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An approach to usability evaluation of e-learning applications

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Abstract Despite recent advances of electronic technologies in e-learning, a consolidated evaluation methodology for e-learning applications is not available. The evaluation of educational software must consider its usability and more in general its accessibility, as well as its didactic effectiveness. This work is a first step towards the definition of a methodology for evaluating e-learning applications. Specific usability attributes capturing the peculiar features of these applications are identified. A preliminary user study involving a group of e-students, observed during their interaction with an e-learning application in a real situation, is reported. Then, the proposal is put forward to adapt to the e-learning domain a methodology for systematic usability evaluation, called SUE. Specifically, evaluation patterns are proposed that are able to drive the evaluators in the analysis of an e-learning application.

Keywords E-learning · Learner-centered design · Usability evaluation

1 Introduction

In the age of Information and Communication Technology, it should be possible to learn being “far away” from the teaching source. There are unique advantages to distance education. Its “any time, any place” nature

could be part of a winning strategy for particular needs such as decongestion of overcrowded education facilities, support for students or teachers who live far from schools and universities, long-life education. Moreover, it could be a valuable opportunity for specific groups of students, such as disabled students, if the learning material is actually accessible to them.

E-learning is the most recent way to carry out distance education by distributing learning material and processes over the Internet. Making remote data and tools available to users requires to consider their different characteristics, such as cultural background, technical experience, technological equipment, and physical/cognitive abilities. It is very important to provide the widest access to e-learning facilities, in order to avoid the digital divide phenomenon in this socially and culturally fundamental application field. Ensuring usability and accessibility to the largest number of users should be one of the main goals of e-learning application developers, as well as a prerequisite that should allow users to profitably exploit such applications.

The purpose of educational software is to support learning. A major challenge for designers and Human Computer Interaction (HCI) researchers is to develop software tools able to engage novice learners and to support their learning even at a distance. Clearly, educational software should take into account the different ways students learn and ensure that student’s interactions are as natural and intuitive as possible. This could require revising traditional interaction paradigms to provide new flexibility and adaptiveness, suited to the peculiarities of the specific application field. Towards this end, there should be a synergy between the learning process and a student’s interaction with the software. Usability features should not only allow people to efficiently manipulate the interactive software, but should also be appropriate for the intended learning task. In Ref. [36], Squires and Preece argue that researchers have not considered enough the implications of usability features of an educational application in order to achieve educational goals. To this end, these authors

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assert that “there is a need to help evaluators consider the way in which usability and learning interact.”

A consolidated evaluation methodology of e-learning applications does not yet exist, or at least it is not well-documented and widely accepted. In Ref. [7], Dringus proposes to use heuristics without further adaptation to the e-learning context. Similarly, in Ref. [22] Parlangeli et al. evaluate e-learning applications by using usability evaluation methods (Nielsen’s heuristics [19], User Evaluation of Interactive Computers System Questionnaire [32]) that were developed to address needs and challenges of users of interactive systems, that is, not specific to e-learning. Squires and Preece propose an approach adapted to e-learning but there is a clear need for further elaboration and empirical validation [36]. In conclusion, the design of e-learning applications deserves special attention and designers need appropriate guidelines as well as effective evaluation methodologies to implement usable interfaces [43].

The authors of this paper have conducted work in the evaluation of specific types of applications in various domains (e.g., hypermedia). In particular, the SUE (Systematic Usability Evaluation) methodology was developed, which systematically combines inspection with user-testing [4, 5, 17]. The main novelty of this methodology is the use of evaluation patterns, called *Abstract Tasks* (ATs), describing how to estimate the compliance of application components with a set of attributes and guidelines, which are preliminarily identified for a particular application class. ATs guide the inspector’s activities, precisely describing which objects of the application to look for, and which actions to perform during the inspection in order to analyze such objects. In this way, even less experienced evaluators are able to come out with more complete and precise results. Such an approach is currently being experimented for the evaluation of e-learning applications and this paper reports the first results of a study that addresses the usability aspects of such applications. The work also includes a preliminary users study involving a group of e-students, observed during their interaction with an e-learning system in a real situation. In order to perform a more systematic evaluation, the proposed approach concentrates separately on two different aspects of an e-learning application: the platform (container) and the educational modules (contents). The main contribution of this paper is the definition of a preliminary set of criteria and guidelines for designing and evaluating usable e-learning applications and the description of an evaluation methodology that exploits such criteria and guidelines to drive the evaluators’ activities.

The paper has the following organization. First, the current state of the art in the domain of usability of e-learning applications is reported. The SUE methodology is briefly described in Section 3. Sections 4, 5, and 6 explain how the SUE methodology has been applied to the e-learning context, first describing the user study that has been conducted in order to identify criteria and evaluation patterns (ATs) to evaluate the usability of

e-learning applications. Finally, Sect. 7 concludes the paper referring to future work that addresses the important problem of evaluating the didactic effectiveness of the e-learning applications.

2 Usability in e-learning applications

From the point of view of people who need to use any interactive software system, usability is the most important aspect of the system. This section analyzes some usability issues in the e-learning field (Subsect. 2.1) and provides a brief description of the state of the art (Subsect. 2.2), in order to better motivate the proposed approach that will be described in the following sections.

2.1 Usability issues

The ISO 9241 standard defines usability as “*The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*” [10]. Usability plays a significant role towards the success of e-learning applications as well. If an e-learning system is not usable enough, it obstructs student’s learning: the learners would not spend more time learning how to use the software rather than learning the contents [42]. If the user interface is too rigid, slow and unpleasant, people feel frustrated, go away and forget about it.

One of the main goals of any learning system is to avoid any distraction to keep all the content fresh in the learners’ minds as they accommodate new and foreign concepts. In the specific case of e-learning, the challenge is to create an interactive system that doesn’t confuse learners. We often find that an e-learning application is a mere electronic transposition of traditional material, presented through rigid interaction schemes and awkward interfaces. When learners complain about web-based training or express a preference for classroom-based instruction, it’s often not the training, but rather the confusing menus, unclear buttons, or illogical links that scare them off. The success of any training program is largely dependent on the student’s motivation and attitude. If a poorly designed interface makes them feel lost, confused, or frustrated, it will hinder effective learning and information retention [15]. Moreover, technology should not become a barrier. Users with different hardware and software equipments should be able to exploit the e-learning artifacts, possibly through a suitable customization of access procedures.

Norman asserts that a formative application should [20]:

- Be interactive and provide feedback
- Have specific goals
- Motivate, communicating a continuous sensation of challenge
- Provide suitable tools

- Avoid distractions and factors of nuisance interrupting the learning stream.

