On Learner Control in e-Learning

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ABSTRACT

Learner control became a crucial issue for the utilization and (re-)development of e-learning environments. Learners should be able to control the selection and presentation of content, as well as the transfer process itself, according to their needs, learning styles, and preferences. We revisited two e-learning developments, both strengthening learner self-control, but developed on different grounds and following different development paradigms. Scholion implemented learner self-control in a bottom-up approach putting learner needs and preferences upfront. Lab@Future transformed key characteristics of a pedagogical theory into learner tasks and a process to support learning in a top-down approach. Field studies of both approaches revealed several types of learner control to be supportive for self-managed learning processes.

Keywords

e-Learning, controllability, knowledge transfer, self-management.

INTRODUCTION

Learner control became a significant design issues in knowledge-transfer settings and e-learning systems. Inputs to the design and evaluation of those systems stem from different disciplines, among them major areas such as educational psychology, occupational psychology, usability engineering, and knowledge management. It is generally acknowledged that learning should be triggered by the self-managed handling of interactive content (cf. Issing & Klimsa, 2002). Learners should be able to control the selection and presentation of tasks or content, as well as the transfer process, according to their needs and preferences.

Maria Montessori (1991) developed a variety of learner-driven concepts. She assigned the responsibility for the individual acquisition of knowledge to the learner. His/her role is to handle material according to inherent properties of the content it is representing, supported by affirmative teacher inputs. Ideally, the material in a prepared learning environment guides the learner to domain-specific properties and tasks that can be accomplished in a self-managed way. Learning occurs through manipulating didactically prepared elements of the learning environment.

Such an understanding of knowledge creation is in line with theories from socio-cultural learning. According to Engeström's Activity Theory (1987, 1994), learning is considered as an on-going process of questioning, discovery, and changing oneself and the world. Learning, that leads to high quality knowledge, the independent mastery of the subject matter and the ability to apply it in flexible new situations, must undergo an integral learning process. Davydov (1988) formulated the theory of investigative learning supporting long-term, complex learning activities. He considered learning to occur along six phases: motivation, orientation, internalization, externalization, critiquing and controlling. In such an active learning process, the learner is an investigator looking for a broadly applicable and functioning explanatory model of the phenomena (problem) being studied. He/she puts this model into practice, reflects, and re-engineers it.

In our research we focus on developments that support learner self-control. This paper deals with self-managed knowledge transfer and learning processes, as they can either be designed in a bottom-up and top-down fashion. As we will show learner self-control can be established by

(i) technology development providing specific features;

(ii) development of specific learning tasks, prompting students for active learning;

(iii) assisting investigative learning processes.

The revisited bottom-up approach (Scholion) let user self-control emerge through a variety of features. Those features were developed to explore didactically-structured information spaces in a transparent and self-guided way. The top-down approach (Lab@Future) implemented action- and problem-oriented learning based on specifically designed tasks, i.e. user control in its most rigorous way.

Scholion allows coupling didactically structured content directly to entries in asynchronous and synchronous communication features (cf. Auinger & Stary, 2005; www.mobilearn.at). Learning subjects are presented to learners in a domain-grounded way, e.g., denoting mathematical definitions in a dedicated way through displayed meta-data. Those content elements can be part of communicative acts among all involved parties. As our empirical results in the fields accounting, electrical engineering, and computer science (eBuKoLab.jku.at; elie.ce.jku.at) revealed, epistemological and personal connections can be set up through the context-sensitive embodiment of learning material in virtual social settings (Auinger et al., 2003; 2004).

Lab@Future (i.e. the revisited top-down approach) supported synchronous, collaborative action-oriented learning such as real-problem solving, exploratory learning and interdisciplinary learning. It was based on concepts from activity theory and the theory of expansive learning (Engeström, 1987, Engeström, 1994, Mwanza & Engeström, 2004). Its implementation in form of concrete learning tasks in four different domains (pneumatics, geometry, history and environmental awareness) provided a variety of instantiations of learner control. The respective evaluation studies provided deep insights into learner-controlled processes of knowledge transfer (Totter & Grote, 2004). Each of the six phases of the investigative learning process showed unique control patterns of the participants.

