Learning and Problem Solving as an Iterative Process: Learners' Living Repository: LEAR

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Abstract. Current learning challenges for competently employing information technology in the working environment is not sufficiently supported by training courses during the introduction phase of new systems, improved on-line help, and user support by local or central consultants. Each of these approaches has deficiencies and even taken as an integrated concept they are insufficient because they do not consider learning as a process.

With the system LEAR (Learners' Living Repository), we propose a solution to support users in exploiting learning and consultation episodes in later situations: Users can identify portions of an animated interaction sequence describing problems they encountered or solutions they found when using the tool, comment on them, and store them as episodes. Users can send episodes that describe questions, problems with the tool, or breakdowns when using the tool as a request for off-line help to a consultant. Episodes that describe learned tool knowledge can be stored in a database called "demotheque" for later use. Representative demos can be made available to a group of users in a "purse for demos".

This paper deals with today's shortcomings of learning in the working environment, discusses the state of the art in the literature, and introduces our ideas of supporting the learning on demand process by creating and using learning episodes and exchanging them within a group of domain workers. We are currently developing a conceptual framework for LEAR; later on, we will evaluate a prototype of LEAR in a realistic work setting.

1. THE PROBLEM AND THE AIM

In complex working environments, requirements for and qualifications of working people change and evolve. Learning became an integrated part of life and an integrated part of work, too. Learning happens planned and unplanned, controlled and uncontrolled, consciously and unconsciously, single and collectively. Today's working life and its widespread use of technology requires more than ever to acquire permanently new domain and tool knowledge.

New approaches for supporting learning and qualification process are needed to circumvent the difficult problems of obsolescence (i.e., trying to predict what specific knowledge someone will needs in the future) and coverage (i.e., trying to teach people everything that they may need to know in the future).

As the user's task competence can dynamically be increased by a flexible work organisation (such as job rotation, job enrichment, group work) and task support (such as information agencies, database access), the user's tool competence should dynamically be increased by systems suitable for learning, exploration facilities tolerant for correction, and support environments reinforcing recapitulation and reuse of problems and solutions. We focus our view on the latter: to increase the tool competence of the user by strengthen the learning process and the reuse of already acquired knowledge in further working situations.

Learning on demand is a viable strategy in a world where we cannot learn everything. It evolves if a user is pursuing a goal by solving a problem and some impasse develops or a breakdown occurs. This breakdown not only induces a user's desire to get around the problem (to get his or her work done) but it can also induce the need and the desire to access and learn new knowledge. Learning on demand supports situated and contextualised learning because it is integrated into work and it has the advantage to provide new information that is directly relevant to what the user is doing thereby increasing the motivation for learning new skills and information.

Three aspects of learning we want to focus on in our work:

- learning is ubiquitous, it has to be supported in every working situation, not only in particular learning phases or environments,
- learning is a combination of exploration and instruction: people learn by trying things out and by asking other people for advice,
- learning is a iterative phenomenon, it evolves step by step using early knowledge for later understanding.

There are three approaches to the learning challenge, (a) training courses during the introduction phase of new systems, (b) improved on-line help, and (c) user support by local or central consultants. Each of these approaches has deficiencies and even taken as an integrated concept they are insufficient because they do not consider learning as a process.

_ *Training:*
Learning efforts cannot be restrained to particular periods or environments of learning. Learning cannot be acquired completely in advance, in school, training or by instruction. Learning in advance does not taking into account that learning is an ongoing process in human life.

_ *On-line help:*
Another answer to the required knowledge acquisition using information technology is to provide improved on-line help, that tries to take into account the current problem and intention of the user. This approach is limited by the capacity of intelligent help systems to infer the user's need from his or her current interaction. It can at best be provided for notorious problems action plans can be defined for by the system developer.

_ *Consultants:*
Local or central consultants are limited in their capacity, they are not available at any time

and site for consultation and their consultation result induces only a volatile trace in the memory of the user.

We will discuss the solutions and deficiencies of learning and problem solving support in the following chapter.