Issues of usability take on an added dimension in an educational environment. It is not sufficient to ensure that e-learning system is usable, it must also be effective in meeting the instructor's pedagogical objective [2]. Silius and Tervakari say that it is important to evaluate the pedagogical design of e-learning systems [33]. They use the term *pedagogical usability* to denote whether the tools, content, interface, and tasks of e-learning systems support various learners to learn in various learning contexts according to selected pedagogical objectives. Obviously, the evaluation of the pedagogical design should not replace but integrate the usability assessment. In fact, an e-learning system should be pedagogically usable, though attractive and engaging. This means that the tools, as well as the kind of interaction provided, must be aimed at supporting the learner in the specific learning tasks and must be fitted to them, rather than being a mere exercise of (advanced) technology. They must be designed based on processes and activities suggested by well-established pedagogical models and outcomes. For example, the use of multimedia tools must be carefully planned in order to avoid a counter-productive overload of sensory channels. Using new technologies does not mean to reject traditional and successful teaching strategies, for example, simulation systems and problem-based learning. Thus, a learning system should allow integrating such strategies.

Looking for a set of features specific for e-learning system interfaces, we can assert that they have to provide a comprehensive idea of content organization and of system functionalities, simple and efficient navigation, advanced personalization of contents, and clear exit.

Nevertheless, a system providing new and flexible functionalities, supporting new strategies and allowing the integration with successful traditional techniques, could still suffer from poor usability. The need arises for a clear and coherent interface, able to involve the user in the learning process without overwhelming her/him. Distraction disturbs learning of new concepts and overall retention of what is being learnt. In other words, in the design of an efficient and motivating educational strategy, it is necessary to concentrate on the needs and goals of the learners.

The key to develop a system conforming to the above usability criteria is to adopt a Learner-Centred (LC) methodology [25]. Whereas User-Centred Design (UCD) assumes users' common culture and similar experiences in the application domain [11], in Learner-Centred Design LCD a variety of learners' categories must be considered, because of personal learning strategies, different experiences in the learning domain, and different motivations in undertaking the learning task. In general, learners are not particularly experienced in the learning domain. They could not even know the learning domain they are approaching, or know it only partially, or even have a wrong idea of it. Moreover,

learners are not all stimulated by the same motivation in undertaking a task, rather, a learner's motivation can be greatly influenced by the success rate experienced in learning. It will then be necessary to pay particular attention to aids that are provided (e.g., to the way scaffolding is managed [25]) and to the acknowledgment of the improvements attained.

While for UCD the user's effort only concerns the comprehension of a new tool to perform a well-known task [11], in LCD the gulf of expertise between the learner and the learning domain must be considered [25]. The goal of LCD can be defined as filling up this gulf, making the learner acquire all the knowledge and abilities related to a given subject. In the case of LCD, the double problem arises to obtain learning of an unknown domain through the use of an unknown tool.

As previously noticed, besides considering technological issues, it is necessary to rely on an educational theory somehow driving the designer in developing suitable applications. It is therefore necessary to rely on an educational theory driving the designer in developing suitable tools. At present, the constructivist theory is widely adopted: learning is recognized as an active process, where the "learning by doing" strategy takes the learner to cognitively manipulate the new learning material and to create cognitive links between such material and prior knowledge. For this approach to be effective, a task must always be included in an actual and collaborative context, to make the learner understand the motivation and the final goal of the task itself. This leads to the view that learners should be assisted in some way to construct and refine concepts in personally meaningful ways. From a constructivist perspective, learners need to be encouraged to take responsibility for their learning, while becoming more aware of their own knowledge. The constructivist approach has recently been significantly extended with social perspectives on the learning process, especially "situated learning." A situated view of learning implies that effects on learning of using information and communication technology will depend on the context in which it is used, with all the components of a learning environment (people and artifacts) interacting and contributing to the learning process. An amalgam of the principles of constructivism and situated learning is often referred to as "socio-constructivism" [34, 37].

2.2 Approaches to e-learning usability

Various usability evaluation techniques exist and choosing among them is a trade-off between cost and effectiveness. Some methods, such as heuristic evaluation, are easier to administer and less costly, but there are problems with using such methods. These problems mostly come from applying a small set of principles, the heuristics, to a wide range of systems. This is pointed out by various researchers, who in order to address this problem have developed more specific guidelines for

particular system classes [3, 16, 35]. For example, heuristics for the usability evaluation of groupware systems [3], and for systems with a large display, as those used for fairs or other exhibitions [35], have been identified. It would be suitable to provide specific guidelines in order to evaluate usability of e-learning systems as well.

Dringus proposes that usability heuristics summarized by Nielsen [19] and Shneiderman [32] can be applied to evaluate e-learning application interfaces as well. They include the following: strive for consistency, minimize user memory load, provide informative feedback, provide clearly marked exits, provide shortcuts, prevent errors, provide help and documentation, provide ease of use and ease of learning the system, achieve aesthetic appeal of the interface, provide controls for parallel and serial group communication, effect transparency of the interface [7]. Ravden and Johnson provide a checklist that emphasizes visual clarity, consistency, appropriate functionalities, flexibility and control, error prevention and correction, user guidance and support. Moreover, they have designed a questionnaire in order to measure users' preference of web-based testing applications [26]. Schwier and Misanchuk introduce principles of simplicity, consistency, clarity, aesthetic considerations (balance, harmony, unity), appropriate use of white space, time, and minimal memory load [31].

In Ref. [21], Notess asserts that usability testing needs additional consideration in the light of the web-based learning environments, such as learner satisfaction with the learning content, learner perception of the applicability of the content, learner enjoyment of the learning experience, and actual learning, measured via tests. In Ref. [38], Squires and Preece propose an adaptation of Nielsen's heuristics [19] taking into account socio-constructivism tenets: match between designer and learner models, navigational fidelity, appropriate levels of learner control, prevention of peripheral cognitive errors, understandable and meaningful symbolic representations, support for personally significant approaches to learning, strategies for cognitive error recognition, diagnosis and recovery, match with the curriculum [23, 34].

For evaluating usability of e-learning systems, in Ref. [42] the authors consider the following factors: e-learning system feedback, consistency, error prevention, performance/efficiency, user's like/dislike, error recovery, cognitive load, internationalization, privacy, and on-line help. The authors use fuzzy systems theory as a basis for representing such factors, and the fuzzy reasoning paradigm applying the Takagi-Sugeno (T-S) model for combining them into a single e-learning usability value [40].

Quinn et al. [24] propose a methodology for evaluating e-learning systems that takes into account design factors and acceptance factors: the former comprises instructional goal, instructional content, learning tasks, learning aids, and assessment, whereas the latter includes level of motivation to use the product, level of

active participation entailed, quality of learning support, and level of user satisfaction.

Recent studies also consider ethnographic issues in developing e-learning guidelines, starting from research about cultural variations influencing personal attitudes towards a number of behaviors and in particular towards aspects of interactive applications. For example, Hofstede identifies, among others, dimensions of individualism versus collectivism, masculinity versus femininity, uncertainty avoidance, and power distance that influence teaching and learning processes [9]. Galtung distinguishes saxonic, teutonic, gallic, and nipponic attitudes towards metacognitive activities such as paradigm analysis and theory formation [8]. Cultural issues might also influence learning styles, so that considering them during design helps obtaining a system suited for different ethnographic groups. The SELIM project is producing a number of guidelines in this direction [13, 14].