Both, bottom-up as well as top-down design of e-learning environments might embody learner self-control to trigger transfer and acquisition activities effectively. In the following we present both approaches from the concept-development and field-test perspective. For each approach characteristic items of learner self-control were identified. They are summarized in our conclusions and put into the context of the respective design approach.

BOTTOM-UP DESIGN

Scholion – Concept Developments

From experiments with constructionist approaches we know 'the process of constructional design is not a simple matter of "programming in" the right type of connections' (Resnick et al., 1996; p. 49), since student behavior is not predictable by developers. 'Developers of design-oriented learning environments need to adopt a relaxed sense of "control" ' (ibid) in the sense of creating "spaces" for *possible* activities and experiences rather than limiting the interaction space. However, developers have to make those spaces dense with personal and epistemological connections. Then, there will be transfer regions, both appealing and intellectually interesting, as demanded by Norman & Spohrer (1996).

Ideally, the developers' task is oriented towards the constructivist learning pedagogy: Designers 'write simple rules for individual objects, then observe the large-scale patterns that emerge. Users do not program the patterns directly; so too with instructional design. Developers of design-oriented learning environments cannot "program" learning experience directly. The challenge, instead, is to create frameworks from which strong connections – and rich learning experiences – are likely to emerge.'

In such frameworks contextual information of learning (situations) has to be kept transparent in the course of knowledge transfer (cf. Kienle & Herrmann, 2002). One way to establish context is to structure material for interactive use and connect it to communication and collaboration facilities. In the Scholion project (Auinger & Stary, 2005) the data model was enriched with information about the state of affairs on particular elements of the material. For instance, an explanatory remark of the coach for the learners was directly linked to both, frequently asked questions, and the term that was defined in the material. The state of affairs might either concern the stage of knowledge transfer, or the level of learning, or the state of discussing. The individual access to materials and additional information, such as links to fundamental papers, as well as commonly shared information and communication spaces, such as the discussion board, were integral part of the virtual learning environment.

The material itself contained meta-structures, such as proposed by the Global Learning Consortium (http://www.imsproject.org). In Scholion, not only domain knowledge was captured, but also annotations, e.g., personal links, and communication data, such as entries in a discussion forum. In this way, the interaction can be directed to emerging patterns of collaboration and knowledge transfer. As Duval et al. (2001) remarks 'producing rich digital learning resources may require a multidisciplinary team with a background in pedagogy, graphical design, computer programming, and other disciplines. Moreover, the integration of digital learning support with more traditional paper-based material and face-to-face lectures in a pedagogically sound way is not straightforward.' (p.73)

In Scholion learners were engaged in individual and collaborative knowledge transfer and learning processes, bound to content, navigation, presentation, and their peer group respectively. In this way, they were able to establish personal and epistemological connections. Scardamalia & Bereiter (1993; p. 37) term processing knowledge this way second-order knowledge processing, since it focuses on understanding and fostering knowledge building, rather than on storing and displaying knowledge. The latter is termed first order knowledge processing. Self-organized and –managed learning gives way to intentional learning. Here the acquisition and exploration process is under total control of the learner: 'Intentional learning is how learners of varying ability choose to empower and transform themselves by making wise decisions, setting goals, and using strategies and processes to ensure learning' (Martinez, 1997; p. 174).

In order to guide learners to this challenging stage of learning ability, mixed-initiative learning, as suggested by Lester et al. (1999) helps to bridge the gap between totally supervised and totally unsupervised procedures of knowledge transfer. In Scholion an attempt towards that scenario was made: the content was accessible via its domain structure (e.g., in mathematics definition, examples, lemma, proof, and summary). The learners were able to navigate according to those structures and enrich the content with personal (or public) annotations (cf. Fürlinger et al., 2004), including communication entries in asynchronous and synchronous communication tools. The context remained visible to facilitate transfer processes.

