Usability of a Virtual Learning Environment Concerning Safety at Work

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Abstract: Most of the VLE design methods focus on producing content for a VLE. However, usability of the VLE is also of great importance. Several potential usability problems have been reported in recent e-learning conferences. These problems could have been avoided by applying usability engineering methods before the VLE was taken into use. This paper describes usability engineering methods used to ensure the usability of Virtu, a virtual learning environment (VLE) concerning safety at work. The results of using each method are summarized and as a conclusion, some general VLE design guidelines are listed to help others in VLE design.

Keywords: VLE usability problems, Usability engineering, Human centred design, VLE design guidelines

1. Introduction

Most of the VLE design methods focus on producing content for a VLE. However, usability of the VLE is also of great importance. If the user interface of a VLE is not usable, the user's focus on the actual content is diminished, because using the VLE requires a considerable amount of concentration. Good usability, on the other hand, allows the user to focus on the content thus improving learning results.

Several potential usability problems have been reported in recent e-learning conferences. Remarkable obstacle to taking VLEs into use rises from the users´ background knowledge of computer technology (Jones et al, Kent 2003). The idea of distance-learning brings social problems like impersonal feeling and non-alignment for the course (Lindh and Soames, Kent 2003). Ever increasing VLE sizes make the VLEs disorganized and therefore a navigational aid is needed (Armitage et al 2003). The high enthusiasm on latent potential of VLEs makes the designers implement as many features as possible. However, the VLEs may thus contain unnecessary features that students never or rarely use (Beasley and Smyth 2003).

Virtu is a virtual learning environment (VLE) concerning safety at work (Figure 1). Virtu was developed in a co-operational project between the Institute of Occupational Safety Engineering and Institute of Software Systems in Tampere University of Technology (TUT). In addition to more traditional VLE content, such as theory and exercises, Virtu contains a virtual enterprise, which simulates a visit to a real company.

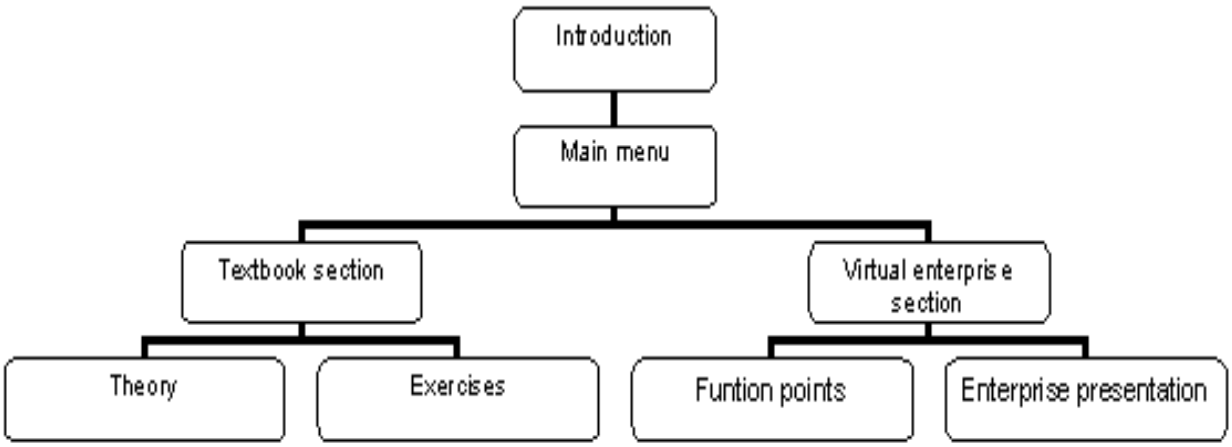

Figure 1: Structure of Virtu

The early design phase of Virtu was done according to ISO 13407 Human centred design processes for interactive systems (ISO 1999). The standard includes four user centred design activities to be started at the earliest stage of a project. These design activities

resulted in defining two main usage scenarios related to two main end user groups for Virtu.