Trincherro proposes an organized set of indicators for evaluating the quality of formative systems based on ICT (Information and Communication Technology) [41]. The indicators express criteria encompassing the entire learning experience, from personal attitudes and abilities of lecturers to logistic suitability of the used infrastructures. Such indicators refer to specific analysis dimensions. Subsets of such indicators can be extracted to evaluate or compare specific learning applications and environments. A summary is reported in Table 1. The approach proposed in this paper also includes some criteria to evaluate e-learning systems that can be compared to the Trincherro's indicators.

To conclude the present discussion, it can be claimed, in agreement with other authors, that the number of studies devoted to identify usability issues of e-learning systems is not large [24, 39], and not proportioned to the importance of e-learning. As already noticed, it is true that a possibly significant part of studies in this field is not well documented or is undisclosed, for example, those performed by a number of institutions for private use. Moreover, it is often the case that the proposed criteria are only vaguely stated, so that an actual measurement is left to subjective interpretation and implementation. This is a general problem, especially when evaluation is based on heuristic techniques. There is a need to systematize the evaluators' work, providing tools to produce more objective outcomes.

While the long-term goal of the authors' research is to define an evaluation methodology that can address issues concerning both usability and didactic effectiveness, the work presented in this paper is mostly focused on the usability aspects of e-learning applications. Nevertheless, even such aspects are bound to the peculiar characteristics of such applications.

In the next section, a methodology for the evaluation of usability is presented that solves some drawbacks of heuristic evaluation and systematizes the work of the evaluators. Such methodology is applied in the e-learning context.

Table 1 Evaluation indicators identified in Ref. [41]

Analysis dimensions	Indicators
Quality of learning	Learning in instructive systems based on ICT Quality of monitoring of student's basic competencies and motivations Quality of lessons content Quality of structuring of the instructive path Quality of participation Quality of students' results
Quality of teaching	Quality of teachers'/tutors' competencies Quality of course preparation Quality of course organization Quality of didactic process Quality of applicative activities
Quality of learning environment	Quality of technological equipment Quality of interface Quality of infrastructures Quality of logistic services Quality of feedback
Quality of interaction	Quality of tutor—student's interaction Quality of students' interaction Propitious class atmosphere

3 Systematic Usability Evaluation

Usability inspection refers to a set of methods through which evaluators examine usability-related aspects of an application and provide judgments based on their human factors expertise. With respect to other usability evaluation methods, such as user-based evaluation, usability inspection methods are attractive because they are cost-effective and do not require sophisticated laboratory equipment to record user's interactions, expensive field experiments, or heavy-to-process results of widespread interviews. Usability inspection methods "save users" [12], though they remain the most valuable and authoritative source of usability problems reports. However, they are strongly dependent upon the inspector skills and experience and therefore it may happen that different inspectors produce different outcomes.

The SUE methodology aims at defining a general framework of usability evaluation [17]. The main idea behind SUE is that reliable evaluation can be achieved by systematically combining inspection with user-based evaluation. Several studies have outlined how such two methods are complementary [19] and can be effectively coupled for obtaining a reliable evaluation process. In line with those studies, SUE suggests coupling of inspection activities and user-testing and precisely indicates how to combine them to make evaluation more reliable and still cost-effective. The inspection has a central role: each evaluation process should start having expert evaluators inspecting the application. Then, user testing might be performed in more critical cases, for which the evaluator might feel the need of a more objective evaluation that can be obtained through user involvement. In this way, user testing is better focused, and the user resources are better optimized, thus making the overall evaluation less expensive but still effective [17].

Most of the existing approaches to usability evaluation especially address presentation aspects of the graphical interfaces that are common to all interactive systems, for example layout design, choice of icons and interaction style, mechanisms of error handling, etc. [18, 19]. SUE proposes, instead, that an application must be analyzed from different points of view along specific dimensions. Interaction and presentation features refer to the most general point of view common to all interactive applications. More specific dimensions address the appropriateness of design with respect to the peculiar nature and purposes of the application.

As previously mentioned, the SUE methodology requires to first identify a number of analysis dimensions. For each dimension, general usability principles are decomposed into finer-grained criteria [10]. By considering user studies and the experience of the usability experts, a number of specific usability attributes and guidelines are identified and associated to these criteria. Then, a set of ATs addressing these guidelines is identified. ATs precisely describe which objects of the application to look for and which actions the evaluators must perform in order to analyze such objects and detect possible violations of the identified heuristics. ATs are formulated by means of a template providing a consistent format that includes the following items:

- *AT classification code and title*: univocally identify the AT and its purpose
- *Focus of action*: lists the application objects to be evaluated
- *Intent*: clarifies the specific goal of the AT
- *Activity description*: describes in detail the activities to be performed during the AT application
- *Output*: describes the output of the fragment of the inspection the AT refers to.

During the inspection, evaluators analyze the application by using the defined ATs. In this way, they have a

guide for identifying the elements to focus on, analyzing them and producing a report in which the discovered problems are described.

According to SUE, the activities in the evaluation process, independently of the analysis dimension being considered, are organized into a *preparatory phase* and an *execution phase*. The preparatory phase is performed only once for each analysis dimension; its purpose is to create a conceptual framework that will be used to carry out evaluations. It consists of the identification of usability attributes to be considered for the given dimension, and the definition of a library of ATs. The preparatory phase is a critical phase, since it requires the accurate selection or definition of the tools to be used during each execution phase, when the actual evaluation is performed.

The execution phase is performed every time a specific application must be evaluated. As described in Fig. 1, it consists of *inspection*, performed by expert evaluators, and *user testing*, involving real users. Inspection is always performed, while user testing may occur only in critical cases. At the end of each evaluation session, evaluators must provide designers and developers with an organized evaluation feedback. An evaluation report must describe the detected problems. The evaluation results must clearly suggest design revisions and the new design can subsequently be iteratively validated through further evaluation sessions. While the user testing proposed by SUE is traditional, and is conducted according to what it is suggested in literature, the SUE inspection is new with respect to classical inspection methods; its main novelty is in the use of ATs for driving the inspectors' activities.

