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Experiences with Adaptive User and Learning Models in eLearning Systems for Higher Education[1]

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Abstract: Cooperative learning is characterized by communication and interaction in a group. Computer-supported cooperative/collaborative learning (CSCL) is a specific form doing away with previous spatial and temporal restrictions. At the starting point of our examinations lie known learning processes and their possible support through a CSCL system. Both the significance of different user models and the variety of styles and roles of learning are analyzed in CSCL systems and illustrated in scenarios supporting cooperative or collaborative learning processes. The practical evaluation of the methods and algorithms was done using an adaptive CSCL system to promote learning effects on the domain of software engineering.

Keywords: CSCL, adaptive eLearning, user modeling, learning models
Categories: H.5.1, H.5.3

1 Introduction

Cooperative learning denotes a type of knowledge acquisition which is characterized by forming groups for a mutual learning experience. It targets a learning result that can only be achieved within the collaboration and not single-handedly. Therefore communication and interdependence are considered the prerequisites for such joint knowledge acquisition activities.

On the basis of this constructivist perspective of learning, the focus has shifted from the results obtained to the learning process itself. The key characteristic of cooperative learning is mutual communication and interaction within the group, thus driving the learning progress of both the individual and the group. While the group on the whole compiles results, the overall activities promote individual learning and knowledge. Since group work calls for cooperation and communication, both the personal relationships between the members within their group and those between members of different groups are pivotal for effective group learning. In contrast to learning alone, cooperative learning offers outstanding benefits: combining autonomous learning with the social interaction, cooperative learning forces the individual to examine his own knowledge and to benchmark it against knowledge of the other group members. Thus, personal knowledge is tested, supplemented, and enhanced. Personal soft skills such as the debating and discussion behavior of the group members are trained rigorously. The often quite different abilities of the

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individuals are brought to bear within the group. The variety of options for support of the group learning effort allows weaknesses and knowledge deficits to be eliminated, while at the same time boosting the staying power. Yet, as is the case for any communication process, there are a number of risks and conflicts that must be traded off against the advantages within the group learning process:

- Learning content, which requires interpretation or elaboration by experts may remain unexplored
- Difficult learning content may be understood incompletely or incorrectly
- Unequal distribution of tasks may lead to redundancy or dissatisfaction in the group
- Poor organization of material may result in overloading
- A dominant instructor or trainer or a few overly active participants may restrain contributions by introverted participants, thus suppressing valuable ideas

To avoid these obstructions, it is therefore necessary to first create a common knowledge background as the foundation for collaborative working.

The individual roles within a group should be defined at the outset. To avoid the formation of hierarchies, the role of the instructor should be limited to that of a mediator. Care should be taken to distribute the learning content equally, and activities should be aligned with the level of knowledge of the learners to allow each of them to contribute actively and to prevent polarization into active and passive roles.

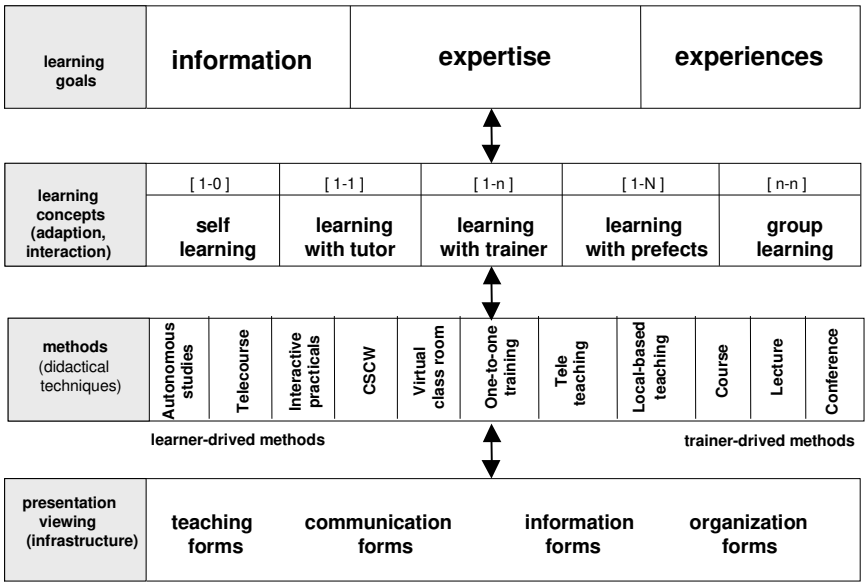

Figure 1: A reference model for structuring and supporting eLearning processes.