Figure 1 summarizes the bottom-up developments. Scholion was based on: (i) instructional design (in the left) allowing for both, epistemological and personal connection; (ii) an educational approach enforcing self-management through constructivist learning (due to subject-inherent principles of content or material); (iii) transfer design that requires distinct role definitions and learner-centered situation design. The learner became an active explorer of physical material or information spaces. The coach became a guide and mentor for the exploration process. He might also be responsible for the design and preparation of the learning environment, since those building blocks influence both, the content and the interaction part in knowledge transfer and learning.

At the content side the labeling of content or the selection of material depending on salient features in the learning domain became the initial task of coaches or e-learning providers. In addition they had to elaborate the different formats for presenting material or content to learners (text, video, graphics etc.). In hypermedia environments, such as Scholion, differently encoded pieces of information might be linked due to inherent domain principles. For instance, a definition was followed by an interactive example. Finally, various levels of granularity might be essential for transfer situations, such as slides for presentations, and full test for exam preparation.

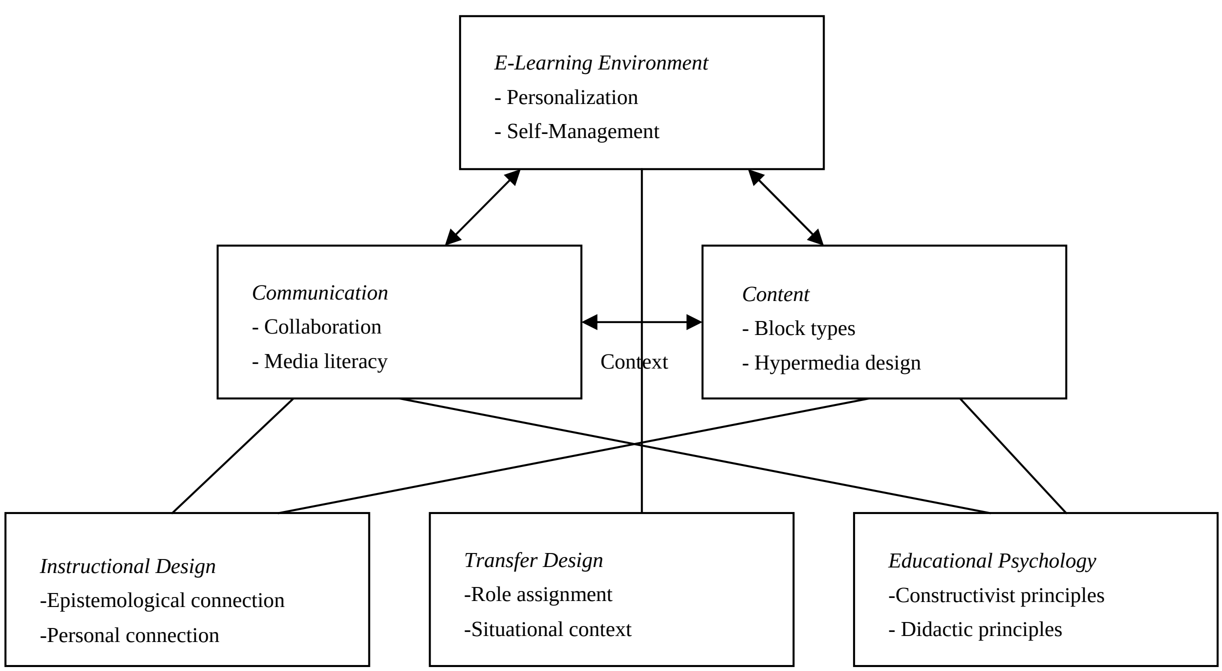
At the communication side various synchronous and asynchronous media and communication channels were set up. They should enable learners one-to-one as well as group communication in a self-managed way. Collaborative learning creates different learning and navigation paths through information spaces. The linkage of content elements to communication tools was handled in Scholion exactly on that content level of granularity learners identify or the coach prepared as ‘unit-of-discourse’. Each content element (e.g., a definition) can be directly linked to communication entries, e.g., in a discussion board. In this way, context provision enabled focused learning, discussion, and discourse.