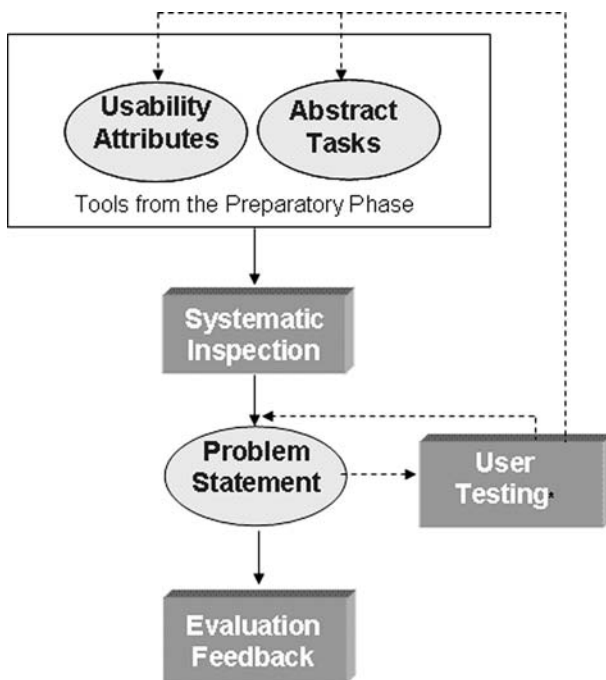


Fig. 1 Combination of inspection and user testing in the SUE execution phase

The advantages of this inspection technique have been demonstrated by empirical validation through a controlled experiment [6]. Two groups of novice inspectors were asked to evaluate a commercial hypermedia CD-Rom by applying the SUE inspection or traditional heuristic evaluation. The comparison was based on three major dimensions: effectiveness, efficiency, and satisfaction. Results indicate a clear advantage of the SUE inspection over the traditional inspection on all dimensions, demonstrating that ATs are efficient tools to drive the evaluator's performance.

The SUE methodology can be applied to different classes of applications, by properly identifying the analysis dimensions and the specific ATs. The study described in this paper aims at adapting such a methodology to the e-learning field. Towards this end, a first set of usability attributes and guidelines was identified capturing the peculiar features of e-learning applications. According to the SUE methodology, the ATs specific for e-learning were derived from such usability attributes and guidelines. The rest of this paper will describe some of them.

4 User study

In order to identify the main features of user interaction with e-learning applications, a user study has been performed in which ten students of a Master course at the University of Bari have been observed during their interaction with a Distance Learning (DL) system. A thinking aloud method was adopted [19], with the students working in the e-learning laboratory of the Department of Computer Science of the University of Bari. Their objective was to learn some new topics about HCI by using only the system via Internet and also performing some on-line tests to assess the learned content. A number of communication tools allowed to exchange information among them and to ask for help. At the end of the course, interviews were carried out for gathering further information from these students about their interactive experience. The basic questions concerned the kind of difficulties met, proposals for suitable ways to organize educational material and services, opinions about the communication tools used (forum, chat, mail).

Both thinking aloud and interviews highlighted a number of problems such as:

1. A major number of participants experienced disorientation and often reported bewilderment and difficulty to proceed, particularly when following a new learning path or using a service for the first time.
2. A number of users complained about the lack of mechanisms to highlight both lesson structure and high priority topics, in particular those scheduled for a particular learning session.
3. A lot of participants linked to a wrong didactic unit. It comes out that learning material presentation, providing a consistent visual conceptual map for easy

navigation, is a relevant aspect for the usability of an e-learning system. It would also be suitable to allow personalized access to the content.

4. Participants also reported problems searching the educational material to study. Search for documents should be facilitated, for example, by a clear specification of key-words for each subject.
5. A number of participants showed frustration when they had to start from the beginning due to network temporary disconnection. Therefore, a number of comments stated that it should be possible to use the platform also offline, preserving the reached educational context.
6. Self-assessment allowed the participants to check their progress, and this was found very motivating.
7. Participants also expressed a positive opinion on the communication tools, allowing collaborative learning: the teaching process can be managed for one or more learners, through synchronous and asynchronous interactions.

Table 2 presents a classification of the gathered comments and observations in three categories that refer to typical significant aspects of user interfaces, based on the hypertext paradigm [17].

The user study confirmed that e-learning usability is very complex. Presentation aspects have to be considered, in particular cues helping learning. Moreover, the presence of hypermedia tools suggests the possibility to personalize the reading path and communication through different channels, while still permitting orientation. Finally, user's initiative should be encouraged; the participants preferred self-assessment tests in order to evaluate their progress. The above aspects are related not only to the e-learning environment, but also to the structure of the educational material.

The next section discusses how the SUE methodology has been applied to design the usability evaluation of e-learning applications, and describes the usability dimensions and attributes identified by means of the user study, as well as the performed analysis of literature.

5 Usability evaluation of e-learning applications

An e-learning application should be evaluated considering both its usability and its didactic effectiveness.

Usability is related to:

- Functions provided
- Visual arrangement of application and content elements

Table 2 Classification of problems

Aspects	Percentage of users reporting problems
Presentation	80
Orientation	95
Functionalities	60

- Modes of interaction with application functions and content elements
- Navigation through application elements and content elements
- Fruition of application facilities and content elements.

Didactic effectiveness encompasses aspects related to:

- Educational planning of content elements
- Educational techniques, which are adopted
- Pedagogical soundness of proposed contents
- Level of detail of proposed contents
- Level of updating of proposed contents
- Correctness and accuracy of proposed contents.

As an example, according to usability aspects, an e-learning application should provide to different users the possibility to navigate, organize, and use the educational contents according to their own cognitive styles. Moreover, easy communication with lecturers and colleagues should be possible, for both coaching and cooperative learning.

It is also important to distinguish between the platform and the didactic module. Actually, an e-learning platform is a more or less complex environment with a number of integrated tools and services for teaching, learning, communicating, and managing learning material. On the other hand, the didactic module is the educational content provided through the platform (the container). Usability attributes for a platform generally differ from those of a specific didactic module (content), since different features must be considered.

However, some characteristics of the content provided through a platform are bound to functionalities of the platform itself. As a consequence, evaluating an e-learning application involves taking into account both components.

In identifying criteria and attributes for evaluating e-learning tools, it is necessary to consider the peculiarity of e-learning, whose primary goal is to allow students to learn the didactic material while devoting minimum effort to interaction with the system. According to the SUE methodology, four dimensions of analysis have been identified [1]:

- *Presentation* encompasses exterior features of the interface, highlighting possibilities and tools provided by the platform or by the didactic module.
- *Hypermediality* considers aspects bound to the communication through different channels and following a possibly non-sequential structure, stressing analysis and personalization of reading paths.
- *Application proactivity* takes into account mechanisms and modalities through which the application supports training and the activities of the user.
- *User activity* is focused on user needs, that is, on the activities s/he would perform, and on how the application copes with them.

The choice of these dimensions is based on the authors' previous experience in the domain of usability

evaluation of hypermedia system, stressing the importance of evaluating an application from different points of view in order to obtain more accurate results. One important aspect is presentation, since in any interactive system the appearance of the user interface plays an important role. The other aspect to evaluate is the structure of the hypermedia and its dynamic behavior due to the use of different media. This aspect is reflected in the hypermediality dimension. The other two dimensions emerge from considering the two interacting actors and their expected activities: the e-learning application, which should support the user (either the student learning the content or the lecturer designing the content) and possibly anticipate her/his needs, and the user, who should be made autonomous in the interaction process.

