User-interface design

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Summary. User interface design is a central issue for the usability of a software product. In this chapter, general requirements referring to the international software ergonomics standardization and specific design features for the user interface of learning systems are presented. Orientation and feedback for the learner are the most relevant issues of interface design of learning systems. Information presentation methods appropriate for learning are proposed. Contextualization of learner support by individualized interfaces, by active and situated learning means, and contextual on-line help are proposed. Reflection during and after the design and development of an interface are recommended.

1 Introduction

In information societies, the changing character of learning requires a learning environment encompassing new interfaces between technical systems and learners during the whole learning process. Learning is not restricted to a separate period of life and not explicitly organized as a learning event. There will be dedicated educational applications that are designed for learning, showing a didactical concept, containing defined learning goals, and aimed at defined learner groups. But learning will be more and more integrated into the work process and in daily life activities where work applications are (also or occasionally) used for learning, e.g., text editors for spelling rules or spreadsheets for statistical methods (Baumgartner 1995). User (i.e., learner) interfaces for both kinds of learning support environments, curriculum based learning, and learning on demand, need particular care. A learner works with a learning system guided by the content presentation (implicit guidance) and instructions how to use the content presentation (explicit guidance). Implicit and explicit guidance have to be sufficient to help the learner to understand the system's use – no help system should be required. This is different from working systems where courses, training modules, or on-line help often is an integral element of the introduction of a new system at the workplace. The more implicit guidance by content presentation is sufficient for the learner the more the attention can be devoted to the learning of the domain content rather than to the system's handling. The content presentation and the facilities of the user to interact with the content are the main tasks of the user interface.

2 General requirements for user interface design

Based on theoretical and empirical work in software ergonomics (human factors) in the seventies and the eighties, standards have been developed for defining the usability of software products. One of the structural basis has become the IFIP user-interface reference model (Dzida 1983). The model proposes four dimensions to structure the user interface: the input/output dimension (the look), the dialogue dimension (the feel), the technical or functional dimension (the access to tools and services), and the organizational dimension (the communication and co-operation support). The model has greatly influenced the development of the international standard ISO 9241 describing the interface design requirements for usability (Dzida 1996).

The *concept of usability* is defined in Part 11 of the standard by effectiveness, efficiency, and satisfaction of the user. Part 11 gives the following definition of usability: „Usability is measured by the extent to which the intended goals of use of the overall system are achieved (effectiveness); the resources that have to be expended to achieve the intended goals (efficiency); and the extent to which the user finds the overall system acceptable (satisfaction).“ For a more detailed discussion of the term usability see (Bevan 1995). Effectiveness, efficiency, and satisfaction can be seen as quality factors of usability. To evaluate these factors, they need to be decomposed into sub-factors, and finally, into usability measures. For a discussion of how effective usability principles are see also (Bastien & Scapin 1995).

The structure of the multi-party standard can be understood by the following figure.