2. STATE OF THE ART: SOLUTIONS AND DEFICIENCIES

Training and learning on the job. We assume the learning process as being integrated into the task accomplishment [Dutke 87, 295f.; Paul 95, 168]. A substantial part of learning does not happen during the training but during task performance. Users explore the system in use and try functions for their goals. A "guided exploration" facility was proposed to support this kind of learning [Carroll 87-88; Carroll 90]. Guided exploration owes its origins in the concept of "discovery learning" out of the late '60s and early '70s [Williams 92, 41].

Not any breakdown or new situation creates the need for acquiring new knowledge, i.e. to learn. Users in contrast do avoid learning. As Carroll and Rosson cite: "I want to do something, not learn to do everything" [Carroll 87, 83]; they resume: "adults resist explicitly addressing themselves to new learning" [Carroll 87, 101]; see also [Knowles 73; Kidd 77]. In particular if the critical situation is supposed to occur only once the user is not motivated to *learn* a solution. It is sufficient if he or she is enabled to create the solution, for instance by the help of step by step instructions not meant to induce a knowledge acquisition with the user. Williams and Farkas give an example where a user who has exceptionally to produce a footnote instead of known endnotes for a particular journal will not accept the "compel ... to 'learn' or 'remember' the procedures that he or she explicitly needs now in order to create the footnotes" [Williams 92, 44]. Only for recurrent problems and tasks new knowledge will be acquired.

Support from on-line help. When problems arise, breakdowns occur or solutions are unknown, addressing the on-line-help is often insufficient for the user. The support users get from on-line help systems is restricted to the information that experts have brought into the system. Help from the system is restricted to information about system functionality and to well-known notorious problem situations [Fox 94, 186f.]. We only know one example that provides growing support based on questions of users and answers of consultants: "Answer Garden", see [Ackerman 90][1].

On-line help support should be extendible to the user's individual results of exploration based learning and to co-operative learning with consultants so as to integrate the learning results into technical support facilities (individualised help system). This individual help environment can be perceived as a user own created guiding solution in contrast to the "guided exploration" manuals proposed by [Carroll 90] that was critiqued by [Williams 92, 49] for its inefficiency and ineffectiveness and its authoritarian nature.

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[1] "TeamInfo" was developed as a shared repository for informal group-relevant information by [Berlin 93]. For producers of software a "Living design Memory" was proposed by [Terveen 93].

Consulting local or central experts. The learning process may occur individually where the user helps him- or herself by exploration (trying things out) but often the user asks for help consulting a competent colleague ("power-user") in face-to-face interaction or consulting an expert by telephone or remote diagnose.

Learning supported by computer help and documentation without social support is not appreciated by many users. Users tend to prefer to "consult the 'local expert' or other users ... to translate their intentions into specific questions" [O'Malley 86, 378f.; see also Brockmann 90 and Horton 90]. This consultation includes a constructive and co-operative communication between humans with complementary types of knowledge and expertise but being familiar with the same tasks and the same working environment, speaking the same jargon. Users are sometimes specialists themselves "assigned topics to master, and other users are made aware of when and whom to consult" [Carroll 87, 85]. It is an illusion that users work alone with an system. "End users make good use of other people in their social environments to help them solve their computing problems and to compensate for gaps in their own knowledge of computers [Nardi 93, 104, 186]. Local experts can be enlarged by professionals with technical knowledge about the system in use but with less connection to the user community and the task at hand. The latter are less accessible for and less accepted by the users [Bannon 86, 406].

Computer experts or skilled domain workers cannot be strictly differentiated. Computer experts dispose of profound knowledge about information technology but only a thin spread of application or domain knowledge. Skilled domain workers dispose of profound knowledge about their technical domain but only of limited knowledge of information technology. Computer experts and domain experts ("users") are no homogeneous entities. Users are widely differentiated by novice and expert users. This distinction is insufficient in supposing a sudden leap from a novice to an expert. Most users will be positions in between as they have knowledge and experience in a limited area of an application and no or only few knowledge in the others. There will be a process of learning different areas of the application's functionality, in particular with occasional or "discretionary users" [Santhanam 93].