As previously noticed, the first phase of the conducted research mainly addresses “syntactic” aspects of platforms and contents. Further investigation is planned of more strictly educational characteristics, that is, characteristics bound to the pedagogical content, which constitute the second factor to gain full didactic effectiveness. A good source might be the indicators proposed by Trinchero [41]. As already shown in Table 1, he identifies the following dimensions: *quality of learning*, *quality of teaching*, *quality of learning environment*, *quality of interaction*. In particular, indicators in the first dimension are very useful for evaluating the quality of contents. The second and fourth dimensions are mostly devoted to evaluate the interaction processes established among students and teachers apart from tools and materials, and are out of the scope of this paper, because they do not measure the result of using an artifact but something related to social mechanisms. The guidelines elaborated in the work reported in this paper partly detail the indicators in the *quality of learning environment dimension* and the *quality of learning dimension*. A thorough analysis of the aspects concerning pedagogical issues and content semantics requires collaboration with experts of education science and experts of learning domains.

The four analysis dimensions previously outlined are further described in the next subsections, along with the evaluation criteria that have been identified for e-learning platforms (Subsect. 5.1) and e-learning modules (Subsect. 5.2).

5.1 Usability dimensions for e-learning platforms

This section analyzes how each dimension is specialized in the context of e-learning platforms.

The *presentation* dimension concerns only those aspects bound to the visual design of tools and elements of the e-learning platform. Actually, the presentation of platform elements, discussed in this dimension, should not be confused with their structuring and modelling, which pertain to other dimensions. In the presentation dimension the issue of the

clarity of presentation of platform tools is considered. It is necessary that the possibilities they provide to users are clear and that errors made using them be highlighted and easily recovered, when not avoided. It is also important that the student can easily identify in which part of the course s/he is at present and how to reach a different one. To this end, the platform should permit the visualization of the course structure, so that orientation and navigation among subjects (that is, through a map or a representation based on the folder metaphor) are facilitated.

Hypermediality appears as an important feature provided to lecturers and students, because it allows the lecturer to appropriately structure the didactic material also exploiting different media and allows the learner to choose a personalized logical path. Hypermediality may contribute significantly to learning if used in an appropriate way. Indeed, it is desirable to insert one’s own links (bookmarks) allowing to further increase the flexibility of content organization.

Application proactivity considers platform mechanisms to support user activities. Ease of use of such mechanisms gains an even greater importance than in generic interactive systems, because the student already makes a considerable effort in learning, which is her/his primary goal. Errors in using these mechanisms should be prevented as much as possible. If an error occurs, the platform should provide appropriate support to manage it. In defining attributes for this dimension, principles of the socio-constructivist approach, the educational theory most reliable nowadays, have been followed. This requires the platform to provide various tools related to this approach, such as communication tools (forum, chat, etc), the use of which should not require special students’ abilities. Ease of use of such tools is an aspect to consider in all UCD systems, and gaining even greater importance in LCD systems, where the user is mainly concentrated in the learning effort, which is her/his primary goal. As any other multi-user system, an e-learning platform must allow access to different user groups. Each of them will hold a specific role inside the educational process: lecturer, student, tutor, and administrator. The platform should allow to define different typologies of profiles and correspondingly provide different views and capabilities. These considerations apply specifically to the repository: lecturers and students are two actors bearing different characteristics and needs, and requiring different access modes to the repository. Moreover, it is necessary to consider the different languages used by the two user roles, usually more specific for the lecturer and less precise for the student; the platform should thus provide different searching modalities.

In the *user activity* dimension all the needs of a student/lecturer choosing to learn/teach at a distance are considered. For example, a student should be able to make assessment tests to check her/his progress, or to annotate and integrate the learning material provided with her/his own documents, or to choose among

alternative paths. Scaffolding and the possibility to personalize scaffolding attenuation must be provided, in order to efficiently cope with the two symmetrical situations of a student needing supplementary scaffolding and a student needing less of it. Lecturer's needs must also be considered. For example, tools should be provided for easy authoring and organization of the learning material. Moreover, even if it is not possible to evaluate students' engagement merely from observation of her/his activities, it is anyway very useful for the lecturer to have a detailed report from which to verify how much and how her/his course is exploited by students.

For each dimension, the general principles of effectiveness and efficiency that contribute to characterize usability as explicitly mentioned in ISO 9241 [10] have been considered. Subsequently, specific criteria have been identified that further specialize general principles.

Effectiveness is further specialized in:

- *Supportiveness for learning/authoring*: concerns the degree to which the tools provided by the platform allow learning and preparing lessons and educational paths in an effective way.
- *Supportiveness for communication, personalization, and access*: concerns the degree to which the platform satisfies these needs, thus increasing learning effectiveness.

Efficiency is specialized in:

- *Structure adequacy*: concerns the degree to which the activities the user usually performs are efficiently structured and visualized.
- *Facilities and technology adequacy*: concerns the efficiency of scaffolding and supplementary supports provided to the user and the degree to which the platform adapts to the technology used by the learner to access it.

With the aim of satisfying above criteria, a first set of guidelines were derived, as reported in Table 3. The user study suggested some guidelines. Table 3 indicates these guidelines, referring by number the problem each guideline addresses among the problems listed in Sect. 4.

5.2 Usability dimensions for e-learning modules

In this section, after describing the four dimensions adapted to the e-learning modules, the identified evaluation criteria are reported.

The *presentation* dimension regards the way the lecturer decides to make visualized both lessons and supports (scaffolding) to the students. New and updated lessons belonging to the same subject or course should have the same layout, both for the graphical aspect and content organization. As reading appears to be more tiring during prolonged video interaction with the e-learning system, it is appropriate to concentrate more important contents at the beginning, eventually high-

lighting their priority through graphical cues. The hierarchical structure of subjects must also be highlighted: this is very effective both from the conceptual point of view and in order to exploit and stimulate student's visual memory.

Hypermediality is currently a characteristic of on-line education. Research on hypermedia has stressed the two problems of *cognitive overload* and *lost in hyperspace*. Both could obstruct student learning. Moreover, it is good practice not to overuse hyper-textual and/or hypermedial links. Activating a link causes a change in what the student visualizes and this could bewilder the student. Finally, in order to facilitate both lecture editing and in-depth study, it is necessary that the learning materials be reusable also in contexts different from those for which they have initially been conceived (that is, they might be used as a deeper insight for one course or as a base subject for a different course).

