

A working paper for EU-funded CELEBRATE-project, delivered May 2003

# Principles, models and examples for designing learning objects (LOs)

## Pedagogical guidelines in CELEBRATE

Liisa Ilomäki (ed.), Tomi Jaakkola, Minna Lakkala, Lassi Nirhamo, Sami Nurmi, Sami Paavola, Marjaana Rahikainen & Erno Lehtinen

Universities of Helsinki and Turku

|   |           |
|---|-----------|
| <b>Introduction</b>   | <b>2</b>  |
| <b>Learning principles</b>                                    | <b>2</b>  |
| Activate prior knowledge                                      | 2         |
| Support conceptual change                                     | 4         |
| Give expert models and guidance                               | 5         |
| Give possibility to face the complexity of the content        | 6         |
| Give multiple representations                                 | 6         |
| Support collaboration that directs to thinking and explaining | 7         |
| Visualisation of thinking                                     | 9         |
| Analogical reasoning  | 9         |
| Skill training  | 11        |
| <b>Principles for creating elaborate knowledge LOs</b>        | <b>12</b> |
| <b>Ideas for implementing pedagogical models in LOs</b>       | <b>15</b> |
| LO for problem-based learning                                 | 15        |
| LO for discovery learning                                     | 17        |
| LO for Progressive Inquiry                                    | 19        |

## **Introduction**

*The goal of this paper is to help designers and producers of LOs to understand and apply the advanced pedagogical principles for designing LOs. WP2 has already produced theoretical foundations for the pedagogical approach (part A, Lehtinen et al., draft and included in the Interim Report). This paper (part B) is a continuum to the theoretical part.*

*A. Pedagogical guidelines, which includes*

- *Pedagogical rationale for the development and use of learning objects,*
- *Three metaphors of learning and expertise*
- *Theoretical explanations of some advanced pedagogical models (problem-based learning, progressive inquiry, discovery learning)*

*B. Principles, models and examples for designing LOs, which includes*

- *Learning principles that could be supported in LOs,*
- *Elaborate knowledge features in LOs, and*
- *Outlining of tool LOs for supporting the pedagogical models.*

## **Learning principles**

The learning principles presented here are based on the ideas of the foundational paper (Erno Lehtinen et a., draft). The aim is to present the most important learning principles, not a complete list of all possible activities that support learning processes.

Learning principles are very close to *the goals of learning*. Learning principles emphasize certain learning activities and these activities support, especially, certain goals. For this reason, applying learning principles in designing LOs means that the learning goals are defined first and then the appropriate principles will be applied.

The aim of presenting the learning principles is to give to the producers hints of features that should be applied in LOs. Note: the aim is not that every principle is used in every LO - this is not even possible. One LO can use one or more of these principles, depending on the aims and the content of the LO.

## **Activate prior knowledge**

There is a considerable unanimity among all modern learning theories that learning is based on previously acquired knowledge and skills. However, learning is not a simple cumulative process in which all the new contents and skill components can be added to the prior ones. The prior knowledge has much more fundamental significance in human

knowledge construction process, because prior knowledge structures and conceptions act actively in many information processing and meaning making processes. For example the previous knowledge structures (mental models, mental presentations) tend to focus human perception and interpretation of perceived information, act on constructing new knowledge structures (or modifying the older ones) and making sense about the world around, as well as impact on procedures of storing on and retrieving from memory. In other words, when new information is provided, learners try to interpret it in the context of their already existing representations (e.g. Vosniadou, 1996; Jonassen et al., 1999).

### **Guidelines to use in designing LOs**

Because the activation of learners' prior knowledge has a significant role in learning of a new content, it's important to bear that in mind in the design of LO. Here are presented some means to activate prior knowledge and some suggestions how these can be applied in the design of LO.

- ***Wake the learner to think what she/he already knows on the content being learned.*** This awakening can be made in the form of questions, which make learners to think about relevant content. These questions should provoke learners' interests in the issues being learned, and therefore the nature of the questions should be thought-provoking, not pre-test like measurement of the level of the learners' prior knowledge
- ***Help the learner to evaluate the limitations of her/his own understanding on the given issue.*** Presenting learners information that challenges their thinking can also activate prior knowledge. In the LOs this information can be provided e.g. in the form of animations, videos, pictures or just plain text, but the main point is that this information must touch on learners thinking. A good way to do this is to present information that is conflicting (but scientifically proofed) to the typical conceptions of learners of that target age/group.
- ***Help to reflect how the issue being learned is connected to the other related issues she/he already knows.*** A good way to achieve this is to anchor the content being learned into problems and contexts that spring directly from learners' everyday experience. When the context of learning is familiar to the learners, it's easier for them to bring up ideas related to learned issues because the cues provided by the LO are acquainted to them. The common thing in all of these means is the importance of waking up the learners' motivation toward learned issues, in addition to activating their thinking.