2 Models and scenarios for cooperative learning

2.1 Models for cooperative learning

Distribution of work in a group lesson is typically done in one of three ways:

- Content-identical group lessons: The areas of activity in the individual groups are identical, promoting a feeling of competition among the individual teams which may stimulate the users to newer heights of effort. This type of instruction should be utilized in learning important subjects. It is essential that illustrative material be available in sufficient quantity and that the content be globally presented both in intra- and inter-group discussions.
- Content-distributed group lessons: The overall learning task is divided up into subtasks and assigned to individual groups. This instruction form is particularly well suited for learning subordinate topics if an extensive area of knowledge is to be compiled within a short time. Again it is crucial that the results be presented and discussed in the groups and between the groups, so that each member can achieve the same level of knowledge.
- Mixed group lessons: Learners address the same general topic with the material distributed as required to the individual sub-groups; some groups work with the same material, others work on divided-up materials. This learning form combines the economical division of work with benefits of competitiveness as the mainspring for the enthusiasm of the individuals toward the learning process. This approach works best for inhomogeneous groups where the methodological know-how varies widely: stronger learners are able to work independently while weaker members receive the benefit of group support. If the topic at hand is particularly difficult, this learning concept acts as a quality assurance method. Since more than one learner works on the same topic, the different degrees of maturity and individual qualifications of the members can be exploited to the advantage of all. Moreover, a lack of illustrative material can be compensated if sub-groups occupied with the same topic are given the same materials and the groups jointly utilize them to independently decide which materials would be best passed on for learning. In this case, the role of the instructor as a central instance in assigning the learners to suitable groups is essential for the success of the undertaking. Or, if appropriate, the instructor may deem it more effective to supervise an independent grouping carried out by the learners. And naturally the quality and quantity of the learning material available plays a pivotal role in the effectiveness of the learning situation.

Classification of the group learning effort may also be place or time dependent: not only can cooperative learning take place synchronously in a single location (i.e. face-to-face learning), it may also occur independent of a specific time and at distributed locations ([Hinze et al. 2001, Wessner, Pfister 2001, Wessner, Pfister, Miao 2000, Scheffler 2001 and Straub 2000])

2.2 Cooperative learning scenarios

In order to support communication between group members and to ensure equal distribution of tasks and activities, a networking of the learners via computers is sensible. Moreover, this prevents isolation of individual learners.

Computer-supported cooperative learning (CSCL) can be understood as a specific variant of cooperative learning: it is the "combination of computer systems and pedagogical-didactic methods that specifically realize the benefits of cooperative learning". CSCL offers approaches that promote transfer of the advantages of cooperative learning to new learning environments while doing away with the typical restrictions with respect to time and location. According to Wessner, the core components of CSCL are communication, which may be either synchronous or asynchronous, coordination (e.g. using a group calendar), and the cooperation itself (e.g. joint usage of whiteboards and info rooms).

A variety of basic conditions and situations are conceivable for cooperative distributed learning. While the scenarios exist in practice, they are however never detached from each other in the pure form, instead merging to suit the needs of the learners.

2.2.1 Distance learning

As the trend in learning nowadays shows an increasing degree of divergence place-wise due to the fact that the places where learners can find training and information offerings are no longer automatically identical with the locations where the actual information can be consumed, distance learning has become more and more popular. Distance learning frees learners from place restrictions and is therefore less time-consuming and cost-intensive. Tele-academies offer a wide range of courses, with learners able to view the course offering and prerequisites for registration from remote locations. During the run of the course, learners complete the individual units at their own speed until they have achieved their target. There are a number of media available which support cooperative group learning:

- Electronic training material: for the electronic presentation (html) and distribution of material (WWW).
- Email: for communication between the instructor and the course participants.
- Groupware: for support of cooperative learning tasks, e.g. through automatic coordination of the activities using a workflow management system.
- Forums: for the exchange of information, discussion of problems, and orientation of instructors.