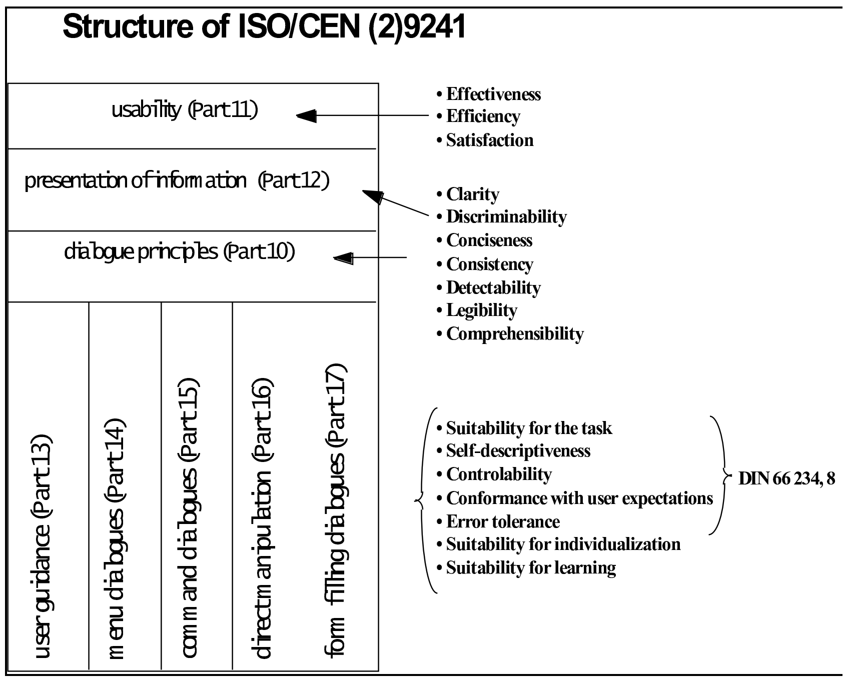

Fig. 1. Structure of the multi-party standard ISO 9241

The dynamic characteristics of a system are described in terms of *dialogue requirements* contained in seven principles of part 10 of the ergonomics standard. This standard establishes a framework of ergonomic ,,principles“ for the dialogue techniques with high-level definitions and illustrative applications and examples of the principles. The principles of the dialogue represent the dynamic aspects of the interface and can be mostly regarded as the ,,feel“ of the interface.

The seven dialogue principles are:

- *suitability for the task*: the dialogue is suitable for a task when it supports the user in the effective and efficient completion of the task;
- *self-descriptiveness*: the dialogue is self-descriptive when each dialogue step is immediately comprehensible through feedback from the system or is explained to the user on request;
- *controllability*: the dialogue is controllable when the user is able to initiate and control the direction and pace of the interaction until the point at which the goal has been met;
- *conformity with user expectations*: the dialogue conforms with user expectations when it is consistent and corresponds to the user characteristics, such as task knowledge, education, experience, and to commonly accepted conventions;

- *error tolerance*: the dialogue is error tolerant if despite evident errors in input, the intended result may be achieved with either no or minimal action by the user;
- *suitability for individualization*: the dialogue is capable of individualization when the interface software can be modified to suit the task needs, individual preferences, and skills of the user;
- *suitability for learning*: the dialogue is suitable for learning when it supports and guides the user in learning to use the system.

The *information presentation* is described in Part 12 of the standard for the organization of information (arrangement, alignment, grouping, labels, location), for the display of graphical objects, and for the coding of information (abbreviation, color, size, shape, visual cues) by seven attributes. The „attributes of presented information" represent the static aspects of the interface and can be generally regarded as the „look" of the interface. The attributes are detailed in the recommendations given in the standard. Each of the recommendations supports one or more of the seven attributes. The recommendations for presentation of information also contribute to the application of the dialogue principles, mainly to the conformity with user expectations.

The seven presentation attributes are:

- *clarity*: the information content is conveyed quickly and accurately;
- *discriminability*: the displayed information can be distinguished accurately;
- *conciseness*: users are not overloaded with extraneous information;
- *consistency*: a unique design, conformity with user's expectation;
- *detectability*: the user's attention is directed towards information required;
- *legibility*: information is easy to read;
- *comprehensibility*: the meaning is clearly understandable, unambiguous, interpretable, and recognizable.

The user guidance in Part 13 of the standard describes that the user guidance information should be readily distinguishable from other displayed information and should be specific for the current context of use. User guidance can be given by the following five means:

- Prompts indicating explicitly (specific prompts) or implicitly (generic prompts) that the system is available for input;
- feedback informing about the user's input timely, perceptible, and non-intrusive;
- status information indicating the continuing state of the application, the system's hardware and software components, and the user's activities;
- error management including error prevention, error correction, user support for error management, and error messages; and
- on-line help for system-initiated and user initiated requests with specific information for the current context of use.

Based on the described general usability requirements in Part 10 to 13 of the standard, the requirements for specific dialogue techniques like menus, commands, direct manipulation, and form filling are described in Part 14 to 17.

For a user interface, the usability requirements listed above should not be regarded as isolated aspects but as interrelated and sometimes constituting conflicts, in fact, e.g., between self-descriptiveness and controllability. User interface design is not a task following mechanically well-defined requirements but user interface design is as well a complex combination of ideas, intuition, and experienced competence (Wood 1998). The usability principles presented in this chapter provide some of the terminology that can be used to describe the requirements for the user interface design specific for educational software in the next section.