For example, if we apply these means into understanding the spherical model of the earth for young pupils, we can activate their concrete experiences and prior knowledge by stating the questions like "do you know why sun sets in the evening?" or "can you explain why there are different seasons during a year?". Secondly, pupils can be made to face the limitations of their own thinking by presenting them an animation of e.g. earth's circulation around its own axis and around the sun, which are typically contradictory to the conceptions of children of that age. Thirdly, the whole approach of the LO can be constructed in a way that it guides learners to discover issues being learned by solving problems that are familiar to them. For example, the issues are presented to learners in a

form of challenges like “why it’s colder in Finland in winter than in summer time?” or “why time in Australia is not the same as in Finland?”

## Support conceptual change

In a number of subjects, especially in sciences, the learners’ interpretations of scientific information are often constrained by deeply entrenched presuppositions about the way the world operates. Sometimes these faulty assumptions can hinder the learning of new contents. Due to learners’ misconceptions, it may be difficult for them to understand some new information, because it violates their presuppositions. Often learners try to reconcile the new information with these faulty presuppositions without giving them up (e.g. ignoring, rejecting or excluding the new information) or changing them only partially. Instead of that kind of assimilation, learners need to go through a process of conceptual change in which their presuppositions and beliefs are gradually revised. Conceptual change means that pre-instructional conceptual structures of learners have to be fundamentally restructured and reformulated in order to allow understanding of the intended knowledge, which requires specific stimulation. In order to revise their preconceptions, learners need to become aware of their presuppositions and explanatory frameworks, which affect on their interpretations, that is, to develop their meta-conceptual awareness.

### Guidelines to use in designing LOs

There are number of ways to support the process of conceptual change. Here are presented some means to support conceptual change and some suggestions how these can be applied in the design of LO.

- **Activate learners’ prior knowledge** about the issue at hand. In order to make conceptual change possible in the first hand, the learners need to become aware of their limited interpretations and understanding about new information. This can be accomplished by making them confront some data that disconfirm their current beliefs (e.g. young learners are shown animations that earth rounds the sun, not vice versa). In this way the gaps in their thinking can be shown to them and they can become aware of what they need to learn.
- **Challenge learners’ thinking** by asking questions and/or presenting conflicting data or multiple perspectives. One promising way to produce such confrontation is to present competing predictions of other peers to the learner. In other words, multiple perspectives are presented (instead of a single right one), which then can challenge learner’s thinking.
- **Give learners an opportunity to express themselves and get feedback on their action.** It’s important that learners can express their own ideas on the content being learned, and then compare them to those of others. In the design of LOs or LO packages this can be implemented for example by using tools like mind map, whiteboard, discussion forums or chat. Afterwards learners should be given an opportunity to get a feedback and compare their own products with others’ products or with the sample of example products.

- ***Give learners a chance to interact with the content.*** The stimulation to learn new concepts and reformulate prior ones can be accomplished by using interactive tools (e.g. simulations) with which learners can manipulate abstract concepts, test their own assumptions about them and see the consequences of their own actions.
- ***Present content by using multiple representations and link them together.*** The understanding of content being learned may benefit from using multiple representations and the affordances of hypermedia. By using multiple representations the abstract concepts can be made more concrete and easier to understand (e.g. the same chemical reaction can be presented with chemical formulas, graphs of molecules, animation of that reaction, video of scientist causing this reaction etc.). The concepts and different representations can also be linked together to explicate the interconnection between them.
- ***Provide scaffolding along the process.*** As stated earlier, conceptual change needs scaffolding, which can be provided either by teacher, more advanced peers or even by LO. The main point in scaffolding is that it doesn't give straight answers and solutions to learners, but engages them with thinking and only subtly leads them to the preferred direction. If the scaffolding is included in the design of the LO, it can be made in a form of activating questions or advices to reflect the work done. The implementation of intelligent tutoring system inside the LO is not a realistic option.

## Give expert models and guidance

In a learning process, learners acquire more advanced understanding of the phenomena under study, if they can reflect their performance against an ideal performance, which we can regard as an expert's performance, or even better, of several experts' performance. This works as a model for the learners. Typically a teacher or a textbook has given the model, but they are often too limited, given as a fact, without arguments or explanations about the solution. A model of an expert should be explained and presented so that the learners can find the differences to their own performance and understanding.

Similarly, expert guidance and scaffolding during the learning process provide learners support that enables them to deal with more challenging tasks than they could otherwise handle.

### Guidelines to use in designing LOs

- Show ***how different experts think*** about the topic, e.g. explanations in text, interviews, and texts of historical fragments.
- Give ***expert models*** e.g. in video clips, pictures or voice, in which ***the critical points*** are shown.
- If the LO consists of tasks, show also ***how an expert would solve the task and why***.
- ***Provide support, just-in-time guidance and modeling of appropriate action to the learners (scaffolding)***. Scaffolding can either be provided by a teacher or by

the LO. In the LO the scaffolding can mainly be done in a form of activating questions and summaries, or hints and recommendations, which prompt learners to reflect their own learning and ways of working with the LO. Modeling of appropriate progression can also be made e.g. in a form of tutorial which can show what kind of discovery processes experts do with the experimenting tools (simulation).