The first scenario is about teaching safety at work for students of Occupational Safety Engineering at TUT. The second scenario is testing and updating industrial workers' knowledge of safety issues related to their work. Virtu user interface was designed applying usability practices including stakeholder and user interviews, prototyping, heuristic evaluation, iterative design and user testing so that both end user groups would find the environment interesting and easy to use (Preece et al. 2002). Virtu supports constructivist learning model where individuals are assumed to learn better when they discover things themselves (Ahmad et al. 1998).

This paper describes usability problems of current VLEs. Usability methods used during Virtu development process are also outlined and, as a conclusion, some general VLE design guidelines are presented. Potential usability threats of current VLEs reported in publications are discussed in Section 2. Section 3 presents usability engineering methods used to ensure usability of Virtu and the summarized results of using each method. Virtu learning environment produced by the software and usability engineering activities is outlined in Section 4. Section 5 provides general VLE design guidelines, which rose from Virtu development process.

2. Usability problems of current VLEs

In their study Jones et al (2003) identified eight primary causes of student withdrawal. Three of these causes were to some extent technology related. Technical problems as such were reported as a cause of withdrawal by 20% of the respondents. Also, own IT skills were identified as a reason for withdrawal by 15% of the respondents. Moreover, the use of technology had an impact on student confusion and lack of understanding, which contributed to 15% of the respondents' withdrawals. Also Kent (2003) reports on students having had difficulties in using a VLE. The lack of technical skills necessary for understanding or participating in activities within the VLE was reported to be one of the features the participants did not like about the e-Learning module (Kent 2003).

Another aspect that propagates the student withdrawal from a course is the impersonal and faceless nature of VLEs (Kent 2003). Lindh and Soames (2003) state that there is still a need for human-to-human interaction. For example, asking questions is much more time consuming in purely electronic environments than in face-to-face contact in a classroom. When more and more students are part time students having work career and family life at the same time, the challenge is to activate students and to make them to commit themselves to a course.

Students' interests towards a course can collapse because of muddled and ambiguous electronic material. Identifying content can be a problem (Lindh and Soames 2003). For example, a document containing multiple pages may come out of printer without page numbers or pages have irrelevant title or no title at all so they cannot be connected to the topic later on. The level of navigational freedom affects to the user's feeling of control (Armitage et al. 2003). Navigational aids providing higher navigational freedom (maps, indexes) give higher feeling of control compared to navigational aids providing lower navigational freedom (back and forward buttons, hypertext). Even navigational aids do not guarantee the optimal use of learning material, but instructions on how to study non-linear hypertext material are also needed (Beasley and Smyth 2003).

According to Beasley and Smyth (2003), students often interact with VLEs in a manner that will not allow them to fully exploit the VLEs' potential. In their paper concerning students' selective use of a virtual learning environment, Beasley and Smyth (2003), in addition to their other results, reported on VLE features which were either rarely used or were not used at all. These features included individual progress report and asynchronous discussion forum.

To relieve the students' stress caused by online activities, Lawless and Allan (2003) recommend that the technology used should be user-friendly and errorless and should provide a pleasant experience for the user. Another aim of VLEs is to provide cost effective education (Lindh and Soames 2003). By designing and testing the VLE according to usability engineering methods before taking it into use, all these objectives can be achieved.

3. Usability engineering

In the beginning of the iterative design process, a paper mock-up of Virtu user interface was developed based on stakeholder

interviews. Usability tests with real end users were conducted using the paper mock-up and the test users were also interviewed. Based on the test results, a software prototype of the user interface was developed and usability tests with end users performed. After the second usability testing round, a new software prototype was designed and heuristic evaluation was conducted by an usability professional.

As a result there was list of changes to be made in every area of design: structure, content and user interface. Because the shortcomings were detected before the implementation was completed, they could be corrected before the final release version. Thus, iterative design process diminished the need for changes in the future.

3.1 Human centred design

Requirements were formed by specifying the context of use (UsabilityNet) and thereby the purpose of use. Also the user and organizational requirements were collected trough stakeholder interviews (UsabilityNet). Technical limitations and updates must be considered in early design phase, too.