3 Specific User interface design for learning software

User interfaces of learning systems have to meet all of the standard user interface requirements of the previous section. Educational software requires particular features for the specific purpose of educational systems. Even there is a huge amount of literature about user interface design, there are only a few with specific concern on user interfaces for learning environments – and those who do intermix specific and general requirements (Jones & Okey 1995). Specific for educational software from the point of view of the user interface is:

- The user of a learning system is a novice of this individual system and can never be supposed to be a routine user of the product. Maybe of course the user is an expert in other software systems. Educational software will be used by a user for a limited time until he or she has learned the content of the system. The user interface of an educational system should therefore be "self-descriptive" and "suitable for learning" to a much higher degree as many other applications. The user should not need to learn the interface before starting to learn the domain content of educational software. The interface should incorporate as much of the interface features of systems the expected user population is familiar with.
- An educational system is not under the control of the user as a working application is. The goals of the system and the sequences of the dialogue follow the underlying educational curriculum. This particularity does not exclude user controllability but requires much more guidance to communicate the meaning of particular elements and particular sequences of the educational system.

Suitability for learning in educational software includes more than the respective user interface requirement described in the previous section. Suitability for learning in working applications means that the user interface of the application supports the understanding of the components and the dynamics of the interface. Suitability for learning in educational software goes beyond these requirements. The user interface of educational software should not require any or should only require a minimal amount of learning.

3.1 Orientation and Feedback

In this section we shall discuss the specific requirements for a learning system in detail.

Learner Orientation and Navigation

In educational systems, an overview about the content space of the system by content lists, graphical displays, or walkthroughs helps the user to know what the system provides about the domain and what the system expects the learner to learn. Expectation means that the learner can develop an anticipation of the content, the dynamics, and the result of the learning system. Anticipation stimulates the motivation of the learner like an appetizer and activates the cognitive readiness to perform the learning tasks expected by the learning system. Surprise – being effective for entertainment – can induce fear of failure instead of hope for success, if used in an unknown learning environment.

Overview can be described on several layers. The first layer is the general overview of the content space of the system. The second layer is the detailed substructure of the chapter the learner is currently working with (context of use). The third layer is the design and distribution of the content and the design and distribution of the interaction controls for a given learning unit (e.g., a page).

For the general overview of the system, content lists can be presented or graphical trees can help the learner to develop an understanding of the issues to be learned and of the sequence of individual chapters. The structure of the system may be hierarchical, linear, or may be designed as a hypermedia. Hypermedia allows for flexible access to specific parts of the learning material, but hypermedia organization requires extensive navigation by the user both cognitively and practically. Linear sequences with “Next” buttons represent the other extreme where the user can only go along a stream of steps predefined by the designer. It is up to the user group and the content whether the flexible hypermedia structure or a hierarchical or a linear design is appropriate.