In the actual learning environment (top level in figure 3) learners were motivated to select those content elements that fit to their learning style, their level of experience, and the current learning or transfer situation. Based on the individual selections learners might mark, comment, and extend the material through individual annotations, including context-sensitive communication as mentioned above. The transfer and learning process was triggered either by individual annotations or collaborative processes under learner control.

From an organizational perspective the management of the learning process was based on self-contained learning units along thematic themes. The latter were bundled to courses that are part of academic curricula.

The development concept is generic in the sense that different domains and scenarios can be addressed. Thus, the scalability of the environment allows dynamic extensions and multiple instances (cf. elie.ce.jku.at, www.mobilearn.at). In each of those different types of control patterns self-management might emerge, either depending on learning styles, transfer settings or individual preferences.

Figure 1. Bottom-up approach.



Scholion – Field Studies

The bottom-up approach led to the development of Scholion, which was used by over 200 students in two field studies (cf. Auinger et al. 2003, 2004, 2005). These studies were conducted in the course of training business-information systems' students in Communications Engineering, and training economy students in Accounting. In both investigations, two groups were established to test the effect of pre-structured content and its context-sensitive links to communication (and vice versa), as well as the annotation tools for individualized learning. One group of students (Scholion group) had access to the prepared e-learning environment Scholion, the other group did not: Neither had this second group access to digital material. They received papers containing content identical to the other group. The second group was not able to share annotations (including communication) the same way the Scholion group could.

The study design included for both groups the measurement of the motivation to use the provided features for individualized and collaborative learning, and the knowledge that could be transferred in respective settings.

The context-sensitive discussion forum was recognized to be ‚the most useful features, since [students] profit from the items brought up by others', as one of the students gave as feedback. Overall, Scholion had some catalytic effect on the context-sensitive and focused interaction among students, and with coaches along the transfer process. The students felt understood properly, and guided in a more comprehensive way when using Scholion features, compared to regular face-to-face meetings for the control group.

Both, for communication, and individual knowledge transfer, the context turned out to be of crucial importance. Learners and coaches were able to act and re-act in an accurate way to learner demands. For learners, the structuring of content according to relevant pieces of information, e.g., definitions in accountancy facilitated the entry according to their learner type. Coaches could intervene immediately when observing the annotation of content, learning results, and the ongoing conversation among students (in case it was made public.)

Both field studies revealed significant impact of e-learning activities on the knowledge level that can be achieved by digital means. Since learners were able to develop individual views on content (using annotation features), they were able to arrange the provided content elements according to their needs and learning style (cf. Röder, 2003). The view mechanism could be compared to putting individual transparencies on top on visual or text material, and making notes, like marking to text or commenting content. Those notes could be stored individually or made public, e.g., to share a common understanding or to exchange meaningful annotations. Since views could be shared, each learner could decide to make information public and open a discussion either on the content itself or/and on the comments or other annotated elements.

The above mentioned results were in line with other investigations. The structuring of content according to the transfer process (i.e. the didactic concept) and the corresponding use of technology seemed to be crucial. Both seemed to override the technology itself (cf. Kerres et al., 2002, Kamentz & Womser-Hacker, 2003). Using Scholion, learning was facilitated definitively by linking content to communication directly. Of particular importance was the embodiment of the links between communication and content elements in traditional annotation facilities.

In summary, the bottom-up design approach featured learner self-control in terms of individualization of navigation, presentation, content, and interaction, the latter concerned content as well as peers and responsibles. The individualization of content was stored in dedicated views. It

(i) started with the selection of content elements that are strcutured to didactic properties of the subject to be learnt;

(ii) captured different levels of details;

(iii) continued with content-specific annotations, such as marking, commenting, linking, and enriching information;

(iv) led to links to communication feature entries, i.e. to provide proper context.