Communities of system users will emerge, in which individuals have different backgrounds of knowledge: substantial computer and substantial domain expertise distributed among different members of the community. The competence of the user groups together with the competence of professional system experts are the basis for their constructive interaction in problem solving.

User support by personal interaction is limited by the capacity and availability of human experts. In particular in repeated situations of the same or a similar problem the consultation of a human expert confronts with restrictions: the user is ashamed to ask for the same help again and again and the expert pulls a long face over the same support demand. Personal interaction is also limited by the access of the consultant to the critical action episode of the user (the problem or error situation). The error occurred *before* the consultant appears. The error or the problem cannot adequately be reconstructed by the user for the local expert and additionally not adequately be described for remote diagnoses. Exploratively acquired knowledge and solutions developed in consulting local experts or professionals are not

reusable for the learner to exploit the substance when needed to solve a similar problem. In particular the way and the pitfalls of a solution are not available.

Empirical studies show that users have problems with consultants and consultants have problems with their clients [Brezizinski 87; Liechti 88; Moning 93]. Consultants are overloaded; their increasing number is over-compensated by a yet increasing the number of clients; members of the user service units show limited availability; they are often not interested in the needs of users; they "forget" promises of problem solving that can't be executed immediately. Consultants have to solve (in their eyes) trivial problems and are therefore not motivated. User support is often organised on several levels [Brancheau 85] where the communication requires an exchange of problem and solution representations where verbal or written descriptions are expensive and misunderstandable.

3. OUR APPROACH: LEARNING AS AN ITERATIVE PROCESS REQUIRING SUPPORT FOR THE RE-USE OF LEARNING RESULTS

Iterative Learning: The learning process is iterative or incremental what means that the learner proceeds in his or her competence by several trials of acquisition and application of qualifications. The first trial to acquire knowledge may be exploratory, supported by technical or human consultants, error prone, with indirect solutions, and with dead ends. The first step of learning provides the user with rudimentary knowledge about errors, risks, and solutions. One experience is not sufficient for full understanding and it is not robust to forgetting. It has to be reinforced and extended by re-use in identical or similar situations. Learning is knowledge-dependent. Skills learning can be described as "consisting of three stages: often called the cognitive, associative and autonomous stages. In the cognitive stage the individual learns the basics of the skill through instruction or observation. In the associative stage the individual practices the skill until it becomes smooth and accurate. In the autonomous stage the individual is able to perform the skill essentially without attention" [Santhanam 93, 223]. Simon reports evidence from learning experiments conducted by [Waugh 65] showing only limited retained items in a first learning step, but with some residual retention of the remaining items in later [Simon 92, 82].

Multimedia Demonstrations with Annotation Facilities: To exploit a former solution, a film of the interaction steps are easier to grasp than a formal description. A demonstration supports the understanding in showing the process of actions and the effects of actions, see [Fox 94]. An interaction film is a first step but not always a sufficient fundament for duplicating a sequence by the user. Reasons for a solution, warnings to misleading assumptions, hints to unexpected side effects etc. can be helpful to the user in understanding the rational of a solution and in transferring the former solution to the current problem.

Annotation facilities can support the user with respect to these goals. Verbal comments can denominate the general concept of a solution and can support its transfer to similar tasks [Alpert 95, 72]. While the file of the action sequence supports what is called the "procedural knowledge" the annotation is to support the "declarative knowledge" [Anderson 76]. A film can support the procedural knowledge type usually possessed by casual or discretionary users [Santhanam 93, 227]. Procedural knowledge can hardly or not at all be learned by description

but best be acquired be observation or even best by practice, see [Brockman 90] cited in [Rettig 91, 22]. An animated demonstration can't replace experience but it can exploit a film of the user's own former practice to support his or her recapitulation of solutions in later situations. [Palmiter 91] and [Palmiter 91] showed that animated demonstrations are superior for learning both in speed and accuracy during training sessions of highly graphical systems. Written instructions supported the deduction of necessary procedures much better. The transfer of knowledge in subsequent sessions was better in the written instruction group. [Payne 92] showed positive effects of un-commented, silent video recordings as instructions for a graphics editor. The results can be interpreted as a demand for harmonising of methods and tools to present processes, concepts and effects to the user in different application domains. What is good for direct copying of procedures in a graphics system is not good for the in-depth understanding of concepts in a data-base. Combinations of methods are requested that take into account the particular application domain, the interaction style and the concepts to be conveyed.