The stakeholders of Virtu were specified first by listing all the factors affecting the use of Virtu and thereby the people related. Virtu's stakeholders included end users, teachers in the Institute of Occupational Safety Engineering, maintenance, marketers and those who are responsible for the safety at work issues in industry.

3.1.1 User and organisational requirements

Virtu has two main end user groups. The first end user group is students of Occupational Safety Engineering at TUT and the second group is industrial workers. The computer skills and the requirements for the content of Virtu differ greatly among these groups.

The approach to safety at work issues should cover all the legislation concerning safety and health at work. It should be challenging enough for students who already have a wide knowledge of the subject. However, the content cannot be too theoretical, because the learning environment is to be used by industrial workers, too. They do not necessarily have a wide knowledge basis on the issue but are more interested in practical ways of improving the safety of their own work.

The human factor goals of end user groups can be established according to Schneiderman's five measurable human factors:

- time to learn,
- speed of performance,
- rate of errors by users,
- retention over time,
- subjective satisfaction. (Schneiderman 1998)

The priorities of the human factors vary between students and industrial workers.

For students time to learn and retention over time are the most crucial factors. Students use Virtu instead of traditional course material, and it is supposed to be as intuitive to use as a book and a pen. The usage time is limited to only few hours a week as if there were traditional lectures. The knowledge of how to use Virtu must be maintained between lectures.

Retention over time is even more important to industrial workers, who may have an intensive course on safety at work, and are returning to Virtu after long period of time. Subjective satisfaction counts when the use of Virtu as a reference book is discussed.

3.1.2 Context of use

The context of use turned out to be complex. At least three environments and three different purposes of use were defined. Users should be able to use Virtu independently at home or at work, and, in addition, by groups in safety at work training. There should also be a possibility to use Virtu as a quick reference book. All these different usages must be taken into account in the user interface design.

In most of the cases Virtu is used for studying occupational safety engineering at university, training safety at work issues related to everyday work in industry or revising issues related to safety at work. Students are enrolled in a course dealing with safety at work. Industrial workers are participating in a course arranged by employee or otherwise are recommended or required to get familiar with safety at work material provided by Virtu.

Students will mainly use Virtu in computer classrooms with internet connections. Computers usually include Pentium 500 MHz processors with 128 MB memory. However, high processor and memory capabilities cannot be expected from computers used by industrial

workers at their workplaces, and in that environment internet is usually not allowed. Both user groups can use the Virtu also at home, but those environments cannot be taken into account in the design process.

3.1.3 Technical limitations and updates

Virtu will be a commercial product and therefore should not be used freely in the internet. Instead, some kind of a copy protection or license practice in its distribution must be implemented. CD-ROM was chosen as the distribution media. Distribution via internet was rejected due to the requirements of participating companies. In the future, Virtu might be used through a web browser, and therefore there should be a possibility to change the user interface to a web based version without changing the application logic.

Legislation concerning safety and health at work changes from time to time and also other new information on the safety at work issues may emerge. To ease the introduction of updates, changing the content must not cause changes in the user interface. Also, changing the content should be possible without programming. Internationalizing Virtu for Western cultures should be easy, too.

3.2 Usability tests

As Virtu was designed according the ISO 13407 Human centred design processes for interactive systems (UsabilityNet, ISO 1999), the proper usability engineering methods including iterative design, user interviews, prototyping, user testing and heuristic evaluation, were used to gather and verify Virtu´s properties.

3.2.1 Iterative design

Virtu user interface was developed based on an iterative design process, which means that new versions of the user interface were produced based on the usability problems and opportunities disclosed by empirical testing (Nielsen 1993). During the iterative design process the interface was evaluated by end users and usability professionals.

Iteration began with user interface drafts drawn in a paper. There was one paper for each type of displays; menus, theory, exercises, virtual enterprise, function points and description of the enterprise. After end users had tested the paper version, a software prototype was developed. In the first phase only menus and one case of each functionality was implemented. After user tests, the first full version was built for further testing.