The *application proactivity* dimension examines the ability to guide user activities and the use of learning tools. The learning domain must be introduced without oversimplifications, possibly with the help of some scaffolding. Suitable support must be provided for novice learners, together with a clear default learning path to follow. Alternative learning paths should be provided to accommodate different learning styles. The student will “learn by doing” and by making errors. When an error occurs, a good e-learning module should explain the cause and help recover. According to the socio-constructivist theory, students will “learn by doing”, making errors, and will also awake their hidden knowledge. To this aim, it is important that assessment tests be organized in such a way to represent deep-insight occasions for the student. A good tool does not limit itself to make the student realize the error, but explains the cause and helps to focus on key-issues of the subject at hand. Related to this dimension is the scaffolding organization. Presence and attenuation of scaffolding must be carefully considered. Indeed, in the LCD context, cognitive effort must be stimulated, that is the learner's activity should not be flattened and oversimplified, as opposed to the UCD context, where the aim is primarily to minimize the cognitive effort. Regarding scaffolding attenuation, there are still a number of open questions, concerning, for example, who should attenuate scaffolding (the student, based on individual needs, the lecturer, based on the provided learning plan, or the system, which will perform it automatically), and the speed of scaffolding attenuation.

The *User Activity* dimension analyzes activities, which the student would need to perform. Examples of such needs are: choosing among different learning paths, searching from the repository through a careful identification of keywords of each subject, creating personal paths or performing assessment tests when needed.

In this context, for each dimension the criteria of *effectiveness of teaching/authoring* and of *efficiency of*

Table 3 Usability criteria and guidelines for e-learning platforms

Dimensions	General principles	Criteria	Guidelines
Presentation	Effectiveness	Supportiveness for learning/authoring	Maintain UCD attributes for interface graphical aspects; introduce mechanism to highlight errors and cues to avoid errors
		Supportiveness for communication, personalization, and access	Provide the possibility to personalize interface graphics
	Efficiency	Structure adequacy	Clearly and constantly indicate system state; clearly visualize progress tracking; clearly visualize options and commands available; clearly visualize course structure (2)
Hypermediality	Effectiveness	Facilities and technology adequacy	Provide adaptation of the graphical aspect to the context of use
		Supportiveness for learning/authoring	Provide support for the preparation of the multimedia material; highlight cross-references by state and course maps to facilitate topic links (3)
	Efficiency	Supportiveness for communication, personalization, and access	Supply different media channels for communication; maximize personalized access to learning contents (3)
Application Proactivity	Effectiveness	Structure adequacy	Allow repository access to both lecturer and student
		Facilities and technology adequacy	Create contextualized bookmarks; enable off-line use of platform maintaining tools and learning context (5)
	Efficiency	Supportiveness for learning/authoring	Insert assessment tests in various forms; automatically update students' progress tracking; insert learning domain tools
User activity	Effectiveness	Supportiveness for communication, personalization, and access	Provide mechanisms to manage user's profiles
		Structure adequacy	Introduce mechanisms to prevent usage errors; provide mechanisms for teaching-through-errors; allow different repository modes for lecturers and students; insert easy to use platform tools (1)
	Efficiency	Facilities and technology adequacy	Maximize adaptation of technology to the context of use; register the date of last modification of documents to facilitate updating
User activity	Effectiveness	Supportiveness for Learning/Authoring	Provide easy-to-use authoring tools; enable to define a clear learning path; allow to define alternative learning paths; provide support for assessment test; manage reports about attendance and usage of a course; allow use of learning tools even when not scheduled
		Supportiveness for communication, personalization, and access	Provide both synchronous and asynchronous communication tools (7); provide communication mechanisms to both students and lecturers; allow the possibility to personalize the learning path; insert mechanisms to make annotations; provide mechanisms to integrate the didactic material
	Efficiency	Structure adequacy	Provide mechanisms for search by indexing, key or natural language (4)
		Facilities and technology adequacy	Allow the possibility to create standard-compliant documents and tests (AICC, IMS, SCORM); provide authoring tools to facilitate documents updating and assessment tests editing

support have been considered. Criteria and guidelines referring to them are reported in Table 4. As in the case of Table 3, in Table 4 also, guidelines derived from the user study are indicated by a number that refers to the problem the guideline addresses.

6 SUE inspection for e-learning applications

Considering the usability attributes and the guidelines reported in Tables 3 and 4, some ATs have been derived

Table 4 Usability criteria and guidelines for e-learning modules

Dimensions	Criteria	Guidelines
Presentation	Effectiveness of teaching/authoring	Update content consistently; highlight high priority subjects (2); stimulate learning without distraction; highlight hierarchical structure of course subjects (2)
	Efficiency of supports	Introduce noninvasive scaffolding to avoid distraction of the learner
Hypermediality	Effectiveness of teaching/authoring	Provide tools to immerse the learner in the learning domain context; use specific communication media for each subject and learning goal; provide means to choose and control media options
	Efficiency of supports	Use communication channels optimally; use hypertextual and hypermedial links carefully; reuse and integrate learning material
Application Proactivity	Effectiveness of teaching/authoring	Provide specific learning domain tools; provide support for novice learners; provide a clear default learning path; allow alternative learning paths; design help and scaffolding carefully; Design reliable testing tools
	Efficiency of supports	Attenuate scaffolding correctly (if attenuation is lecturer-driven); use document formats not requiring specific plug-ins
User activity	Effectiveness of teaching/authoring	Introduce assessment tests on demand (6); provide a way to choose among different learning paths; provide blended-learning simulations
	Efficiency of supports	Facilitate search for documents by a correct and clear specification of keywords (4)

that support the inspector in the evaluation of specific components of e-learning applications, that is, in checking whether the application follows the guidelines and satisfies the usability attributes, as described in Sect. 3. Specifically, these ATs are grouped in the following categories (see also Table 5):

- *Content insertion and content access*: this category includes ATs to evaluate tools that permit and facilitate authoring or content search.
- *Scaffolding*: this category includes ATs to evaluate mechanisms that support the user in complex tasks.
- *Learning window*: this category includes ATs to evaluate the features of the virtual environment for learning, that is, the environment where the student works, studies, and verifies her/his learning level.

ATs are distinguished into *basic* and *advanced* (AT TYPE column in Table 5). Basic ATs aim at supporting evaluators while analyzing the basic features of the application objects and behaviors. On the other hand, advanced ATs are used for a more detailed analysis of the application characteristics. In the last column in Table 5, there is P or M if the AT is defined to evaluate features of the Platform or of the e-learning Modules, respectively.

In the following, two examples of ATs to evaluate the fruition of a course document are reported: the first refers to the platform aspects (P), the latter to modules (M). The ATs are defined according to the template indicated in Sect. 3.

LW_2 (P): modality of fruition of a course document
Focus of action: learning window.

Intent: to evaluate modalities, commands, and any mechanisms to access course documents.

Activity description: given a learning window:

- Execute commands to move among the course documents.
- Execute commands to move among the topics of different courses.
- Access offline to the document.

Output: a description reporting if:

- A personalized content fruition is possible (e.g., through a predefined path, through a course map, etc.).
- An interdisciplinary content fruition is possible.
- The system status and the student position in the course are always indicated.
- It is possible to use the commands to move among courses and topics without leaving the learning environment.
- Offline access to document is possible without leaving the learning context.

LW_3 (M): suitability of formats of a course document

Focus of action: learning window.

Intent: to evaluate modalities, commands, and tools for access to course documents.