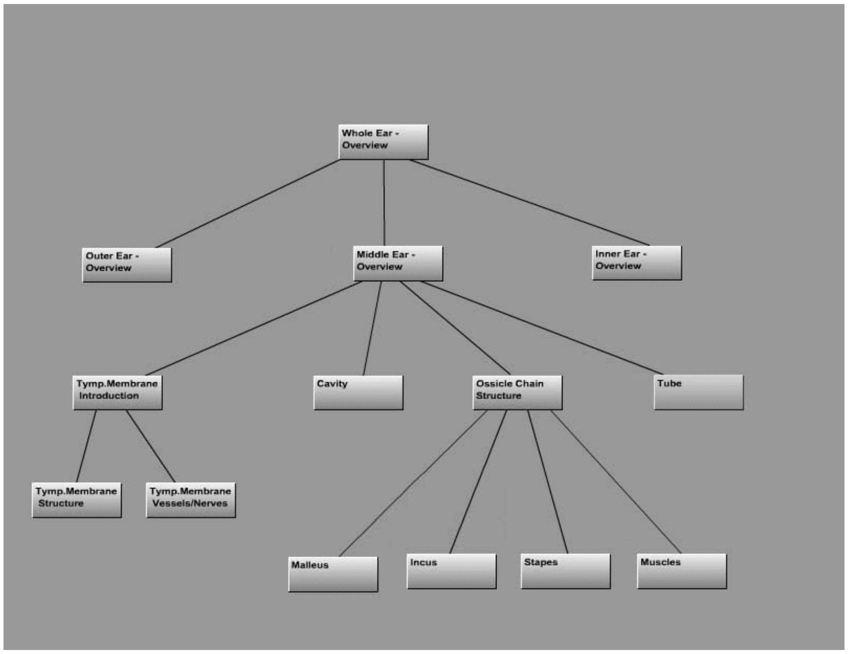

Fig. 2. Overview of the hierarchical structure of learning chapters

For a detailed overview of the current learning chapter, the user interface can show the relation between the given context of learning by showing prerequisites and successors within the learning system to support the orientation of the learner. Switching between performing a learning task and the overview of the local or general environment should be possible.

For the overview of the learner about the current task, time and space related design principles are to be applied. Time related principles require a simultaneous presentation of prompts (instructions) and task completion. The learner shall be able to study the instruction while performing the solution. There are learning systems designed as a sequential dialogue with instructions either automatically disappearing after a short time or to be answered by an OK button and the task to be performed subsequently not seeing the instruction or question any more. This is particularly unacceptable if the instruction comprises several actions or several parameters to be considered by the learner. If instruction and performance cannot be displayed simultaneously, the instruction should be recallable by the learner during the task performance.

Space related principles require a presentation where information and interaction entities form a unit displayed on the screen or in a window respectively. Screen sizes may vary between learners unknown to the designer and a screen size in principle may be too small to display all information relevant to a learning task on one screen at a time. But information organization for a learning unit must take into account limited space for presentation and should organize the unit so that the information can be displayed coherently (Schwier & Misanchuk 1993). If the length of content requires scrolling the main content (keywords) should be presented on the first page. Arrangements of information on the screen may include headings of content in tables or graphics. If the content list of tables exceeds the expected size of a screen, scrolling of the content items should retain the headline continuously displayed for the user. The same is true for buttons to control the information presentation and or the navigation through the learning system if the navigation controls are not separated from the information presentation, e.g., as a panel on the left side of the screen.

To support a time and space related overview for the learner during the learning process, the sequence of presentation should follow the cultural reading habit of the learner. In western societies, the sequence of working through a page should follow the reading habit from top left to bottom right, i.e., the instruction should start on the top left, the content follows in the middle, and the interaction controls to submit answers or questions can follow at the bottom.

Orientation in the system is supported by clear presentation of instructions, learning materials, and feedback. All three elements of a learning system should be clearly distinguished. They can be coded by place, color, frame, or by wordings that make clear that a string is meant to be instruction, learning material, or feedback. The following figure shows an example of place coded discrimination between different display areas.