3.2.2 Stakeholder and user interviews

Many aspects of usability can be studied by simply asking the users. This is especially useful for issues that are related to users' subjective satisfaction and possible anxieties (Nielsen 1993). In the beginning, when nothing was implemented, the stakeholders of Virtu were interviewed. The analysis of results of the interview produced requirements for the first paper prototype of Virtu. During Virtu usability test with a paper mock-up, the users were asked to fill two interview forms.

The first form was filled in the beginning of the test. It contained open and multiple-choice questions concerning users´ computer usage and demographic information. The age of participating students varied from 20 to 29 and the age of participating industrial workers from 27 to 53, being very typical to both user groups. The sex ratio in interview was 4/5 females in students and 2/6 females in industry workers. 80-83% of both groups used computer about 3 hours per day. Most of the students but clearly a minority of industrial workers used computer also for leisure. 2/6 of the industrial workers used operations and work management systems in their work.

The second form, filled at the end of the test, contained five open questions. This questionnaire was about the ease of use of Virtu and the users' subjective opinion about it. The results indicated that all students but only half of the industrial workers considered Virtu to be easy to use. The main reasons for finding Virtu difficult to use were navigation problems. More than half of the students and less than half of the industrial workers said to be interested in using Virtu for studying purposes.

3.2.3 Prototyping

Prototypes are useful for conducting system-specific usability tests early in the development process. Their role is to demonstrate and test aspects of human-computer interaction, which might be difficult or more time-consuming to produce in another medium (Lindgaard 1994). Especially low-fidelity prototypes like paper mock-ups are useful, because they are simple, cheap and easy to produce and thus easy to modify for testing alternative design ideas. Software prototypes as high-fidelity prototypes are useful in testing out technical issues (Preece et al. 2002). Both paper mock-up and

a software prototype were tested during Virtu development.

3.2.4 User testing

User testing with real users is the most fundamental usability method, because it provides direct information about how people use computers and what their exact problems are with the concrete interface being tested (Nielsen 1993). During Virtu development, formative evaluation was carried out in order to improve the user interface as a part of iterative design process. Formative evaluation was performed as a typical thinking-aloud test.

The major finding of the usability tests with the paper mock-up was the need to divide the content to different difficulty levels to match the needs of different user groups. In the beginning of the tests, there was only one common content, which most of the industrial workers found quite irrelevant because it was too theoretical compared to their work. Another important finding was the users' difficulty in navigating in the virtual enterprise section. A ground plan of the virtual enterprise with marked function points, for example *Gate* or *Check in,* was used for navigation. The users did not recognize the function points as buttons but were wondering what they were supposed to do with the ground plan.

There were also some minor findings. Navigation from one page to another in the textbook section was considered somewhat difficult by some industrial workers, because there were only arrow-buttons without a text to indicate where the button leads to. Most users considered the link from the virtual enterprise section to theory topics quite unnecessary.

Usability testing with the software prototype only provided some minor findings. Some of the function points in the virtual enterprise section contain questions, for example "*Do you know the nearest emergency eye rinsing at your workplace?*", for industrial workers to consider at their own working environment. The users found the visibility of such points on the ground plan to be quite weak and they also thought the questions were not separated clearly enough from the rest of content of the function point. Also the terms in the main menu were considered to be quite ambiguous, and it was not clear to the users what each section contains.

3.2.5 Heuristic evaluation

Heuristic evaluation and user testing should be alternated, because these two usability practices have been shown to find fairly distinct sets of usability problems (Nielsen 1993). Heuristic evaluation is done by studying a user interface and then forming estimation about what is good and bad about it. The evaluation is conducted according to a certain set of rules, such as those listed in typical guidelines documents (Nielsen 1993). In Virtu heuristic evaluation, the list of Nielsen's ten usability heuristics (Nielsen 1994) was used.

Nielsen's ten usability heuristics include:

- elements in user interface (4 heuristics),
- language (2),
- interaction (2),
- error prevention (1) and
- helping information (1).