The individualization of navigation emerged when specific content was filtered according to a learning situation or an individual learner type. The presentation of information was individualized through look-and-feel modifications of user interface elements. The individualization of interaction was enabled by the selection of communication tools for interaction, and the individual binding of communication entries to content elements. The latter enabled context-sensitive interaction. Since all features of learner self-control were available at the user interface of a learning platform, bottom up design in this way allowed the individual exploration of information and communication spaces, either in order to accomplish a certain learning tasks, e.g., to complete an assignment, or to enhance factual knowledge.

TOP-DOWN DESIGN

Lab@Future – Concept Developments

The Lab@Future system was designed to support pedagogical concepts and learning practices based on constructivism, combined with action-oriented learning such as real-problem solving, collaborative learning, exploratory learning and interdisciplinary learning, stemming from activity theory and the theory of expansive learning.

Following a top-down approach the learning tasks, the learning process, the technical requirements of the Lab@Future system as well as the evaluation methodology were aligned in accordance with these pedagogical theories. As a first step a literature review was performed identifying a list of relevant pedagogical characteristics. This list was drawn from literature of constructivism, activity theory and investigative learning (Mwanza and Engeström, 2004, Schaumburg, 2002, Blumstengel, 1998, Wilson and Cole, 1991, Jonassen, 1994, Jonassen, 1991, Jonassen, 1991, Honebein, 1996, Ernest, 1995, Engeström, 1994). According to this list, when designing learning tasks, the following characteristics were relevant. Learning tasks should (i) be part of the actual curriculum in schools. One should cite the concrete text of the learning curriculum along with the description of the task; (ii) tasks should represent a (more or less complex) holistic real life problem. The description (instruction) of this problem should be embedded in authentic context and not at the level of an abstract instruction. For each task a most authentic background story should be created which provides the real life context. Students should be able to realize in which real life context this kind of problems can occur. (iii) When selecting the tasks (problems) one should consider the experience and interests of the students – which kind of problems occurred to them so far; with what kind of problem could they be confronted in the near future? (iv) When students would analyze the problem they should be able to view the problem from several perspectives. The focus on different perspectives should support the transfer of knowledge to other similar, but not identical problems. (v) Multiple representations of the problem should be provided (i.e. different kinds of information visualizations).

The pedagogical theories also influenced the context in which the learning takes place. During the learning process, the following aspects should be considered: Learning should be an active process and students should collaboratively perform practical tasks to improve not only their factual knowledge but also their procedural knowledge. Students should structure and control the learning process – they should choose the approach, and the methods for solving the task. The learning process should enable knowledge construction; students should develop their own ideas and approaches. They should be able to identify a contradiction or a conflict in the task. Students should investigate their learning with respect to methods used to organize their information and interpretation. Finally, they should analyze and evaluate their solution with respect to strengths and weaknesses.

The teacher should act as a coach, analyzing students' strategies during the collaborative learning process, diagnosing mistakes and misunderstandings and supporting students. Figure 2 presents the top down approach, highlighting the relationship between the pedagogical theory and the derived task and process characteristics.