4. OUR SOLUTION: "LEARNERS' LIVING REPOSITORY (LEAR)"

With LEAR, we introduce a conceptual framework that places special emphasis on integrating working and learning and on supporting self-directed and group learning. Prototypes of a support environment for learning and consultation in and after face-to-face or remote interactions will be developed and evaluated in a realistic work setting. The idea of LEAR can be described as follows:

Users can identify portions of an animated interaction sequence describing problems they encountered or solutions they found when using the tool, comment on them, and store them as episodes. Users can send episodes that describe questions, problems with the tool, or breakdowns when using the tool as a request for off-line help to a consultant. Episodes that describe learned tool knowledge can be stored in a database called "demotheque" for later use. Episodes that describe users' personal experiences of solutions can be made available to a group of users.

The elements of the solution are described in more detail:

- **Recording interactions**:
  The interactions of a user with the system are temporally recorded by an interaction recorder. A temporal recording of, say, the last 1000 interaction steps is an opportunity to reconstruct the history to explore an error or to demonstrate it vis-à-vis a consultant. Errors can be understood and corrected by the user's own capabilities more easily when he or she knows the process that led to its occurrence. The communication between a user and a consultant in a problem situation can be facilitated by the possibility to precisely demonstrate the history of the situation.
  The recording is application overlapping to ensure that the user gets a record of all actions over a particular sequence no matter if and how many transitions between the finder and several applications are concerned.
  To protect the history against external supervision the records of the interaction history have to be stored under the exclusive control of the user.

Aim: The user can duplicate the history to reflect an interaction sequence (e.g. an error situation) and can show the sequence to a consultant.

- **Defining relevant demos**:
  Interaction episodes can be defined in advance as a relevant sequence to be kept for personal future demonstration. Also existing interaction records can be selected ex post by the user as a relevant sequence and be stored permanently in a "demotheque". The interaction recorder provides cutting and past facilities for a permanent copy (!) of temporal records to enable the user to build an individual support repository with solutions he or she has successfully used. The resulting "demotheque" is protected against external supervision.
  Aim: The user can select a relevant episode and keep it for similar future situations.

- **Annotating demos:**
  Permanent copies of interaction records as members of the demotheque can be accompanied be voice, textual, graphical, and deictical annotations to comment the rational and follow up, alternatives and pitfalls of solutions or to focus the attention of the recipient. The exploring or consulted user or the consultant can comment the demo episode. The annotation can be performed during the learning or consultation phase (thinking aloud) or in a subsequent editing phase.
  Aim: The user can give interpretations and warnings to what he or she has done accompanied by the animated demonstration. Different modes of annotations should help to avoid information overload of a single sense organ.

- **Retrieving demos:**
  The demotheque is a dynamic repository of personal demonstrations. The demonstrations support the recapitulation of episodes to recall a solution. This recall is supposed to stabilise the "cognitive" stage of skill learning and precedes the "associative" and "autonomous" stage. To organise the demotheque and to find the relevant item in a critical situation different kinds of presentations should be possible. The user can give an episode a name when including it into the demotheque. The name can be combined with keywords to characterise several aspects or synonyms of the demonstrated concept or solution. The retrieval can further be supported by presenting the demos according to the creation date, the respective application(s), function(s), or object(s)/document(s).
  Aim: The user can select different kinds of accesses to retrieve the relevant episode from the demotheque.