User should have appropriate feedback in time and the system status should be clearly seen. All the error descriptions and UI terminology should use users language and terminology. Consistency can be maintained for example by using standards and UI guidelines. Operation is made easy and efficient by providing accelerators, shortcuts, exits and easy escapes. The interface should contain all the essential elements but nothing more. (Faulkner 2000)

Heuristic evaluation was conducted for each display and for Virtu as a whole after user tests with the software prototype in order to search for usability problems undiscovered by user testing. Usually the heuristic evaluation is carried out before user tests, but in this iterative process it was reasonable to use the usability professional to verify the design decisions before release version of Virtu.

Results indicated that some terminology like *ground plan* and *enterprise description* had to be changed into more user oriented vocabulary like *visit* and *table of contents*. Easy exits had to be added in the theory section, and the cursor had to be changed in appearance, when placed over buttons to show to the user the possibility of interaction. Some minor notes were reported about consistency among different parts of Virtu.

4. Virtu learning environment

The structure of Virtu was split into two entities because of the requirements (Figure 1). Some educational material concerning safety at work already existed, and it needed to be presented

in electronic form in order to utilize the interaction possibilities of VLE. It was also necessary for both user groups to see some real life examples of safety at work. The practical part should also support the adaptation of theory.

The two parts of Virtu are:

- textbook section,
- virtual enterprise section.

The textbook section was divided to theory and exercises. The virtual enterprise section contains interactive function points and a description of the enterprise providing background information on the virtual enterprise. The material provided in function points was gathered from three real life companies.

4.1 Textbook section

The textbook section can be studied as a guided tour including theory and exercises on every topic. Each theory topic can also be studied independently from the others and the textbook section can thus be used as a quick reference book. The use of textbook section begins by selecting one of 8 topics covering different areas of safety at work.

The content of the textbook was divided to two difficulty levels based on usability test results. *Theoretical level* contains information on different safety at work topics including legislation, occupational safety management, risk management, ergonomics, occupational hygiene, machine and system safety, mental welfare and occupational accidents. This level is to be used in industry by the people responsible for safety at work issues and by the students, because they need a deeper understanding of the issue.

Practical level is to be used by industrial workers. Thus, the topics included differ slightly from the content of the theoretical level. The practical level contains information on risk assessment, ergonomics, occupational hygiene, occupational accidents, signs and traffic. Included information can be easily applied into practice in the user's own work environment. Even the topics, which are same or similar to ones in the theoretical level, were re-designed to match the requirements of the group using this level.

4.1.1 Theory

Theory displays were designed using a book metaphor (Figure 2). Each view reminds opened book, which consists of two pages. The user's location in the Virtu is indicated on the top and there is always possibility to exit the current theory section. User is informed of the total number of pages included in the section.

Figure 2. Theory display

User navigates between theory displays using back and forward buttons at the bottom of the pages. Menus in the bottom of the display are consistent through the program. The user is expected to read the content as traditional textbook content. The main difference compared to traditional textbooks is the amount of graphics and the length of text chapters. Text chapters are short because reading is 25% slower from screen than it is from paper (Nielsen 1997).

4.1.2 Exercises

The textbook contains seven different types of exercises including for example multiple-choice questions, drag and drop exercises, and crosswords (Figure 3). Feedback on the correctness of the user's answers is given in graphical form. Also exercises on each topic can be used independently. Thus, Virtu can be used to test the user's knowledge of safety at work issues for example in the beginning of a safety at work training session or to test learning at the end of such session.