## Give possibility to face the complexity of the content

Too often learning contents are presented without the real life's roughness, just as clean models or simplified truths. For learning this is a wrong approach because it doesn't help the learner to recognize the phenomenon in real life and the connection between the model and the phenomenon may not be understood.

Authenticity is a way of facing the complexity of the content. It means that the learning process, content, activities and tools emphasize knowledge and understanding in real life situations. These are typically ill-defined and there are several ways of solving the problem, or several perspectives to think about the problem. It is also essential that the content is not thought too narrow-minded but it combines all necessary domains.

### Guidelines to use in designing LOs

Facing the complexity can be brought in to a LO in several means:

- **Support authentic problems**, which are not ready-made problems, but wide and they offer various approaches to some phenomenon, and represent the information in a way that raises questions
- **Help to understand the complexity of a problem.** Accept several ways of can be defining a problem, and solutions as well as the processes. Help to understand that there are even problems, which cannot be solved.
- **Help to relate the content to other LOs and materials,**
- **Help to relate the learning in the previous work** of the domain, e.g. by saving and reusing former student products
- **Support content and activities that are authentic also to the learner** and close e.g. his/her age, culture and thinking.

## Give multiple representations

Learning often involves the acquisition and use of complex systems of symbolic expressions represented in different media. Appropriate representations are important elements in any learning and construction process, but the problem of relevant external representations is highlighted when complex concepts and skills are the content of learning. Deeper learning in many situations requires the ability to manipulate, connect,

and understand the meaning and interrelationship of different kinds of external representations. However, such skills are difficult to acquire. Students often fail to understand the relationship that exists between symbolic expressions and the situations to which they refer. It is typical that the concrete external representation used by the teacher is considered to be the complete concept. When students are not encouraged to pay attention to the abstract concepts and operations "behind" the concrete facts and algorithmic routines, they try to learn the subject matter by imitation and memorization of the mechanical procedures and symbolic expressions.

By providing multiple representations of the same phenomena in different contexts and externalizing the relationships between different models we can facilitate students' thinking. Computers can be very helpful in this, since technological representational tools can help the students to externalize their idiosyncratic and informal hypothesis and to compare this hypothesis with scientific concepts and culturally shared definitions.

### **Guidelines to use in designing LOs**

- ***Simultaneous representations of the same phenomena in multiple formats:*** Text, digital video, images, or immersive virtual realities, etc. differ from one another. They all have representational properties that are more suitable in one context than in other. By simultaneously using many Medias, one can better clarify the properties of a phenomenon. Different Medias thus complement one another.
- ***Externalize the informal representations.*** Link graphs and symbolic representations to the qualitative representations formed by experts, as well as literal aspects of the situation to which they refer. E.g. chemical equations and graphs of chemical changes are represented simultaneously with animations of the reaction at the molecular level. This facilitates understanding of abstract concepts by integrating them with a visual representation of a normally invisible process.
- ***Top-down and bottom-up representations:*** Novices are frequently constrained by the surface features of the problem and fail to see/understand the relevant conceptual deep structure. To address this issue we should make explicit how structural dimensions of knowledge (i.e., abstract domain concepts) apply in various case or problem context. Furthermore, we should also provide multiple cases, which work under the same rules. With these inter-case hyperlinks we can connect the surface features of a case or problem with the conceptual deep structure represented by the abstract domain concepts.

### **Support collaboration that directs to thinking and explaining**

Cognitive research indicates that advancement of learning can be substantially elicited by relying on socially distributed cognitive resources, emerging through social interaction between the learners, and collaborative efforts to advance shared understanding. In a shared problem-solving process, agents who have partial but different information about

the problem in question appear both to improve their understanding through social interaction. Through social interaction, contradictions, inconsistencies, and limitations of students' explanations become available because it forces them to perceive conceptualisations from different points of view. Deep conceptual understanding is also fostered through explaining a problem to other inquirers. In order to explain one's view to his or her peers, an individual student has to commit himself or herself cognitively to some ideas, explicate his or her beliefs, as well as organize and reorganize his or her knowledge.

A challenge in developing virtual learning objects and tools is to develop tools that help a partially or completely virtual community, or people working asynchronously, to manage their collaborative activities, and utilize knowledge and other things produced by their fellow students. The tools may involve shared active representations and dynamic visualizations that allow the participants to interact through various modalities, such as visual or conceptual communication.

A crucial aspect of collaborative learning is to guide students to pose questions or problems that direct their work. It appears that themes and questions that arise from students' own interests have a special value in collaborative learning. By encouraging students to systematically create and build together their explanations for problems being investigated, the participants can be guided to trust their own voices rather than merely rely on the teacher's cognitive authority. A critical condition for progress in collaborative work is that the teacher deliberately guides students in improving their conceptions by evaluating each other's productions and building on shared knowledge base.