Activity description: given a learning window:

- Explore a document following different logic learning paths.
- Open some documents to identify the required plug-in.

Table 5 Some ATs for inspecting e-learning applications

AT CATEGORY	AT TYPE	AT CODE AND TITLE	P or M
Content insertion and content access	Basic	C_1: check of authoring tools	P
		C_2: check of the window for requests to repository	P
	Advanced	C_3: reuse verification	M
		C_4: check of insertion of alternative learning paths	P
		C_5: check of managing of alternative learning paths	P
		C_6: check of the different access modalities	P
		C_7: check for support to authoring	P
		C_8: check for support for flexible content organization	P
Scaffolding	Basic	S_1: help verification	M
		S_2: graphic layout	M
		S_3: check of scaffolding presence	M
		S_4: check of scaffolding attenuation	M
Learning Window	Basic	LW_1: organization of a course document	M
		LW_2: modality of fruition of a course document	P
		LW_3: suitability of formats of a course document	M
	Advanced	LW_4: check of assessment test availability	P
		LW_5: check of assessment test presence	M
		LW_6: check of presence of communication tools	P
		LW_7: check of usage of communication tools	M
		LW_8: check of presence of alternative learning paths	M
		LW_9: check of learning tools	P
		LW_10: adequacy of learning tools	M
		LW_11: advanced personalization verification	P

Output: a list reporting if:

- the documents structure permits different personalized learning paths.
- which plug-ins are necessary.

Two more examples of ATs are exploited to check the assessment testing. The first refers to the platform aspects (P), the latter to didactic modules (M).

LW_4 (P): check of assessment testing availability

Focus of action: assessment of testing tools.

Intent: to verify validity of the testing tools.

Activity description: given an assessment testing tool:

- Choose a course topic.
- Make an error during the test.
- Try to visualize the achieved progresses.

Output: a description reporting

- How the assessment testing tool addresses errors.
- If errors are highlighted.
- If there are links to the theory that explains the topic in which the learner found difficulties.
- If tracking mechanisms of the learner progresses exist and if they are visualized after the test or at any time.

LW_5 (M): check of assessment testing presence

Focus of action: assessment of testing tools.

Intent: to verify validity of the testing tools.

Activity description: given an assessment testing tool:

- Choose a course topic.
- Identify the cornerstones of the course.
- Try to use an assessment testing tool related to the identified points.
- Simulate an error during the test.
- Try to visualize the achieved progresses.

Output: a description reporting:

- If the tests are especially focused on the cornerstones of the considered topic.
- If the system considers the knowledge level that the learner has achieved.
- How the assessment testing tool deals with errors, for example, if it explains to the learner the reason of his/her error.

7 Discussion and conclusion

One of the current applications of HCI is the design of software tools that support people to learn the material available online in an educationally effective manner. A number of new issues have been raised because of the new “vehicle” for education. The two-fold challenge emerges of implementing advanced e-learning functionalities and designing their interface so as to provide an easy interaction grasping the students’ interest. A poorly designed interface makes students spend more time in learning it than in mastering the provided knowledge, thus becoming a barrier to effective learning. Despite the advances of electronic technologies in e-learning, a consolidated evaluation methodology for e-learning applications is not yet available.

This paper has presented the first results of a research aimed at defining a methodology for evaluating e-learning applications. The underlying approach is to adapt to the e-learning domain of the SUE methodology [17]. This methodology combines a novel inspection technique and user testing for the evaluation of software applications. The inspection is driven by the use of evaluation patterns, ATs. Examples of ATs for

the e-learning domain are provided. These ATs are derived from guidelines defined on the basis of (1) the authors' experience in e-learning application [27–30], (2) the study of literature, and (3) a user study. According to the SUE methodology, that requires the definition of specific usability criteria and some criteria that capture e-learning system features have also been proposed. The definition of both ATs and usability criteria refer to the SUE preparatory phase. Once these tools are available, a specific application is evaluated by following the steps of the SUE execution phase, as illustrated in Fig. 1.

It is worth mentioning that human factors experts can only evaluate “syntactic” aspects of e-learning applications, that is, aspects related to interaction and to navigation in both platforms and didactic modules. In order to perform a deeper evaluation, features concerning the didactic effectiveness of the e-learning systems must be considered. This means to analyze pedagogical aspects and content semantics of such systems. In this current phase of the reported research, attention was focused on defining a methodology to evaluate the usability of e-learning application. Further studies are being conducted to understand more in detail as to how pedagogical issues could be evaluated, in collaboration with experts of education science and experts of the learning domain, with the aim to identify guidelines and criteria for the evaluation of didactic effectiveness. For instance, evaluation from a pedagogical point of view concerns the coherence and the congruence of the learning path design. More specifically, the following must be evaluated:

- *Analysis of learning needs*: in designing the courseware, has a detailed analysis of the learning needs been performed?
- *Definition of learning goals*: are the learning goals well-organized in terms of cognitive and metacognitive abilities that the learners have to acquire?
- *Didactic content organization*: is the organization of didactic resources consistent with the organization of defined learning goals?
- *Selection of the teaching methodologies*: is the teaching methodology selected during the design phase appropriately implemented?
- *Learning assessment*: are the assessment methods and tools suited for the courseware?

Another important objective is to evaluate accessibility. Guidelines in literature usually provide high-level/generic indications on alternative forms of didactic content to enable access to content by people with different abilities.

Finally, it is planned to conduct further user studies for validating the elaborated approach to usability evaluation of the e-learning applications. These studies should help refine the preliminary set of guidelines and ATs and possibly define other guidelines in order to address all the peculiar aspects of e-learning applications.