2.2.2 Synchronous learning

Discussion topics which address specific content are offered on a training server. There are no pre-defined knowledge goals. Dates and times for the discussions are set and specialists are available to answer questions put. A central role as that typical for the instructor does not exist here. The participants are largely responsible for the content with the specialists adding input to steer the discussion if needed and to promote knowledge building. Suitable tools are available to support this cooperative group effort:

- ASCII *chat*, audio or video are employed for support of communication.
- *Application sharing* is utilized for demonstration purposes.
- A *group calendar* can be set up to support coordination of activities.
- *Forums* allow user-driven presentation of learning content.

2.2.3 Medium-oriented learning

At the heart of this primarily asynchronous learning scenario lie training materials presented in hypermedia. Learners work independently in this phase but may address any questions to instructors or authors of the material via email. A forum where open questions may be posted is established, with bonus points often given for solutions presented by learners. Furthermore, regular or, if need be, same-time discussions can be implemented. Support of this form of cooperation is available through two key means:

- The instructor maintains a central pool of information for the learners.
- Discussions are held in the form of forums with *n* learners per instructor or *m* experts per forum.

2.2.4 Requirement-oriented learning

This learning concept is also asynchronous in nature. It supports situational formation of groups by the members. First, the group members define the learning content and work out their group objectives or any problems to be solved. They then set their priorities as required and complete the tasks and activities accordingly. Each of the learners contributes knowledge to the whole. If need be, specialists from outside the group can be integrated into the learning effort. Also, a moderator is available for additional support. For this form of cooperative group learning, there are a number of supporting components:

- The moderator acts as a human coordinating instance; the majority of the work lies in the activities undertaken by the groups.
- Topics are specified in an asynchronous discussion forum and groups formed in a collaborative effort with the other participants.
- Learners may join a group at any time.
- The results achieved in the individual groups are presented to the community in the forum for general viewing and discussion. Contributions by outsiders and experts alike are desired and possible.
- Minutes of meetings are created automatically and made accessible for all. They are evaluated by a member of the group and offered for discussion in the relevant forums.
- A summary of the results is archived in a common knowledge base for access after the groups have been disbanded.

2.2.5 Cooperative role play

Learning content is not provided in the form of static media but instead as distributed role plays or multi-user simulations. The benefit of this method is its anonymity, which enables problematical topics to be treated openly and without the usual inhibitions. The following offer support of this form of learning:

- Application sharing is a useful tool.
- Synchronous discussion forums are held for the purpose of coordination of the group learning effort.
- Asynchronous discussion forums are used to present summarized results.
- Group calendar for scheduling.

2.2.6 Project-accompanying learning

The learning content and goals are derived dynamically from the knowledge deficits recognized during the run of the project. This learning system is helpful when looking for experts to support project work. Supporting cooperation alternatives are as follows:

- The learning system provides search functions that answer inquiries much as querying a database would and enable a classification according to topics. If needed, the system sets up connections in the form of discussion forums between individuals or learning and working groups.
- Learning and presentation sessions are held with experts who take over the role of the instructor.
- Concurrent with the deployment of the system, a common knowledge base develops and is made accessible to the learner through an easy-to-use user interface.

2.2.7 Knowledge market

Provision of knowledge in the form of a knowledge market is founded on the principle of supply and demand. The product *knowledge content* is generated by a supplier (instructor) and requested by the customer (learner). This knowledge can be provided by means of either a human or machine broker. Support of this form of cooperative group learning, which has a number of characteristics with the above scenario in common, is provided through the following:

- The notion of "information on call" governs this system, i.e. the instructor supplies information on the relevant activities in hypertext and in the indices of (intra-organizational) search engines created expressly for this purpose. This information is accessible for anyone who is interested.
- Questions are answered via email.
- A specialist or expert may also act as a kind of search engine by providing a web page containing notifications of the events of interest. If there are any queries with respect to the content or cost, learners can contact the expert personally via audio/video media (for reasons of confidentiality).
- The course provider does not necessarily have to be the instructor; courses may easily be brokered.

2.2.8 Virtual classrooms

Knowledge is provided in the form of a metaphor: a two- or three-dimensional classroom. Agents (instructors, learners) and learning content are visualized in the metaphor selected; this ensures that operation is largely intuitive in nature. Support of cooperative learning is provided as follows:

- Access to courses is effected via a browser or actual physical entry into rooms where audio/video media are set up for presentation of the learning content held in virtual classrooms.
- Participants may utilize common resources in the virtual classroom; the content created is then provided to the learners in the form of machine-generated minutes/reports or scripts.
- Continual visual contact from and to the virtual classroom.
- Learners may attend courses in both real and virtual classrooms.