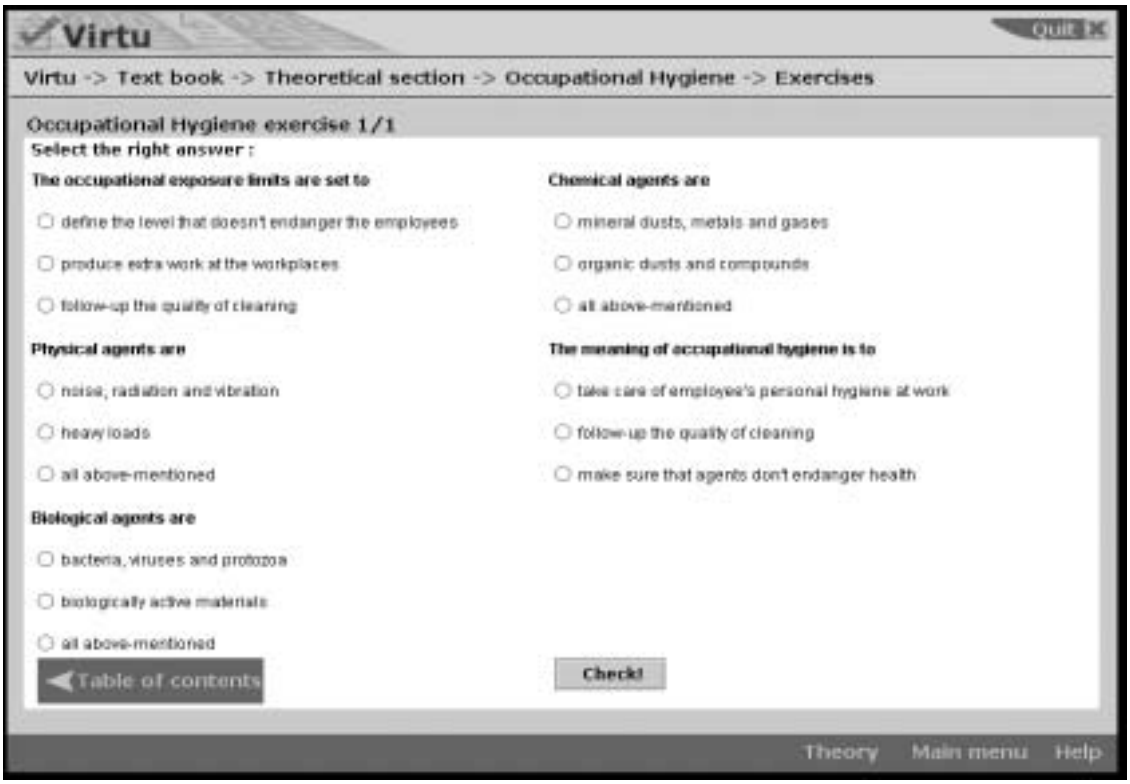

Figure 3. Multiple-choice exercise display

In the beginning of the exercise page user is guided how to carry out the exercise. There is a possibility to check if the answers are correct. In the case of an error the right answers are not displayed, but the user has to revise them based on the theory part.

4.2 Virtual enterprise

The virtual enterprise is to be used by both user groups. Its purpose is to simulate a visit to a real company and to spread good safety at work practices to industry. The content of the virtual enterprise includes photographs, pictures, text and video and it has been integrated of three different industrial fields (metal, paperboard and plastic). Material collected from real companies makes the virtual enterprise realistic.