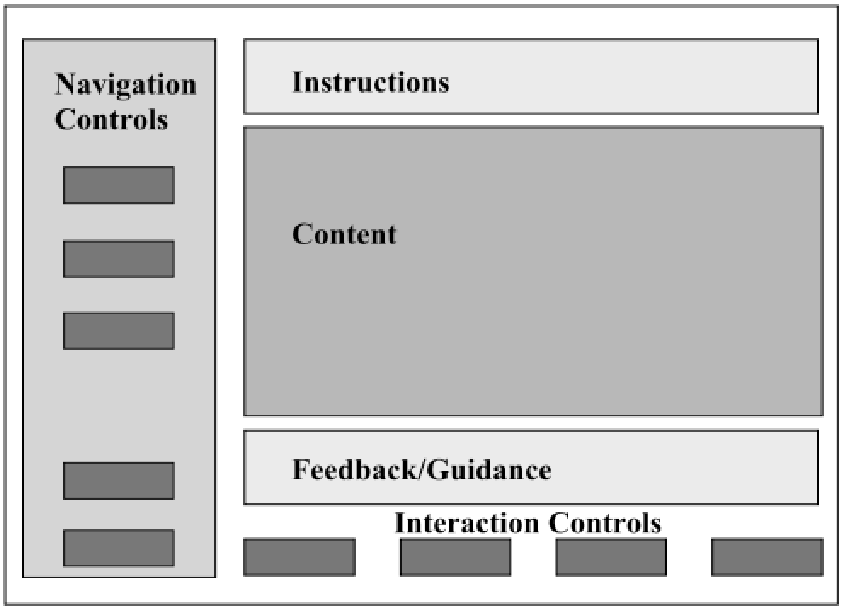

Fig. 3. Place coded discrimination of display areas on the screen

Whether instruction is given or more self-directed learning by the learner is envisaged, depends on the educational philosophy. Instructions are based on a (hierarchical) structure of goals and sub-goals and an analysis of steps that lead to these goals. Constructivist approaches doubt the appropriateness of instructions as a guiding element in a learning environment (Laurillard 1993). Exploration in the information space of the learning system allows for more flexible and self-directed user actions (see below).

By the overview of the system and by navigation of the learner through the system, a cognitive map will be produced in the mind of the learner. A cognitive map helps to structure the content space and to remember parts of the elements in the context of total learning space. To support the development of a cognitive map the system should allow the learner to know where the learner is in the learning space, what he or she has already learned and how much and what is still to be learned. Navigation can be supported by information about the learning path of the learner, how he or she comes back to a certain chapter like using an Ariadne thread, and hints how to access particular further contents. Navigation can also be supported by structural information about how the learner has progressed so far. The following figure shows an extension of the overview shown in Fig.2 by giving an example how information about the current status of the learning process can be displayed.

The figure contains the overview about (a subset of) the system's learning chapters (rectangles), the amount of visited learning units belonging to the learning

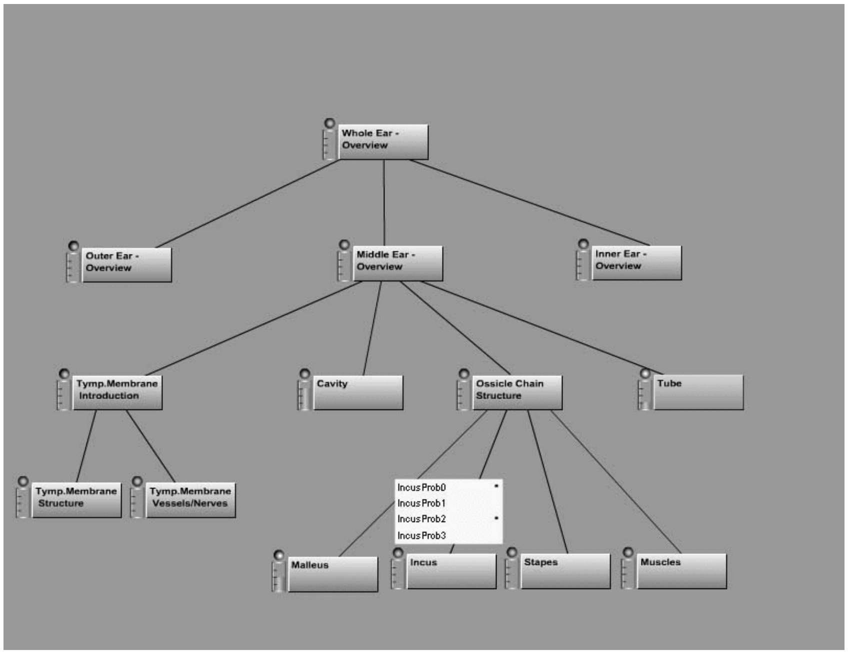

Fig. 4. Learning status overview (see Fig. 2 for the structure overview)

chapters (glass tubes indicating the proportion of completed units by green fillings), and colored circles indicating whether the test tasks of a learning chapter has been performed (the circles change from yellow to green for all tasks performed successfully). Moving the mouse over the glass tubes displays a list of all learning units constituting the chapter with check marks for the completed units; moving the mouse over the colored circle displays a list of all test tasks with checkmarks for the successfully completed test tasks. The example is taken from a medical education system (Novak & Simm 1999).