2.2.9 Real learning centers

Core components of synchronous scenarios are the meetings between those involved in the learning process in learning centers, for example at the beginning of a course. This social interaction does its share to knock down some of the barriers to learning that go hand-in-hand with the anonymity typical of distance learning systems, creating a feeling of trust, facilitating orientation in handling and operating media, and enhancing motivation. A number of elements assist in supporting the cooperative group learning effort:

- Same-time, joint practice (instructor shows, learners do) sessions are used for orientation in handling the learning system. Technical details are discussed and agreed in the overall group (e.g. invoicing, assessments, distribution of materials).
- Liveboards are provided for summaries of the content and provided to learners as hypertext.
- Lessons are characterized by hardware-supported methodologies such as joint (digital) sketching or seminars where course work is presented (e.g. using liveboards).
- Synchronous brainstorming is utilized for preparation and revision of learning content, with the participants remaining anonymous and equally entitled to ask questions.

2.2.10 Live-lectures

A further same-time scenario for group learning is the live lecture with audio/video transmission. Instructors and learners are hooked up to the learning system via broadband communication channels. The client computers deployed come with the latest in multimedia equipment. The following options for this form of collaborative learning are conceivable:

- A synchronous A/V channel from the instructor to the learner is made available.
- If the size of the group exceeds a certain threshold, it is advisable for reasons of effective coordination to keep this channel unidirectional with the learners not even able to contact the instructor via audio. In this particular case, a synchronous text-based forum would be preferable, with the instructor able to contact individual learners by opening the A/V channel as required.

2.2.11 Mobile learning

The greatest part of this learning system is tailored to access by mobile course participants. Narrow-band communication is not an obstruction to participation in the system. Cooperative learning is supported as follows:

- Presentations may be downloaded.
- Questions have to be put and answered via email.

2.3 Classification criteria for cooperative learning models

An analysis of the individual scenarios and models for cooperative learning, which is not gone into here, enables the following classification criteria to be derived.

- Knowledge level: homogenous – heterogeneous.
- Aspect of time: synchronous – asynchronous.
- Aspect of space: - spatial - distributed.
- Learning place: virtual – real.
- Duration: limited - unlimited.
- Training objectives: pre-defined – open.
- Learning content: defined – open.
- Learner: limited – arbitrary.
- Identity: public – anonymous.
- Group size: group - organization - society.

If knowledge is transferred from an instructor or trainer to a learner, this is called asymmetric CSCL due to the discrepancy in the cognitive skills. Yet, should all of those involved in the collaborative learning process possess a comparable level of knowledge, this is symmetric CSCL. In addition, the literature differentiates asynchronous (different-time) and synchronous (same-time) CSCL. And cooperative learning can occur at the same place (face to face) or at distributed locations with collaborative working carried out in both virtual and real rooms. Groups may be formed for either short, limited periods of time or may be of unlimited duration. Furthermore, goals and learning content may be as specific as necessary or as open as desired. The degree social interaction is determined by factors such as the size of the group and its composition.

3 Styles and roles of a user model to support individual learning

Exactly how individualized the learning process is depends largely on the following aspects:

- **Availability***:* Learning is independent of any specific time or place as long as learners have free access to learning content.
- **Goals**: Learning content and the level of difficulty can be controlled by the learner within the framework of the program.
- **Learning speed**: Learning contents may be repeated and reviewed as needed, with the speed of learning aligned with the individual's progress.

- **Learning methods**: Alternative didactic methods allow the learning process to be harmonized with the needs of the learners.
- **Comprehension monitoring**: Criteria-oriented checks of the learner's progress are geared for improvement of individual performance.

The prerequisite for any degree of individualization is an awareness of the level of experience as well as the weaknesses and strengths of the learners. Yet, because learning programs are developed for large user groups, they target the requirements of the average learner and are thus, by their nature, not well-suited for learners at the upper and lower ends of the spectrum. These programs can therefore only satisfy the needs of the individual to a limited extent.