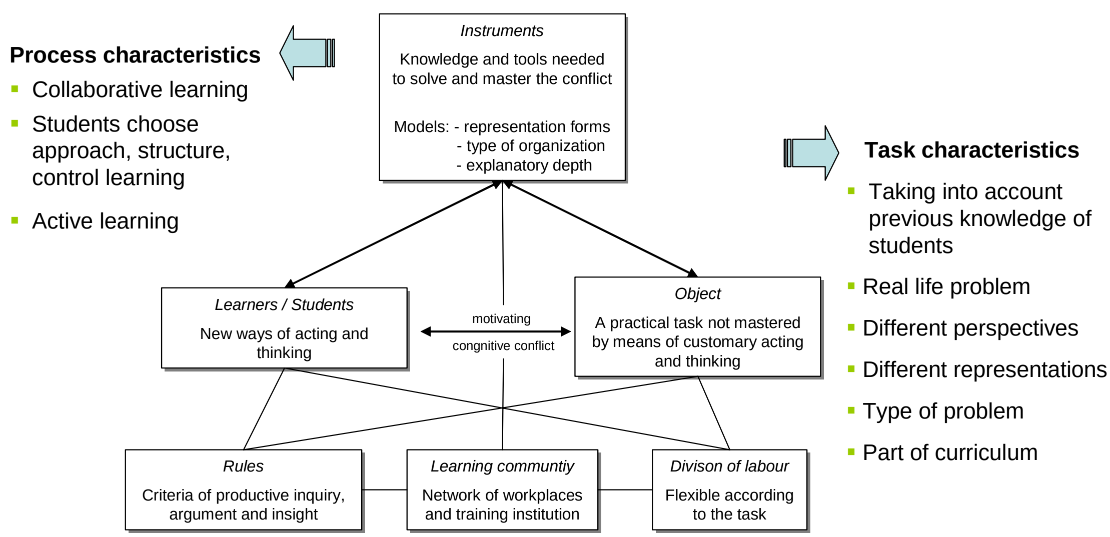


Figure 2. Top down approach.

Once the task as well as process characteristics were identified, in the next step, the technical requirements of the e-learning systems had to be defined (for an example see Table 1).

Lab@Future – Field Studies

The top down approach was developed and used within the Lab@Future project (http://www.labfuture.net/showcase/). Within this project an e-learning system was designed to support action oriented learning such as real-problem solving, collaborative learning, exploratory learning and interdisciplinary learning by implementing a set of mixed reality scenarios (experiments), employing shared virtual spaces and mobile e-learning. The top down approach not only guided the development of concrete learning task, but also defined the development of technical setting, that optimally supported the investigation and finally the accomplishment of these learning tasks. Within the Lab@Future system three main sets of functions were implemented, namely administrative support functions, asynchronous communication functions and synchronous communication functions.

Table 1: *Derivation of technical requirements from pedagogical characteristics*

Pedagogical characteristics	*Technical requirements*
Active problem solving	Students are able to jointly work on tasks
	Loading and saving of static objects
Collaboration	Formal and informal communication
• Coordination	Synchronous and asynchronous system use
• Communication	Multi-user interaction
Historical development	Capture history of idea development
Awareness of others	Awareness feature
	• Nick-name
	• IP-address
Acquiring curriculum based knowledge	Common metadata structure

The administrative support tools implemented the functionalities required for learning session configuration and management. There were off-line session tools, and on-line session tools.

The asynchronous communication tools were used when the users were working in an autonomous way, each one performing his/her own learning task without any synchronous interaction with other users. If users wanted to communicate with others, they use asynchronous communication tools like asynchronous chat or e-mail, or any other communication tool outside of the collaborative platform.

During a synchronous learning session three main collaboration and communication services were available: Informal communication among users was supported through audio/video-conferencing (in a unicast or multicast setting) and chat. Document sharing was possible through whiteboard and video streaming. Management of single-user applications was enabled through application sharing, or management of multi-user virtual environments and collaborative browsing.

The general architecture of the Lab@Future System comprised a set of distributed user workstations interconnected to a WAN network; mobile user workstations, like wireless laptops, a set of distributed servers, comprising the Lab@Future server, four experiment specific servers (ESS), the Generic collaboration and communication servers (GCCS) and Multi-user virtual reality servers (MUS).

The Lab@Future System based on the pedagogical approach has been applied and evaluated in four didactical settings (pneumatics, geometry, history and environmental awareness). For each pedagogical setting a number of learning tasks reflecting the pedagogical framework have been developed.

For instance, in the geometry field study students received the following task: A satellite dish had to be adjusted to point to the TV-SAT2 satellite. Students had to translate this real life problem into a geometric problem to be able to identify two angles, which were needed to adjust the satellite dish. Web links were presented with additional information about geostationary satellites; images were also given to help understand and translate the problem. The experiment specific server gave the students access to a virtual scene in Construct3D, which showed a small model of the earth where all continents and seas could be seen, to help pupils find the correct places on earth and to immerse them further into the problem.