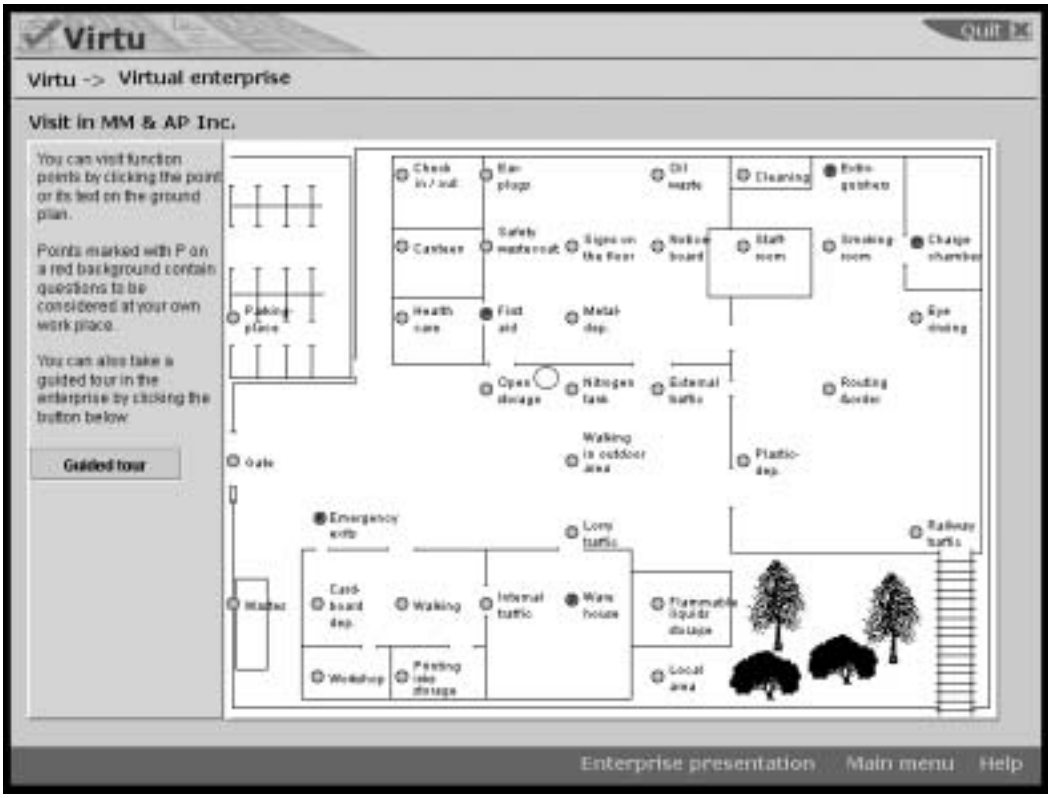

Figure 4. Ground plan used for navigation in the virtual enterprise

User navigates in the virtual enterprise by clicking the marked function points on the ground plan (Figure 4). The function points are buttons through which additional information on the subject can be found. Some of the points contain safety at work questions for industrial workers to consider in their own working environment.

4.3 Implications of usability engineering

As an outcome of paper mock-up testing and interviews, some changes were made to both content and the user interface of Virtu. Because the user test results showed a need for different difficulty levels in the content, the people responsible for developing it were informed, and some new content with a more practical approach to the issue was thus developed.

Navigation in the virtual enterprise was made easier by adding instructions to the ground plan display. Also the marking of function points was improved to make them easier to recognize. Some texts, which might disturb the user, were removed from the ground plan so that then only texts left were those of function point buttons. The link from the virtual enterprise to theory was removed, and description texts were added to the arrow buttons used in navigation.

Usability testing with the software prototype resulted in some minor changes in the user interface. Visibility of function points containing questions for industrial workers was improved in the ground plan by changing the icon, and the distinction between the questions and other content was made clearer by adding a title for the questions and marking the title with the same icon as on the ground plan.

The main implication of heuristic evaluation was that the virtual enterprise section was divided to two different sections already in the main menu. Also the terms in the main menu that were difficult to understand were changed, so that they would be clearer to the user. Changing the cursor when the cursor is over some button was also included.

However, the possibility to jump to the table of contents while the user is in the middle of a theory section or a function point was not provided. The rationale for this is that in a case of a VLE it is sometimes appropriate to limit user freedom to improve learning (Alessi et al. 1991).

5. Conclusion

The experience of developing Virtu can be presented in three guidelines of VLE design:

- Specify the stakeholders of the VLE.
- Specify how the VLE is used.
- Apply usability engineering methods in designing and testing phases before taking the VLE into use.

User groups can be defined as a wide range of stakeholders or as the end users of the VLE only. The stakeholders could be for example maintainers of the VLE or teachers responsible for teaching the content of the VLE to students. The advantage in wide range of users is a design covering all areas related to the use and lifecycle of VLE.

The purpose for using the VLE can vary from being like a textbook or scientific material to be more like demonstration or even a game. The VLE may be used only once or the users may refresh their memory with VLE when needed. In some cases there can be many users simultaneously. They may all use one computer together or interact through networked computers.

As technical difficulties may cause dissatisfaction resulting in student withdrawals, the technical skills of the potential users should be accounted for, and the user interface should be designed respectively. Unnecessary features increase implementation and maintenance costs. Therefore, the features included in a VLE should be carefully considered according to the usability engineering results in designing phase. Many of the usability problems in current VLEs could have been avoided by applying usability engineering methods before taking the VLE into use.

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