The key focus of such learning programs is the learning content to be communicated – and not the learner. Learning processes are planned, i.e. while learning methods can be selected, they are typically restricted to those offered by prepared structures. Generally even the permissible questions are implicitly defined by the degrees of freedom and constraints of the learning program. Individualization is limited to the room defined by the content author: the emphasis is on communication of the prepared content and not on clarification of the spontaneous ideas generated.

Thus, for enhanced support of the learning process through CSCL, we first need to analyze user-adapted learning styles, learner roles, and learning scenarios in order to appropriately integrate them.

Examining the different learners, we defined the following learning styles:

- **Active experimenting**: This style supports study which is based largely on experimental work. Here, the most effective learning forms are projects, homework, and discussions in small groups. Experimental learners typically dislike passive forms of study such as lectures.
- **Concrete experience**: This receptive, experience-oriented form of study is based strongly on subjective feelings with the learners highly appreciative of teachers who are sensitive and offer practical application of learning content. Theoretical considerations are not found helpful as the learners prefer to derive global rules from individual use cases. Most effective in reinforcing learning content is feedback on the experiences made with other learners who feel comfortable with this style.
- **Reflective observation**: These learners are hesitant to embrace new content and need to reflect on what is learned on the basis of careful observations. They therefore prefer study situations such as lectures which allow them to assume the role of the objective observer.
- **Abstract conceptualization**: This style is an analytical, conceptual approach towards learning which is based on logical intellect and rational evaluation. These learners focus more strongly on things and symbols than on people. Thus the most effective study situations are controlled and impersonal, with an emphasis on theory and systematic analysis.

To round off the overview, we find that four learner roles can be defined in addition to the different learning styles.

The converger: The dominant learning abilities are a convergence of abstract conceptualization and active experimenting. The greatest strength of the converger lies in the practical application of ideas. This role is most effective where it is necessary to find a clear answer to a question or a problem.

Convergers are relatively unemotional and prefer to react to things instead of interacting with people. Their interests tend to focus solely on technical topics and they generally specialize in the sciences. This style of learning is typical for engineers, for example, and the associated learning behavior is characterized by the following:

- Abstract conceptualization.
- Active experimentation.
- Putting ideas into practice.
- Pursuit of clear answers and solutions to problems and their application in problem-solving.

The instructional methods preferred by *convergers* are as follows:

- Lectures for the acquisition of background information.
- Internships.
- Projects and seminars for practice and reinforcement of the learning content.
- Research in the relevant literature.
- Discussions in small groups.

The diverger: This role is the complete opposite to the converger: the dominant area is concrete experience and reflective observation. The diverger has the special ability to view concrete situations from many perspectives. The diverger generates ideas, is interested in people, and is imaginative and emotional.

Divergers have broad cultural interests and are often artistic in nature. For this reason, they are often found in the fields of social sciences and philosophy and often work as consultants. The diverger's learning behavior is characterized by four elements:

- Concrete experience.
- Reflective observation.
- Examination of facts from different perspectives.
- Idea generator.

The instructional methods preferred by *divergers* are as follows:

- Lectures for the acquisition of background information.
- Gathering of ideas for their structuring and elaboration.
- Discussions, simulations, and case studies and their application for the reinforcement of acquired knowledge.

The assimilator: The dominant learning styles are abstract conceptualization and reflective observation. The great strength of this role is in working out theoretical models. The assimilator excels in uniting observations to an integrated explanation. Any theoretical knowledge offered must be logical and precise or these learners will recheck all the facts.

Mathematics and the sciences are the chief interests of the assimilator. Assimilators are therefore often found in research organizations or planning departments. The assimilator's learning behavior is characterized by the following:

- Abstract conceptualization.
- Reflective observation.
- Development of theoretical models.
- Unification of various observations into an integrated explanation.
- An occasional distancing from practice.

The instructional methods preferred by *assimilators* are as follows:

- Lectures for the acquisition of knowledge.
- Independent evaluation of knowledge acquired in lectures and comparison with the knowledge provided by the instructor.
- Reinforcement and elaboration of the knowledge acquired through research into the literature.
- Development of theoretical models.

The accommodator: This role contrasts with that of the assimilator. This learner is strongest in the area of concrete experience and active experimenting. Accommodators can explain plans and experiments and enter into new experiences most easily. They choose situations in which adaptation is needed. If a theory or a plan doesn't correspond to the facts, this learner will analyze the reasons and arrive at the facts. The accommodator will solve problems intuitively using trial-and-error techniques.