- **Selecting Views:**
  The demonstrations can be used as an annotated film of interaction sequences. The mode is appropriate to give the user a conceptual understanding of the solution to be presented. The film can interactively be controlled to enable the user to stop, repeat and continued on demand. This presentation will be selected during the re-learning phase. The presentation has the same form and size as the original sequences so that the learner can follow the interaction and read input and output produced originally by the user and the system. Films and annotations are volatile media. A representation is necessary to support the transfer from re-capitalising to re-performing a task completion. The demonstration will therefore be selectable in a presentation mode where the action input of the user is displayed in a separate window. Character strings, selected menu options, parameter values, mouse clicks

etc. are displayed to support the user in the transfer phase of the demo. Based on the annotated film a re-cognition can have been induced with the user but to execute a complex task a re-call of details of the original interaction sequence is necessary. Re-call can be supported, i.e. it can be replaced by re-cognition, in displaying a window with the original user inputs. Relevant parts of these inputs should be transferable to the new situation more or less by copy, paste and modify functions.
Aim: The user can select different kinds of views to exploit a relevant episode from the demotheque for supporting the re-learning of a solution and for supporting the transfer of the solution to the current task.

- **Exchanging questions and answers:**
Users asking for help can electronically send a film about an error or problem sequences with comments and questions to a locally and timely apart consultant. The consultant can diagnose the user's error or problem and answer his or her question by sending the user a film with a commented solution.
Aim: A remote consultation can be supported to enable the user and the consultant to exchange questions and answers independent of their time and space constraints.

- **Exchanging solutions:**
The resulting facilities of distributed information repositories called demotheque are primarily a container for examples and solutions for problems individuals discovered when dealing with problems relevant to their task at hand. Representative items of the demotheque for a group of users with similar or complementary tasks can be collected in a Bulletin Board System (BBS) called "purse for demos" for computer-mediated communication between members of the community for exchanging knowledge and experiences. The individual user can transfer copies of the own demotheque to the purse for demos if the items are supposed to be helpful for colleagues. Individual users can consult the purse of demos instead of consulting a generic on-line help or a human consultant if a human consultant is too expensive or unavailable.
Aim: The users of a co-operative work environment can exchange task and tool competence by providing and requesting error and problem solutions typical for the workspace.

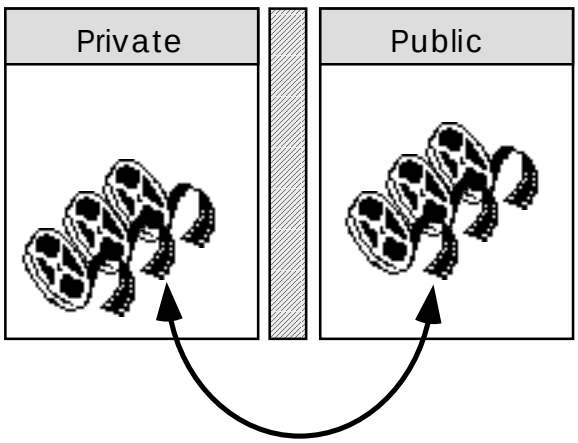

Figure 1: Transfer of a Film from the User's Personal Demotheque to a Public Purse for Demos

The support facilities can be provided for different interaction types between a user and a consultant. The user can (a) explore problems and solutions on his or her own (no social interaction at all), the user can (b) consult somebody face-to-face (typically a power-user or a member of the decentralised local support unit) or the user can (c) consult somebody remote (typically a specialist of the central user support unit). The consultation can happen synchronous and asynchronous. The following figure shows the different (inter-)action types with the supporting illustration facilities for an error, problem access from the user for a consultant and a solution from a consultant for the user.