### **Guidelines to use in designing LOs**

- One collaborative learning object can be *a meaningful, asynchronous discourse tool* (knowledge building area) that has built-in supports. The support can be, for instance, in the form of guiding learners to categorize their computer entries (posting to the database on learning environment in question) according to essential aspects of work ('thinking types', Scardamalia & Bereiter, 1991). The discourse tool can also include templates, examples or instructions for labeling the postings or organizing the collaborative process, such as: What I still need to know? Can I explain what I mean with this?
- A collaborative learning object, for building knowledge together or for fostering social awareness and community feeling, can also be *a synchronous tool*: chat function, writing template, graphical tool or "white board" that makes it possible for a group of students to author or edit collaboratively the same shared artefact at the same time.
- Even though there is no collaborative tools or functions in LO, *the learning tasks, and the recommendations for carrying them out*, can be designed to encourage, and even require collaborative effort of a group of learners, such as a joint research task or a school journal.

## Visualisation of thinking

Students often face difficulties in monitoring their own learning processes. They find it difficult to remember or distinguish between different phases of their work (reasoning), which then causes problems in correcting their reasoning when they, for example, fail to complete a task in a desired manner. Students also find it often hard to keep more than one complex hypothesis activated at the time. By providing appropriate visualisation tools we can diminish these problems. Concept maps, modelling of the process, advanced visualisation & design tools are typically tools that help to visualize thinking processes. For example, a graphical (e.g. tree-like) representation can work as a cognitive map for a user to explore the steps of her/his reasoning process more easily, and allow her/him to navigate back and forth, whenever needed, without disturbing the actual problem solving process. The graphical representation projected on the student screen can also serve as a shared point of reference, which can help a group of students to better focus on the task in hand. It can also help teacher to monitor, and more adequately support students' problem solving.

### Guidelines to use in designing LOs

- **Provide tools (LOs) which record every action** (e.g. decision) **made by a student and represent that action graphically** (e.g. tree-like concept map).
- The tool could also include a feature for **student notes**, etc., which can make student's thinking even more visible.
- **Work of individual student should be made accessible for everyone**: monitoring of the progress made by others helps students to evaluate her/his own work.
- The tool should also **allow commenting** of the different phases of each other's work.
- **Track the changes feature** – the tool could also be organized in such a manner that the same representation would, simultaneously, show the work (modifications) of different participants (individuals or/and groups) on the same task (e.g. object).

## Analogical reasoning

Solving of complex problems and making sound decisions are difficult processes for each of us. Studies of problem solving reveal that people often don't retrieve their relevant knowledge at appropriate times (Bassok, 1990; Gentner & Landers, 1985). And furthermore, even if one can retrieve appropriate knowledge from memory there may be obstacles in implementing this knowledge in novel-appearing problems and situations (Thompson et al., 2000). Thus having solved one problem does not offer much help in solving an analogous problem when the two problems come from very different contexts (Reeves & Weisberg, 1994). One of the biggest problems in knowledge transfer is that people tend to access previous knowledge that bears surface, rather than structural, similarity to the problem at hand (Thompson et al., 2000). Often these surface features of

the problem are constraining and can prevent to recognize relevant conceptual deep structure (Chi et al., 1988).

How we can facilitate knowledge transfer, which is based on the structural, not superficial, similarities between different problems? The answer is to encourage analogical reasoning, that is, to draw a comparison between two or more problem situations. If successful analogical transfer relies on perceived similarities between current problem and stored experiences, perhaps the abstraction of general principles during learning can form the basis for a perception of similarities in new problem situations involving the same principles (Forbus et al., 1995). People seem to draw such abstractions readily when explicitly asked to compare. However, often this kind of comparison does not occur automatically, and the encouragement to compare is important (Thompson et al., 2000). The abstraction of common structures can be achieved by focusing on shared aspects between example problems with different surface features. After constructing abstractions of common structures of example problems, these abstractions can be used, retrieved and applied in future. Furthermore, this kind of analogical comparison can inform students which aspects of the problem are relevant and which are not.

### **Guidelines to use in designing LOs**

Support for analogical reasoning is based on example problems/contexts, which are authentic-like and relevant to the learners. Therefore, the used examples of problems are very important in designing of LO, and those should be presented in motivating way to the learners. The most important guidelines to support analogical reasoning in the designing of LO are as follows:

- ***Present several examples of problems situations/contexts to the learners***, which have a) same deep structure and surface features, b) same deep structure, but different surface structures, c) different deep structure, but same surface features, and d) different deep structure and surface features. This can be done for example with animations or video clips presenting different problems to the learners (e.g. If we take an example from chemistry, learners can discover molecular changes in chemical reactions (evaporation, melting etc.) with different materials. At the surface level, all the materials behave generally in the same way when heated, but e.g. the boiling point differs between different materials).
- ***Facilitate the comparison by asking explicitly the learners to compare the examples***. Very effective mean is to present questions, which requires the learners to compare previously represented examples (e.g. do the molecular structures of example matters differ (and in what way), are the molecular changes different etc.). Comparison can also be facilitated by pointing out some interesting differences or similarities to learners, which they barely see without prompting (e.g. note that this matter has one extra carbon atom here etc.).
- ***Encourage the learners to find out similarities and differences between different examples***. This can also be made in a form of questions, which especially require finding similarities and differences (e.g. in what way these matters are different from each others etc.)