These learners typically have a practical or technical background. They are found primarily in activity-oriented organizations such as marketing or sales enterprises. The accommodator's learning behavior is characterized by four elements:

- Concrete experiences made.
- Active experimentation.
- Willingness to take risks.
- Strongly dependent on information acquired from others.

The instructional methods preferred by *accommodators* are as follows:

- Lectures for the acquisition of experience.
- Internships.
- Projects and seminars to test and evaluate the experiences made.
- Discussions and case studies to elaborate and confirm the experiences made.

3.1 Interaction analysis for the user model

To integrate the different styles and roles of learning effectively in a CSCL system that supports the individual learning process, interaction analysis is a suitable method for this examination. The results of the interaction analysis are context dependent: they are contingent on the reactions of the learner to the educational materials and tests, the possibilities of cooperation with other learners offered or the CSCL system

as well as on the key influences on the individual learning process such as navigation and communication behavior. There are three kinds of interactivity in CSCL systems:

- Reactive interactions, pro-active interactions, joint interactions.

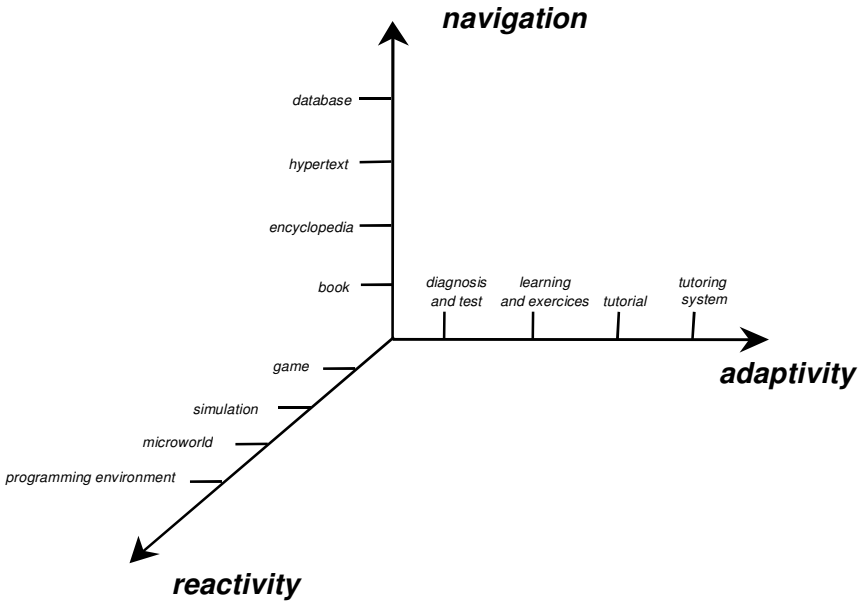

Figure 2: Interaction analysis for adaptive eLearning systems.

Reactive interaction originates pro-active interactions from the behaviorist reaction paradigm. A reactive interaction is the answer to the educational content presented, e.g. an answer to a question asked.

adaptivity

- control by the user (system, model, algorithm)
- control by the eLearning system
  - adaptivity components (function, communication, navigation, help)
  - adaptivity process (control by user or system, done automatically)
  - adaptivity strategy (before/during/within learning session)

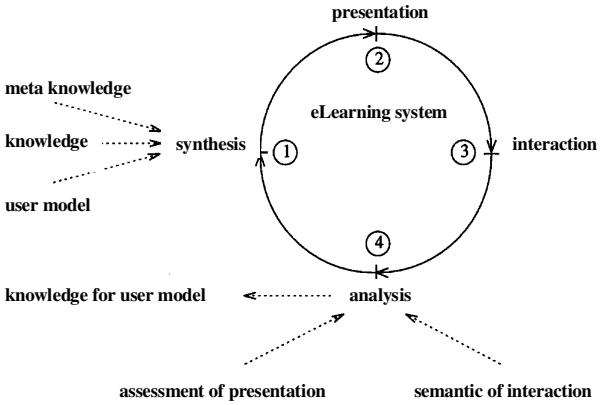

Figure 3: Adaptivity of user and learning models.

In reactive interaction, the author keeps complete control over the contents, the presentation, and the exercise standards. With the other types of interaction, control changes more strongly over to the side of the learners.