Learner Feedback and Guidance

“The provision of feedback is a central function in learning environments.” (Boyle 1996, p. 153) User feedback is best be given by implicit system reaction, provided by simply accepting the user’s allowed input. Explicit feedback should be reduced to necessary extend not to interrupt the workflow of the user. In learning systems, feedback is to be given explicitly for solutions if the learner is to be ensured that the task is performed correctly or incorrectly. Explicit user feedback at least should be provided on request. Feedback on request in a particular learning unit or about the overall learning result can be given by graphical displays containing the chapters of the system, the learning units, and the completed tasks.

Feedback about learning results can be presented to the user by pop-up text boxes, overlapping the learning window to save separate feedback fields on the screen. An overlapping text box should be located context sensitive not hiding relevant information areas; the box should be relocatable by the learner. Pop-up text boxes can also be used to present annotations and help on demand. When initiated by the user, it can be evoked by a mouse click or by mouse over, most popular as 'bubble help'. In former case and when initiated by the system, the text box can be designed as a modal or a non-modal box. Whether or not the text box is of a modal type or can be quit by direct continuation of interaction with the learning task depends on the quality of the information to be presented. If the information is critical, the text box should be quit explicitly; if the information is not critical, the box should disappear by direct user interaction with the learning material. The type of text box should be communicated to the user, e.g., by OK/Cancel buttons only if modal text boxes are used. Text boxes should be clearly separated from the learning environment, e.g., by color or frame.

Fig. 5. Annotated content overview: arrow highlights current unit, red units have missing prerequisites, units with a hook are already mastered

In intelligent systems, learner models contain assumptions about the learning success that can be visualized for the learner (Schoech, Specht, & Weber 1998)—for intelligent and adaptive systems see Chapter 1-9 in this volume. At the interface level, access to inspection and correction of learner assumptions can help the student to understand and benefit from the intelligent guidance. Annotations of recommended entries, or issues not recommendable for the pre-knowledge of the learner can be designed by icons associated to the content list: green bullets for already learned issues, arrow for current issue, yellow bullets for recommended issues, and red bullets for non-recommended issues.

3.2 Information Presentation

The information presentation in learning systems should reflect the type of the learning material (text, graphic, sound, video), the type of the learner (expertise, interests, preferences), the task and the environment of the usage of the system (noise, light, social community). The type of learning material appropriate for the learning goal is considered by the content designer of the learning system. What matters for the interface designer is the kind of information presentation once the type is decided by the content designer.

Modality and coding of information presentation

The learning material will encompass several types including text, graphic, tables and perhaps sound and video. Negroponte who is not suspicious to underestimate the importance of multimedia says, “the power of the word is extraordinary” (Negroponte 1995, p. 7). Pictures and icons can be used as eye catchers to direct the attention of the users. “Color infuses life and aesthetic impact to the presentation. It can also signal screen composition, and code and separate blocks of information.” (Boyle 1996, p. 151). Three functions are distinguished for pictures, illustration, structuring, and decoration (Thissen 2000). Weidenmann describes a function of pictures to be compensatory if receivers of information are not capable to understand abstract or textual descriptions (Weidenmann 1995b, p. 108). Pictures and icons are helpful to structure the information presentation for the learner; to be understandable, icons should be accompanied by text. In learning systems, buttons with a label are preferable while in routine applications the prominence of icons may be designed for their fast visual addressability.

Whether or not acoustic presentation of text should be chosen depends on several factors. Natural language should be used if the learner has to follow a dynamic presentation (animation, film) or has to understand a graphically presented structural description. Acoustic presentation of natural language and graphical presentation of still or moving pictures/graphics can make use of both sensory, eyes and ears synchronously. If the explanation is presented as written text, the learner has to jump with his or her eyes between demonstration and explanation. Acoustic presentation of natural language can only be chosen if the learner is alone or is prepared to use a headphone. Learning in a classroom with speakers is disturbing other students.

Formatting of information presentation

If learning materials contain longer text passages, text presentations must be designed for legibility. Long text passages should be structured into several short and middle range portions to be readable. Short lines of about 60 to 80 letters per line (like this text, for example) are appropriate for the reading flow on the screen; on paper the length may be a bit longer. A line space of 1 1/2 or 2 is appropriate for the screen with less space being OK for print outs on paper. Alignment left is superior to justification because the spaces between words are more homogeneous.