- ***Highlight the relevant deep structure of example problems.*** Using the visualization power of modern technology important aspects of examples can be highlighted. Relevant features of example problems can be emphasized visually (e.g. pointing with an arrow on some important actions in molecular changes) or verbally (e.g. explaining in a narrative way what is going on in the example chemical process). All the time it is important that example problems are compared with each other.
- ***Facilitate the ownership of working,*** that is, to give the learners an opportunity to solve the problem also by themselves with their own methods. There should be tools available with which learners can make their own discoveries and experimentations with example problems. Especially highly interactive simulations can be appropriate means for students-led discoveries.

## Skill training

A skill is defined as learned ability of associating an optimal action with the task process state or its characteristics. Skill training is based on repetition and re-enforcement that fosters the adaptation of a new skill or enables and improves specific task performance. In practice, exercises (drills) that perform skill training are very condition and action specific. They usually contain only simple IF-THEN logic rules that make them easy to implement.

Although contemporary learning research doesn't favor the idea of skill training, there are still many domains, in which fundamental skills are critical to acquire before more advanced activities can occur. Further, there are certainly basic skills that can be trained very easily and efficiently with computers. Foreign language vocabulary, arithmetic facts, reading and basic calculations are obvious examples.

### Guidelines to use in designing LOs

- A drill should ***focus on one or two well-defined skills*** rather than on several simultaneously.
- A drill should ***produce immediate, easy and brief responses*** on user actions.
- A drill should ***provide feedback regarding user's performance.***
- A drill should ***remedy those skills that user do not perform well.***
- The ***user should be able to change*** the difficulty level / complexity and presentation speed of ***the drill items.***

## ***Principles for creating elaborate knowledge LOs***

One important characteristic of learning objects is the conception of knowledge that they reflect. LOs present knowledge differently but what kind of characteristics belongs to advanced LOs when different conceptions of knowledge are taken into account? Knowledge can be presented (often implicitly) as immovable truth without history or development (“dualistic” right-or-wrong conception of knowledge), but it can also reflect and instigate expert-like activity with knowledge (trigger students to develop knowledge, to compare various perspectives, to weigh evidence, to defend your own viewpoint, etc.) Facts are important but how to bring forth facts and at the same time activate more advanced conceptions of knowledge?

We have collected various (and partly overlapping) *features that represent more advanced conceptions of knowledge* (cf. also Learning Principles above and the Art-LO example):

Theoretical thinking, interaction between various forms of knowledge

1. Activating *theoretical thinking* in relationship to facts and observations; phenomena but also those deeper (theoretical) principles that are *behind* these *phenomena*; theoretical principles but also those factual and conceptual puzzles why they are needed; why-questions especially important, what-questions not enough
2. *Interaction and relationship between various kinds of information* (e.g. theoretical knowledge vs./and observational knowledge; authentic richness of material vs./and conceptualizations of this material; theoretical knowledge vs./and practices, research questions in the field vs./and various answers)

The meaning of questions and problems

3. *Problematized knowledge*: e.g. that which is not yet known (but could be known) to the fore, i.e. interesting but open questions
4. *What are those questions and problems to which theories or conceptions in question are answers* (e.g. how these questions have arisen historically; what are those questions that need to be answered with this material or with these theories and explanations)

Authenticity of knowledge

5. *Authentic knowledge* (authentic material, sources of knowledge to the fore, wealth of material)
6. *Contextual features* of some particular knowledge; e.g. metaknowledge about sources of knowledge: who have produced this knowledge, for which purposes, when etc.
7. *Complicated nature of knowledge* to the fore; how various things are related to each other; how various conceptions can compete with each other

Various perspectives to the fore

8. Same theme or problem from *different perspectives*; presenting even contradictory conceptions with each other
9. How *various schools of thought* have understood, and can understand and interpret same things differently

Material and room for own judgment

10. Activating *comparison and weighing of evidence*
11. *Information, but also evidence* for this information; to make clear what is the evidence for statements and assertions (and to leave the opportunity to interpret the situations and evidence perhaps differently)
12. *Activating own judgment* and work concerning knowledge; long-term development of ideas starting from student's own interests

### **How to apply these principles for supporting elaborate knowledge in designing LOs?**

There are several alternatives, which all are useful and dependent on the content and on the aims:

- a) Writing the text so that it as such reflects the characteristics above. The text can then include e.g. real examples (5), contradictory views (8), and questions that are not known about the phenomenon (3). These might also be presented in hypertext links.
- b) Separate LOs or elements that include various characteristics presented above. E.g. an independent element can be metatext about the explanations, simulations, or other elements (6) or rivaling theories (9).
- c) The characteristics can be presented by using different media elements at the same time, e.g. by giving authentic observations of some phenomena with video clips and comparing that information to theoretical knowledge of the same area.
- d) The characteristics can be built into tools that are supposed to be used when the material is processed, so that the learners use special tools that provide opportunities for more advanced conceptions of knowledge, e.g. simply to write down their own thoughts about the content (and these are then encouraged to share collaboratively) (12), or the tool that supports the creation of own explanations and theory-building (1)
- e) The LOs can also simulate authentic, real life material, situations, activities, and tools as much as possible. The visual outlook can e.g. support the content, or the tools used can be similar to tools used of experts in real life.

The aim is *to present the content = the phenomenon as "rough" as it really is* instead of cleaning it to a pure model or headlines, as typically many LOs and school books do but at the same time providing scaffolding and help for central problems and information about the phenomenon in question.

## **An imaginary example: application of knowledge principles to the ART-LO (or actually a package of LOs)**

(Presented in Nancy in Feb. 2003)

First is the original text describing the LO with font 10, then numbering with italic, referring to the text above (*features that represent more advanced conceptions of knowledge*), within parentheses.

### 1) Theories of colors in art

Some main theories (e.g. Albers, Goethe) of colors and their interaction (9). Explanation about the differences of the theories, (8) although the explanations and hands on –activities could concentrate on supporting and practicing one of the different theories. Histories of the theories (narrative stories) (4).

Very important: hands on –activities with the basic exercises (like same color, different backgrounds, different backgrounds and try to choose a color that looks same, organise colors based on their density, try to do transparent (to both directions) of two cubics of different colors. (There are plenty of such exercises to study "color", and they are rather easy to present and practice on screen.) (1,2)

The exercises should be organised according to the content they are about (and thus presenting both one structure and an expert's view of the topic and the reason, why the exercise is chosen). Every exercise should have also a written explanation: what does this exercise show about colors, how can you find the critical point of the exercise [e.g. when do different colors have the same brightness], etc. (11,1)

### 2) Colors in different art periods and artists' works

History of the color ingredients within different techniques. (8)

Some examples of important changes and milestones of understanding and using colors in art history (e.g. impressionists' deep change in how they comprehended light and color) (8)

Some examples of important artists' usage of colors (color periods, like in Picasso's work) (5)

### 3) Color as a biological phenomenon

Theory (theories) about how a human being receives the light in the eye and how the perception is sensed. Anomalies of the normal sense. (8, 4)

The development of the theory; rival theories. Histories of the theories (narrative stories). (8, 4)

Differences between a human being and some animal examples. (1)

This should be presented in pictures and videos and a student should be able to compare e.g. the picture seen by the examples.

### 4) Color as a physical phenomenon

Theory (theories) how colors are constructed from the physical point of view. (8, 4) Not too complicated, integrated into science curriculum. Hands on –activities so that a student can change parameters (e.g. light) to see how these changes affect in the colors. The hands on –activities should include a precise written explanation, too, so that the students know what happens. (1)

### 5) Content-specific guidance

A template of recommendations and hints that explains how the various parts of the content, views and exercises relate to the each other and to the topic (Colors in art). The template could also give guidance for the users (both teachers and students) about links relating to the topic. (6)

## ***Ideas for implementing pedagogical models in LOs***

The main idea in this report is that the content-specific LOs can be used in various combinations, contexts, and pedagogical approaches. When using LOs in the classroom, it is usually teachers' responsibility to organise the learning environment and scaffold students' activity and learning. But it is also possible, and helpful for both teachers and students, to offer ready-made material for managing and structuring the learning and working process according to the more advanced pedagogical approaches and learning scenarios. This kind of pedagogical support can be offered in the form of separate, "content-independent" LOs, representing the basic principles and structures of a pedagogical model. These LOs can be called "pedagogical tools". They can be compared to, e.g., project-management tools and templates, that support actualisation of different kind of projects in working teams.

In the first part of the pedagogical guidelines we presented three concrete models (problem-based learning, discovery learning, and progressive inquiry) that support the new pedagogical approaches. These are just examples, there are several others, too. In this section we have shortly outlined possibilities for such kinds of LOs.

Such a *pedagogical tool LO* should include meta-knowledge of the basic principles, steps or phases of the process, and cognitive guidelines, hints and checklists for actualising them. Each phase should be "meta-explained" by telling what to do, why to do it, and how to do it. The LO includes also tools or empty templates for carrying out the processes by writing, drawing, designing, etc. The template might be, for instance, an "empty" formula to be filled with students' own writing, including main parts of the process with explanations. The meta-knowledge explanations of each element should be easily available for the students when using the template, but not disturbing. The templates can include such functions as writing, making notes and bookmarks, sending and receiving messages, sharing ideas in collective forums, or tools for information search. The tools used in the templates should be common applications, if possible, instead of developing special, un-standardised applications just for the LO.