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References

1. Ardito C, De Marsico M, Lanzilotti R, Levialdi S, Roselli T, Rossano V, Tersigni M (2004) Usability of e-learning tools. In: Proceedings of AVI 2004, May 25–28, 2004, Gallipoli (Italy), pp 80–84
2. Asdi AK, Daniels BH (2000) Special interest group: “learnability” testing in learner-centered design. Extended abstracts on Human Factors in Computing Systems CHI 00, The Hague, 1–6 April, 2000, pp 309
3. Baker K, Greenberg S, Gutwin C (2002) Empirical development of a heuristics evaluation methodology for shared workspace groupware. In: Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW 02), New Orleans, 16–20 November 2002, pp 96–105
4. Costabile MF, Matera M (2001) Guidelines for hypermedia usability inspection. IEEE Multimedia, Vol. January–March, pp 66–69
5. De Angeli A, Matera M, Costabile MF, Garzotto F, Paolini P (2000) Validating the SUE inspection technique. In: Proceedings of AVI 2000, 23–26 May, 2000, Palermo (Italy), pp 143–150
6. De Angeli A, Matera M, Costabile MF, Garzotto F, Paolini P (2003) On the Advantages of a Systematic Inspection for Evaluating Hypermedia Usability. Int J Hum-Comput Interact 15(3):315–335
7. Dringus L (1995) An iterative usability evaluation procedure for interactive online courses. J Int Instr Dev 7(4):10–14
8. Galtung J (1981) Structure, culture and intellectual style: an essay comparing saxon, teutonic, gallic and nipponic approaches. In Social Science Formation, SAGE, London and Beverly Hills, pp 817–856
9. Hofstede G (1997) Cultures and organizations: software of the mind, McGraw-Hill, NY
10. International Organisation for Standardisation (1998) ISO 9241: Software Ergonomics Requirements for office work with visual display terminal (VDT), Geneva, Switzerland
11. International Organisation for Standardisation (1999) ISO 13407: Human-centered design process for interactive systems, Geneva, Switzerland
12. Jeffriess R, Miller J, Wharton C, Uyeda KM (1991) User interface evaluation in the real world: a comparison of four techniques. In: Proceedings of ACM Conference on Human Factors and Computing Systems (CHI'91), New Orleans 1991, ACM Press, pp 119–124
13. Kamentz E, Schudnagis M, Womser-Hacker C (2002) SELIM: human computer interaction in the context of multimedia learning systems and the aspect of adaptivity on the basis of cultural differences. In: Wagner E, Szucs A (eds) EDEN second research workshop 2002. Research and policy in open distance learning. Research workshop book. Universitat Hildesheim, pp 211–215
14. Kamentz E, Womser-Hacker C (2003) Using cultural differences in educational program design and approaches to computers for adaptation concepts of multimedia learning. In: Stephanidis (eds) Universal access in HCI: inclusive design in the information society. Proceedings of the tenth International Conference on Human-Computer Interaction, HCI 2003, pp 1128–1132
15. Kruse, K. (May, 2000). Web rules: effective user interface design http://www.learningcircuits.org/may2000/may2000_web-rules.html
16. Mankoff J, Dey A, Hsieh G, Kients J, Lederer S, Ames M (2003) Heuristic evaluation of ambient display. In: Proceedings of ACM Conference on Human Factors and Computing Systems (CHI '03), Ft. Lauderdale, 5–10 April, 2003, pp 169–176

17. Matera M, Costabile MF, Garzotto F, Paolini P (2002) SUE inspection: an effective method for systematic usability evaluation of hypermedia. *IEEE Trans Syst, Man and Cybern—Part A* 32(1):93–103
18. Meyhew DJ (1992) *Principles and Guidelines in Software User Interface Design*. Prentice-Hall, Englewood Cliffs
19. Nielsen J (1993) *Usability Engineering*. Academic Press, Cambridge
20. Norman D (1993) *Things that make us smart: defending human attributes in the age of the machine*. Perseus Publishing, Cambridge, MA
21. Notess M (2001) Usability, user experience, and learner experience, <http://www.elearnmag.org>
22. Parlange O, Marchigiani E, Bagnara S (1999) Multimedia system in distance education: effects on usability. *Interacting Comput* 12:37–49
23. Phillips DC (1995) The Good, the bad, the ugly: the many faces of constructivism. *Educ Res* 24(7):5–12
24. Quinn CN, Alem L, Eklund J (1997) A pragmatic evaluation methodology for an assessment of learning effectiveness in instructional systems, <http://www.testingcentre.com/jeklund/Interact.htm>
25. Quintana C, Carra A, Krajeik J, Elliot S (2001) Learner-centered design: reflections and new directions. In: Carroll (ed) *Human-computer interaction in the new millennium*. ACM Press, New York, pp 605–626
26. Ravden SJ, Johnson GI (1989) *Evaluating usability of human-computer interface: a practical method*. Wiley, Chichester
27. Roselli T (1995) *Artificial Intelligence Can Improve Hypermedia Instructional Technologies for Learning*. *ACM Comput Sur* 27(4):624–626
28. Roselli T, Faggiano E, Rossano V (2003) A further investigation on the effectiveness of a WWW hypermedial system for cooperative learning. In: *Proceedings of International Conference on Computer in Education (ICCE 2003)*, Hong Kong, December 2003, pp 440–442
29. Roselli T, Faggiano E, Grasso A, Rossano V (2003) A platform for building and using personalized courseware. In: *Proceedings of E-Learn 2003: World conference on E-Learning in Corporate, Government, Healthcare, & Higher Education*, Phoenix, November 2003, pp 141–144
30. Roselli T, Faggiano E, Grasso A, Pragnell MV (2003) A formal model for developing e-learning software. In: *Proceedings of IEEE International Convention (Mipro 2003)*, Opatija, Croatia, May 2003, pp 70–74
31. Schwier RA, Misanchuk ER (1993) *Interactive multimedia instruction*. Educational Technology Publications, Englewood Cliffs
32. Shneidermann B (2003) *Designing the User Interface*, Addison-Wesley
33. Silius K, Tervakari A (2003) The usefulness of web-based learning environments. In: *Proceeding of the International Conference on Network Universities and e-learning*, Valencia, Spain, 8–9 May 2003
34. Soloway E, Jackson SL, Kleim J, Quintana C, Reed J, Spitulnik J, Stratford SJ, Studer S, Eng J, Scala N (1996) Learning theory in practice: case studies in learner-centered design. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'96)*, Vancouver, British Columbia, Canada, April 1996. ACM Press, New York, pp 189–196
35. Somervell J, Wahid S, McCrickard DS (2003) Usability heuristics for large screen information exhibits. In: *Proceedings of Human-Computer Interaction (Interact '03)*, Zurich, September, 2003, pp 904–907
36. Squire D, Preece J (1996) Usability and learning: evaluating the potential of educational software. *Comput Educ* 27(1):15–22
37. Squires D (1999) Usability and educational software design: special issue of interacting with computers. *Int Comput* 11:463–466
38. Squires D, Preece J (1999) Predicting quality in educational software: evaluating for learning, usability, and the synergy between them. *Int Comput* 11(5):467–483
39. Storey MA, Philipps B, Maczewski M, Wang M (2002) Evaluating the usability of web-based learning tools. *Educ Tech Soc* 5(3):91–100
40. Takagi T, Sugeno M (1985) Fuzzy identification of systems and its applications to modelling and control. *IEEE Transac Syst, Man Cybern* 15:116–132
41. Trincherò R (2004) Valutazione della qualità dei sistemi formativi basati sulle TIC, http://puntoeduft.indire.it/160mila/b/moduli/app/corsi_fortic/b6/6.3/pdf/6.3.pdf
42. Wong B, Nguyen TT, Chang E, and Jayaratna N (2003) Usability metrics for e-learning. workshop on human computer interface for semantic web and web applications, 3–7 November, 2003, Catania, Sicily, Italy, Springer-Verlag, Berlin Heidelberg New York, Germany, LNCS No: 2889, pp 235–252
43. Zaharias P, Vasslopoulou K, and Poulymenakou A (2002) Designing on-line learning courses: implications for usability, http://www.japit.org/zaharias_etal02.pdf