Reading text on the screen is more fatiguing than on paper. For learners, perceiving text on the screen is more similar to scanning than to reading (Thissen 2000, p. 71). The structure should show a relaxed arrangement. Serif fonts are less legible on screen due to the at least four times lower resolution compared to printed text. Given appropriate resolution, serif text provides a higher discriminability of similar letters, e.g., “Illness” with serif fonts compared to “Illness” with sanserif. On screen, sanserif fonts and font sizes 12 or bigger are preferred (Boyle 1996, p. 156).

Capital letters should be avoided for text presentation, including highlighting important keywords. Capitals are hard to read because the height is unique for all letters.

Modern systems make extensive use of colors. Too many colors and too much contrast by highly saturated colors should be avoided (Marcus 1992). For learning materials to be read on the screen, an appropriate background color is required. The choice of background color has to consider two requirements: being light enough and proving appropriate contrast to the colors of the learning material. White is one option that is light and neutral to the foreground learning material; but it may be too loud for large proportions of the screen. Grey is another option that can satisfy both requirements, being neutral and light. Blue is a third option as an unobtrusive color, “the distribution of cones in the eyes also makes peripheral vision of blue over large areas quite effective” (Boyle 1996, p. 162). Pictures used as semi-transparent background should be avoided if only used as decoration; it may be nice but it reduces the legibility of the learning material too much.

3.3 Contextualization of learner support

Individualization of user interfaces to personal needs

Users with different background and preferences may use a learning system. It is helpful for the learner to use a system adapted to the personal needs. An adapted system can be achieved by a special development or adaptation by a designer. This will seldom occur because it needs a personal requirements analysis and individual design. A second approach is a user interface that is adaptable by the user. In this case, tools and methods are needed for user adaptations. A third option is an automatic adaptation performed by the system, evaluating the user interaction. Here, user-modeling techniques are required to provide an adaptive user interface. Adaptable interface features can be helpful, e.g., for the background colors (for color-blind learners), for font sizes (for vision impaired learners), or for presentation modalities (written or spoken text for different personal preferences or external factors). Individualized user interfaces should keep the control in the hand of the user. A shared control by providing initiatives of adaptation for both, users and the system with a final decision about the adaptation by the user and the execution supported by the system may be appropriate (Oppermann 1994, p. 2). Beyond the user interface, adaptive systems can also provide individual learning support by adaptive user feedback and user guidance as mentioned above and described in chapter 1-9 in this volume.

Active and contextualized learning

Learning theory based approaches try to reinforce active learning styles as superior to passive learning (Carroll & Mack 1985; Paul 1995). Active learning can be done by exploration. Exploration supported by facilities of the learning system allows the user to develop hypotheses and test the hypotheses by simulation of models about the domain. The exploration of a user can be relieved by a user specific limitation of all possible actions reflecting the history and knowledge of the learner and suitable exploration options (Kashihara, Oppermann, Kinshuk, Rashev, & Simm 1997). Active learning by exploration supports the understanding and the retention of the learner. This does not mean that all learning takes place as exploratory learning. In particular with new dynamic media also observation based learning by animations and movies can be very successful and at the interface level different styles of learning optionally should be available.

Exploration can be integrated into the learning context where the result of the exploration is only represented in the head of the learner, i.e., his or her understanding of the domain knowledge. Exploration can also be embedded into the work context where the result of the exploration with real data matters. An explorative learner experimenting with real work data in the work context needs means to control sample actions. The learner has to be aware of and sure about the possibility to take back any or a particular set of actions without enduring consequences to the work data. The feature to control user actions to support trial interactions experimenting with hypothetical solutions is known as a (sequential) UNDO/REDO facility (Paul 1995; Thimbleby 1990). An UNDO function in a learning context needs more than to take back a (series of) user interactions. In a learning context, (graphical) displays of paths are helpful for the learner to understand different solutions with optimal, sub-optimal, and wrong results. Additional feedback about the learner's trial and error solutions increases the cognitive benefit of the learner. Errors in a learning context have another quality than in a work context. It is true in general that we learn a lot by evaluating errors. This is in particular true in a learning context where errors are indications of the learners state of understanding and learning progress. Feedback about errors or sub-optimal solutions can be generated by the system (intelligent guidance) or given by the learner by own contextualized annotations (Oppermann 1996). Exploration embedded into the real work context increases the authenticity of the learning tasks and increases the motivation of the learner. Embedding the learning system into the work context also supports the application of the learning result to the work situation – for situated learning see (Andriessen & Sandberg 1999; Lave & Wenger 1991; Mandl, Gruber, & Renkl 1995).