User-consultant interaction / **Time of interaction**	**user alone**	**face-to-face**	**remote**
synchronous	(explorative) learning with a film about the past (errors or problems) and for the future (solutions)	consultation with one screen about the presence and films about the past (errors or problems) and for the future (solutions)	consultation with shared screen about the presence and films about the past (errors or problems) and for the future (solutions)
asynchronous	—	—	consultation with the user's films about the past and presence (errors or problems) and the consultant's film for the future (solutions)

Figure 2: Kinds of (inter)action for different time and site conditions

The proposed technical support for exploiting learning and consultation results is to strengthen the users and the consultants of Information Centres. Users can help themselves in re-consulting solutions they found on their own or solutions that they received from consultants in the past; they get more independent from help by third parties. Help-desk or background support members are supported in the communication with the users by receiving authentic sequences of faulty user actions and by sending demos of solutions the user can explore as intensively and often as he or she likes. Also downloaded Bulletin Boards and Mailboxes of technology providers [Knolmayer 90, 157] can be locally combined with the demotheques of users and the purse of demos of user groups. Local copies of individualised bulletin boards will more probably be accepted than generic external ones. The support personnel is relieved of repeated requests because users can consult the own demotheque or the local purse of demos instead of re-addressing human consultants.

User support units tend to develop decentralised structures in their mature state [Moning 93, 535]. Demotheques and purses of demos as a locally available user information repository can

amplify this development. They also supplement the dominance of phone-based hot-line services found by [Moning 93, 536]. Demotheques and purses of demos can reduce the overload of central and local user support units only if they follow in structure and content the dynamics of the support requirements for user service units are not only faced with quantitative capacity problems but also with rapidly changing qualitative user demands [Moning 93, 539]. Demotheques and purses of demos have to be structured and maintained carefully to not mislead users with out of date information. For a local expert it might be a consultation job to look for the individual demotheques of the users and a maintenance job to look for the demotheque of the user group. Nardi reports the role of a "gardener" to support users as a formal position with benefits far outweighing the costs [Nardi 93, 116].

5. PREVIOUS WORK

LEAR is the newest project in our ongoing research efforts to explore concepts and prototypes for supporting domain workers in getting their job done. In a former project we developed prototypes of a system to be adaptive or to be adaptable to the user [Oppermann 94a; 94b; Thomas 93]. Adaptive or adaptable interfaces can increase the usability of applications. What we learned in designing and evaluating adaptable and adaptive features of a user interface was that users had to learn a lot about the rational, the handling, and the benefit of adaptable or adaptive features. The learning process and the access to the results of adaptation has to be supported by the technical system (in that case by the adaptation component). The adaptation of a system is a process rather than an act and calls for opportunities of doing and undoing, performing and reflecting adaptations both initiated by the user and initiated by the system.

Opportunities for reconsideration and modification of action sequences are far more general demands in the learning and mastering process of complex systems. Opportunities for reconsideration and modification of action sequences in problem or error situations beyond the issue of adaptation are the issue of the new project we are presenting in this paper: The support for enhancing the learning and consultation process and its exploitation in later situations.

6. FUTURE DIRECTIONS

Future work with LEAR will go into two directions: (a) an empirical analysis of today's shortcomings in real applications domains, and (b) the development of a conceptual framework for LEAR.

The empirical tests will be conducted based on a questionnaire for user-consultants working in different domains, such as assurance companies, banks, and industrial companies. We ask them how consultation is done when domain workers ask for their help. Moreover, we would like to study domain workers at their workplace when dealing with their daily computer working environment.

The second direction is preparing a conceptual framework and a prototype that will be used when the empirical tests are conducted. The framework includes the integration of a general recording facility into a Macintosh or PC environment, able to record users interaction with

applications. Some commercial software products with recording facilities are available, both for Macintosh and PCs, but their functionality is beyond what we think is needed and should be made accessible. Our hope and expectation is that more complex recording facilities will be available in the nearest future.

But recording is only the first step, other steps are to comment and edit on episodes, classify them and store them in a demotheque and make them accessible for the future as easy as possible. This is a general problem of how to store information, locating it, searching for it, or finding it again. In another project, BASAR [Thomas 95], we are dealing with how information consumers can be supported in their searching for information process by software agents. The insights we gain form this project are invaluable for the design of intelligent access to the episodes in LEAR, so that domain workers when being in trouble are "getting the right episode at the right time".

ACKNOWLEDGEMENTS

We would like to thank Udo Bleimann (FH Darmstadt) and Gerhard Fischer (University of Colorado at Boulder) for their contribution to the ideas of the paper.

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