the service network( The current work load does not generate enough traffic to stress the Virtual Private Network infrastructure used). As the current evaluation did not make significant use of IPoCs and SpoCs, feedback on the
tight integration of collaborative scenarios into the e-learning courses is expected in future work.

5) Future work
With e-learning as an alternative and complementary medium of teaching, new technologies to support the learning process any time and any place at a reasonable price are expected. The major work required includes:

1. Authoring support for large organizations,
2. Simulation frameworks
3. Access devices
4. Business Models for sustaining learning infrastructures and services for all countries

Authoring Support
As large international corporations and national organizations have a need to produce large amounts of e-learning material, a specific emphasis on large-scale authoring is needed. Besides courseware engineering support such as version and variant management, appropriate standardization efforts, cultural context, languages and business context need to be developed and will require a large team of instructional designers, media specialist and domain experts that can create and release high quality e-learning material. The current results from the usage of L3 tools show that capturing the relevant metadata is a good step but needs to be well integrated into an overall engineering process to ensure high quality results. As in other disciplines such as software engineering and civil engineering only a transparent and standardized approach to create complex systems will allow organizations to build on previous results and experience. The creation process is typically distributed among teams of specialists and requires research concerning the limiting factors involved in the creating of e-learning material.

Simulation Frameworks
As self-paced training needs a high rate of interactivity with the e-learning environment, the usage of simulation and the animation of complex scenarios is a key success factor. Today, most specialized systems build simulation environments that provide the necessary interaction, but are very expensive to create.

Strategies that are derived from games focused on real-life business scenarios can actually improve competencies such as soft-skill development. The integration of cooperative scenarios is necessary to engage the learner (one of the reasons for the success of multi-party games over the network). As today’s simulation systems are either highly specialized or expensive to build, the development of a simulation toolkit that can be applied to numerous domains would enhance the current usage.

Learning Appliances
New devices like pocketPCs, PDAs and WebTablets that are wirelessly connected to the Internet will enable a broad use of e-learning material beyond the current usage of desktop environments. The resulting research themes are in the areas of:

- Adaptability of e-learning material to small screens
- Human computer interfaces for learning (replacing mouse and keyboard by pen and voice)
- Networking of these devices for usage in classrooms as well as Wide Area Networks
- Designing of device specific instructional strategies that allow different collaboration scenarios depending on the quality-of-service and human input/output channels available. First results can be found in [Soloway et.al. 2001].

The benefits for the learner will be seen from constant usage as these personal appliances will be present at many situations during the business day being mobile, on travel, at customer sites, on campuses or schools. Another major advantage will rely on the fact that these appliances area less expensive both in cost-of-ownership and initial cost allowing more people to have access.

Business Models
The business models developed inside the L3 project are focusing on a learning service for a national backbone are applicable in a society that is already on a path to make usage of IT infrastructures for value added services. This is true for Europe and North America as well as highly developed countries in Asia Pacific (e.g. Japan, Australia). The mapping of this model to developing countries in Africa, Latin-America and Asia is an important task. The resource and cost-intensive solutions have to transformed into sustainable solutions that can grow with emerging technologies and infrastructures. A first pilot project has been spin-off from the L3-Project to South Africa (Western Cape Region) called DASSIE (DISTRIBUTED ADVANCED STRATEGIC SYSTEM for INDUSTRIAL E-LEARNING) to explore the VPN approach to a...
network of technical colleges to support the vocational education in subjects like electronics and mechatronics. 

A first set or results is expected by end of 2001.

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