In total 99 participants evaluated the Lab@Future system. A quasi-experimental evaluation design was developed to test the learning outcome as well as analyze the learning process in very detail, focusing on the communication patterns throughout the learning session (for further detail see Totter & Grote 2005).

In summary, the top-down design approach featured learner self-control in terms of developing learning tasks of given domains that led to individual and group work spaces to accomplish those tasks. It prompted students for active learning, investigating a problem in a real life context. Technology therefore supported learner control

(i) by letting students investigate the learning tasks in an explorative way – they did not have to accomplish the task in a pre-defined way.

(ii) by viewing the learning task from different perspectives (either different knowledge perspectives but also different representations of the task (textual information, simulations, etc.);

(iii) through communication tools enabling collaborative learning between peers and an informal way of asking the teacher for support.

CONCLUSIONS

Our developments and evaluations revealed that self-control for learners in e-learning environment could not be subscribed in a standardized way. A variety of control patterns evolved in the course of self-managed transfer and learning processes.

Of crucial importance seemed to be context-sensitive interaction in self-controlled e-learning settings: Content should be coupled to communication, not only to increase the interaction between learners and coaches in order to overcome the deficiencies of virtual knowledge transfer, but also to *put learners in control of the learning and transfer process*, allowing for *context-sensitive interaction*. It promoted learning, as it aimed 'to maximize four different opportunities that promote learning: Focused encounters with the representational capabilities of the system; planned activities that induce conversations about those representations; serendipitous conversations and discoveries about the representations; and more meaningful encounters with the teacher in relationship to the material.' (Tatar et al., p. 34)

Based on the top-down developments we considered individualization support of content as a major objective of the developments. Learners should be allowed to individualize content to his/her needs and associations. This requirement was traditionally implemented through an annotation concept, providing textual notes, marking, and multimedia attachments directly in the courseware. Content was either adapted to learner knowledge or actively changed by learners including. Features for individualization should also comprise the possibility for learners to learn mutually.

According to the empirical results, the annotation concept was considered as key for individualization and for coupling content to communication. It should be based on a flexible hypermedia scheme for the representation of content elements. Then it enabled learners to (i) mark a specific position in a content element for learning, (ii) post questions, answers or comments, and (iii) additionally link the contribution to a discussion theme from a global (discussion or information) board. The latter link might guide the user to the adjacent discussion of the content. In case of real-time online connections, e.g., chats, the questions and answers could pop up immediately on the displays of all connected users (e.g., available in a buddy list). In addition, the content elements referred to should be displayed at the same time as the means for social communication, e.g., a discussion board, administrated. Topics of discussions should be created either manually by users or triggered by asking a question.

Finally, the presentation concept of an e-learning environment should not only support device-sensitive display of content, navigation and manipulation features, but also the decoupling of layout from content elements, thus allowing dedicated look and feel for particular content elements and interaction features.

As the bottom-up design approach was based on the inputs of a variety of building blocks (instructional design, educational psychology, transfer design) learner self-control was bound to content and communcation that both were part of learning environments. Actually, the design of the transfer setting determined how many features for individualization could actually be instantiated and utilized by an individual learner. Given a task-specific environment the filtering of content and assigning content elements to task steps might be major operations. Given a collaborative organization of learning tasks, annotations and view development might be the focus. Hence, the context had to be shifted according to the organization of transfer and learning.

The top down approach followed a particular pedagogical theory. As such, the design of the environment was determined by the structure of a task, and the ways to accomplish that task. Actually, the way how an individual dealt with a certain task determined the control mechanisms that were required for learning and knowledge transfer.

Concluding, learner control of knowledge transfer processes concerned actual problem-solving tasks, didactically structured content, navigation support to select and manipulate data, and presentation adaptation to display information in an individualized way. It also included communication, as learning in constructivist environments was based on social interaction with peers. Controllability was not only an essential principle to ensure the usability of technical systems, but rather a fundamental design principle for learner-controlled knowledge transfer and learning settings. Its enablers could not only be driven by technology, but also theory-based learning task design, the latter focused on prompting students for active learning and assisting investigative learning processes.

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