4 Evaluation of the adaptive user and learning models

Computer-supported learning denotes learning processes that are carried out in environments that are geared for learning using electronic media. The term does not imply that such environments make learning more effective, more entertaining or simpler: they do not have a great deal to do with the actual learning process of the individual learner.

If we examine and evaluate the popular CSCL systems from the perspective of cognitive psychology, we find that most of the offerings target the organization and distribution of container knowledge (support of the behaviorist learning model) that is to be delivered in the form of relatively simple packages to the various addresses via electronic means of communication. Only in a few cases can we speak of a learning concept (support of the cognitive learning model). How this is related to learning per se is not addressed (support of the constructivist learning model).

The promises made by many CSCL systems are often misleading:

- They pursue goals that are in the best interests of the learner.
- The learning contents selected are important for the learner.

- The learning methods employed are based on experience and knowledge gained and both initiate and support learning processes.
- If learners take advantage of the overall offering, they will achieve their desired results.
- So-called eLearning methods are easier and more interesting than conventional forms of learning.

However, experience shows that CSCL systems cannot guarantee that the targeted objectives will be reached. Moreover, practice has illustrated that identical course offerings may lead to very different learning results.

In fact, the very different basic conditions and situations surrounding cooperative learning call for customized learning scenarios. Depending on the features and functionality offered, such learning environments provide the group members with an excellent opportunity for collaborative learning through their mutual engagement in a coordinated effort. Spurred on by the other members of the group, learners find that their thirst for knowledge is increased: collaborative knowledge building promotes the desire of the individual to continually expand his or her knowledge. Furthermore, since learners are required to present their know-how in ways that are understandable for others or to support their argumentation when confronted with different perspectives, they oftentimes find themselves slipping into the role of the instructor, thus developing their own cognitive skills.

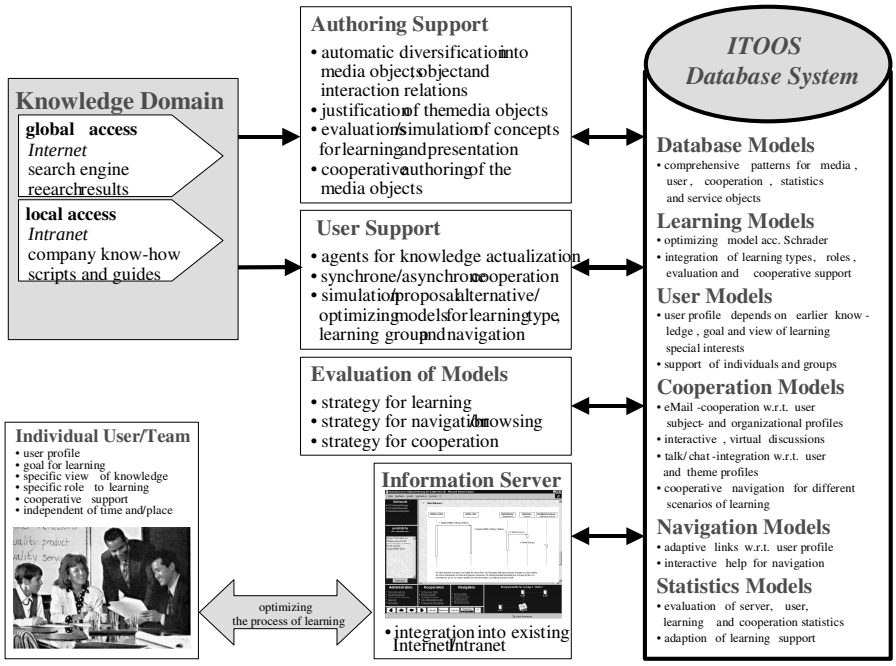

Figure 4: Architecture of the adaptive information system.

Not only were the various models for cooperative/collaborative learning evaluated by using an adaptive eLearning system but also techniques for user modeling have been evaluated and tested. The structure and architecture of the information system are depicted below.

Most of the learning scenarios described have been realized by the adaptive information system and were tested using training lessons related to software engineering. To conclude, the experiences gained have shown that adaptive learning systems support individual learning by the integration of different types and roles of learning and user models within the complete process of knowledge analyzing, presentation, interaction analyzing and synthesis of new knowledge and presentation forms.

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