The LO should also include theoretical knowledge (written in appropriate level) of the pedagogical model itself, its goals and implications for learning, to add students' metalevel understanding of the learning and working process.

### **LO for problem-based learning**

Theoretical background of the model in general, and list of useful references are presented in Theoretical foundations for the pedagogical approach (part A).

A LO that aims to support problem-based learning can be either a LO that is related into a defined content or a LO that supports the process of problem-solving. LOs that are related into a content should have similar features as content directed LOs for discovery learning or inquiry learning, e.g. LOs that present the content from multiple perspectives or provide possibilities for exploring. These LOs are then used in one or more steps of the problem-solving process.

A LO that supports the process are tool-like applications. As a simple one, it can be just an empty template with the steps, and the learner group uses the template as a model for guiding their work. The template gives the structure for the learning process. Then the teacher defines the context and creates the larger problem entities or helps the students to formulate the problem environment, helps to find information for the process, and provides the study group with tutoring and content-related scaffolding. The application might give common guidance about what to do in each step.

Essential is a clear structure of the problem-solving. The steps should be guided well, e.g. by additional help of each step (*e.g. what is essential in this step, how to do it; with help to evaluate the results of the steps*). Each step would need a collaborative writing space for developing ideas, commenting, and arguing. It should be possible to save these texts and use them for the next steps.

A structural template and the situated process guidance for the problem-solving process could be as the following:

1) Clarify the terms and concepts

*Guidance: Pick all the terms and concepts used in the problem description and explain them. If there are terms or concepts that you don't know find information about them. Be sure that you understand the overall context.*

2) Define the problem

*Guidance: Think about the problems from multiple perspectives. What is the real problem, which are minor problems or reasons? Define the problem in a concrete way so that you can find solutions to it.*

3) Analyze the problem, produce possible explanations and hypotheses

*Guidance: Find answers to your problems, even odd ones. Don't start to criticize them too early. Make a decision, which ones to use as hypotheses. Write down the arguments for choosing one and leave the others. Remember, you might need to come back to hypotheses during the later phases.*

4) Summarise

*Guidance: Make clear the all in your study group recognize the problem, your previous understanding about it and the hypotheses you try to testify.*

5) Formulate learning objectives

*Guidance: Define what you need to know to solve your problem and testify your hypotheses. Write them down in a concrete way, so that these form clear learning objectives, which can be used to set concrete tasks for each member of the group.*

6) Self study based on the objectives. Acquire the knowledge needed.

*Guidance: use your previous understanding and find out the information needed.*

*Remember that you might need to read much about the topic because there are only seldom a clear answer to the questions. You might find contradictory information and you have to make the conclusions by your self. Make good notes!*

7) Report back to the group discussion, evaluate the essence of the knowledge.

*Guidance: It is important to share the knowledge acquired by the members and discuss about its relevance for the question. If needed, continue the knowledge acquisition.*

## LO for discovery learning

Theoretical background of the model in general, and list of useful references are presented in Theoretical foundations for the pedagogical approach (part A).

LOs can be one way to provide support in the process of discovery, in addition to their usefulness for supporting the development of domain knowledge. Therefore, a possible LOs used in discovery learning can be either a LO that supports a specific content or a LO that supports different processes of discovery learning.

LOs that support a specific domain are such as individual simulations, demonstrations, or other virtual material describing some specific content-related issues (e.g., scientific phenomena or mechanism of a law of nature), providing base for experiments, etc. The most important aspect is that learners can explore the domain/problem in question in authentic and concrete way (e.g., they can try out variables). Another important point is that learners should be provided with multiple representation of the phenomenon in question. There should be different ways to present the phenomenon to learners, so that they can choose from or find different angles to look at it.

*LOs that support the processes of discovery:* This category of LOs includes tools that give specific support and scaffolding for different processes that learners are supposed to be involved while conducting discovery learning, or help learners to organize their discovery processes, such as, planning or evaluation, and general regulation processes. The processes of discovery form the structure of the tools: there can be different templates for different processes. Templates should be flexibly accessible from one to the other. The tools should also enable the integration of the processes, so that learners can save their whole process of discovery (e.g., which tools they used during the process). This integration part should also include some visual representation, as well as textual information about discovery learning. For instance, different processes and their relation to each other could be drawn into a graph, and by clicking the different parts (= processes), learners could get more specific information about this particular phase.

In the following, the support and scaffolding tools are described according to the different processes.

### *1. Orientation*

During the orientation process, learners build their first ideas of the domain and the learning environment. There should be available introductory and/or background information, or www-links to the phenomenon. In a tool, there could be questions to guide the learners with exploring the domain, and relating their prior knowledge about the domain:

- What do you know about this domain/ problem (beforehand)? What you don't know?
- What are the variables in the given problem?