Learning is a continuum of acquiring, using, and forgetting knowledge. Learning is a sequence of cumulative knowledge acquisition and application. Annotations to elements of the interface and recording episodes of errors and problem solving can support the process of learning for later use (Collins, Brown, & Newman 1989; Oppermann 1996; Weber 1996). Learning in a situation is based on previously acquired knowledge – we learn what we already know.

An new issue of interest for contextualized learning is introduced by nomadic computing (Kleinrock 1997; Oppermann & Specht 1999). Nomadic computing makes use of both mobile and stationary devices to supply information access everywhere and every when. Nomadic computing differs from mobile computing that nomadic computing makes use of all types of devices, including mobile ones, for providing information access to personal and public information spaces. Nomadic users can get equipped with mobile devices being continuously connected to public and personal information spaces and to the user's personal learning environment. The system can provide suitable information by location awareness components adapted to the user's current position and orientation, by domain models adapted to the users learning task, by a student model adapted to the learner's knowledge and by an environment model adapted to the physical surroundings and the technical equipment of the user. Taking into account these elements, i.e., the position and orientation, the task, the learners knowledge, and the environment, constitutes a contextualized information selection and presentation. Contextualization (Abowd, Dey, Abowd, Orr, & Brotherton 1997; Alpert, Singley, & Carroll 1995; Brézillon 1998; Fischer 1991; Resnick 1989) provides an extensive means to increase motivation and effectiveness of learning.

Presentation of On-line help

Questions to be asked about the interface and its functionality. On-line help that is specific for the current learner's situation is called contextual help. Contextual help evaluates the user's possible problem and goal and tries to provide a suitable solution. Suitable solutions can seldom be provided as a one-shot-solution. A restraining approach is recommended to leave the learner the possibility to select a personal solution out of a set of probable options prepared by the system. Fox et al. propose a hierarchical browser to present focal solutions together with higher or lower level alternatives respectively (Fox, Grunst, & Quast 1994, p. 141ff.). Contextualized help need not to be presented automatically by the system, interrupting the user during his or her learning task. Contextualized help can be provided as well on request, preparing the contextualized view to the learner's current task in the background.

Presentations of possible solutions can be supported by the user interface of a learning system to increase the self-descriptiveness. Contextual help can have two goals: supporting domain issues (what to learn) and supporting interface issues (how to use the learning environment): The latter has been the focus of this chapter

4 Conclusion

The described features of user interfaces are principally relevant for all kind of applications not only to educational environments. In particular, user interfaces for educational systems must keep in mind that learners have to be supported by the user interface to gain an overview about the structure of the learning space, the learning methods, and the learning procedures. Users of learning systems are principally novices in this individual system and can not be considered as routine users who will learn how to use the application before they start to use it. Overview, navigation support, and recommendations are main features of the interface of an educational system. Upcoming features like individualization, intelligent guidance, and contextualization of information selection and presentation by environment sensitive mechanism increase the capability to cope with the demands of learning on demand and life-long learning.

User interface design is as good as the support for a good design. This support can comprise the designer competence, interface guidelines, construction tools, and evaluation feedback. The competence of the designer can be based on individual intuition and explicitly acquired competence. Good interface design can also be supported by tools to provide on-line recommendations (guidelines) and generic solutions for good interface design (Reiterer 1994). Interface guidelines like (Microsoft 1995) are more concerned with compatibility and standardization but they also consider “good design” solutions. Good interface design can finally be assured by formative and summative evaluations of design results (Oppermann & Reiterer 1997) – for evaluation methods of the educational component of learning systems see also Chapter 2 – 7 in this volume.

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