The LO should contain structures where learners can collect and write down information that they gathered, and questions that were raised during this process.

### *2. Hypothesis generation*

In the hypothesis generation process, learners start formulating their first hypotheses about the problems and questions of the domain.

In a tool, there should be a template that has hints and instructions about how to create a hypothesis, as well as guiding questions, such as:

- What is the relation (between the variables) that you are trying to investigate?
- Why did you create this hypothesis?

It should be possible to make a reference to the information that was generated during the Orientation phase. Based on the outcomes of the Orientation phase, learners can start building a more structured description of knowledge that they have and do not have about the domain.

### *3. Hypothesis testing*

This part should include template to test the hypothesis generated by learners. When learners are going to test hypotheses, they need to decide on the set-up of these experiments; which variables to change, how they are changed, how many experiments they will need, what will be measured, etc. LOs for hypothesis testing should contain a practical reference guide with formal descriptions and heuristics about setting up experiments, to inspire learners to make sensible choices.

### *4. Conclusion*

During the conclusion process the learner should review the hypothesis in the light of the evidence that was generated in the hypothesis testing process. The learner should decide whether the evidence is in line with predictions derived from the hypothesis, or identify discrepancies between evidence and predictions. This may lead to revision of hypotheses and/or the generation of new ones. A LO that supports this phase, should help the learners to make these decisions.

### 5. Regulation: Planning, Monitoring, and Evaluation

The overall processes of discovery should be made visible, by having a place where learners can monitor their process during the discovery learning. This could be done with a graphical representation that contains the other processes, and possible transitions between the processes. The graphical presentation should clarify that the process is not necessarily sequential, and how planning, monitoring and evaluation play an essential role in progressing towards a goal. This should be done for the overall process, as well as for the sub-processes. Each of the above mentioned LOs should make these processes explicit to the learner.

## LO for Progressive Inquiry

Theoretical background of the model in general, and list of useful references are presented in Theoretical foundations for the pedagogical approach (part A).

It is difficult to define a type of *content LO*, for studying a certain content, which especially supports progressive inquiry because many kinds of LOs are useful, depending on the elements of the process. Probably a very good LO is such, which is designed according to the ideas of Principles for creating elaborate knowledge LOs. The LO is then a source for information. The learners can explore the domain/problem in question from several points of views, provided with multiple representation of the phenomenon in question. Just as in Problem-based learning and in Discovery learning, there should be different ways to present the phenomenon to learners that they can choose from or find different angles or levels to look at it.

A *tool LO* that support the processes of progressive inquiry, should give specific support and scaffolding for processes that learners are supposed to be involved while conducting progressive inquiry. The elements of progressive inquiry form the structure of the tools: there can be different templates for different elements.

An overall framework can be presented as, e.g., a structured text template or report formula that a student/students can use when progressing in their inquiry and constructing knowledge. The template should include the following elements: *Creating the Context, Setting up research questions, Constructing working theories, Critical evaluation, Searching deepening knowledge, Generating subordinate questions, and Developing new working theories*. In addition, progressive inquiry is supposed to be a collaborative process; therefore, tools that explicitly enable collaborative sharing of knowledge and ideas, are valuable in supporting *Distributed expertise*.

The general framework should include hypertext links to the metalevel explanations and guidelines of each element. There can be separate guidelines for teachers (how to organize the process and support students in each phase), and for students (what to do in each phase and why).

Following are some examples of possible guidelines and hints for students in a LO that supports progressive inquiry:

*Guidelines for the phase “Setting up research questions”:*

In this phase you generate problems and questions to direct the inquiry. The main goal in learning is to understand and explain in deeper level the phenomena under study. Studying is a problem solving process, and large initial questions get more defined in the process. By formulating the main questions you set up the goals for your inquiry and study. It helps you to focus the inquiry on those issues that are problematic and difficult to understand.

- What is it that you wonder in the issue under study? What you don't understand?
- Don't ask “easy” questions which can be answered by simple factual information (Who?, When?, How many? etc.), but don't help in understanding. Instead, make “explanation-seeking” questions (Why?, How?, etc.), which are challenging to answer but advance your understanding.
- Write down your wonderings in the form of a question.

*Guidelines for the phase “Constructing working theories”:*

It is important to define your own explanations or hypotheses of the issue you are wondering, based on your own background knowledge, before you use external information sources for seeking answers to your questions. The purpose is to make gaps in your own knowledge and understanding more explicit.

- Write down/draw/design your own conception or answer to the main questions, based on your current understanding.
- The working theory can be a single idea or a guess; it does not have to be a complete theory. Don't hesitate to explicate also uncertain or vague conceptions.
- Explain also the justifications for you opinion.
- Modify your explanation or working theory in the way that also others understand what you mean.

Other elements and phases of progressive inquiry should be supported, similarly, in a template or framework. There could also be links to other sources that are helpful in different elements; for instance, links to information search engines, to guidelines for writing a research report, or guidelines to use references.