Ecodesign - an Online University Course for Sustainable Product Design

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Abstract: The Ecodesign e-learning course conveys knowledge about ecological product design. The following paper describes the Ecodesign e-learning system, its aims and its pedagogical foundation. Two courses with beta versions of the Ecodesign e-learning system were being held in spring and summer 2004. These courses were evaluated by interviews and logfiles and the results of the evaluation were used for the redesign of the system which is completed by now and in use for a university course. The evaluation was concerned among others with the structure of the content, the examples the students work on as well as with the navigational behavior of the users.

1. Introduction

Continuing education becomes increasingly important. Due to the fast development of technologies, there is a growing demand for vocational training in various fields. One of these fields is ecology. International standards (ISO 14000) and competitive advantages through ecological production induce companies to invest in environmental education of their employees.

There is, for example, an increasing demand for courses in ecological product design from manufacturing companies. At the Vienna University of Technology, such courses are offered to all kinds of students. Especially employees of manufacturing companies sometimes have difficulties to attend. Small and medium enterprises often find it troublesome to send employees who fill in vital positions to longer courses. This is all the more relevant for companies located in remote geographical areas. Therefore, it seems to be a sensible solution to offer training in ecological product design as an e-learning course. In a project that started in September 2003 such a system was being developed. This course is based on the experience of face-to-face classes. The instructional material so far being used was a book with a CD-ROM (Wimmer & Züst 2001).

2. Description of Course and System

The aim of the Ecodesign e-learning system is to convey knowledge about ecological product design to adult learners. There is an increasing demand for learning systems for adult learners, especially for professionals looking for additional training. These learners have specific requirements for e-learning systems (Rudestam & Schoenholtz-Read 2002). Such e-learning systems have to incorporate problem-centered learning and address the experiences of the learners. Flexibility of time, place and pacing is very important to enable adult learners to arrange work and learning conveniently.

The Ecodesign e-learning system which was developed from scratch in the open source platform Zope tries to fulfill these requirements. It can be accessed with any conventional WWW browser. The basic functionalities it offers are access to various kinds of material, access to examples, and communication with other members of the group or teaching staff. Consequently, it consists of three sections: materials, examples/tasks and communication. The design

of the Ecodesign e-learning system is based on an office metaphor. The three sections of the system (materials, examples/tasks, communication) can be accessed by doors. All three sections can be imagined as rooms. The examples can be found in the “office” (Fig. 1) and additional material in the “library”. The final solution uses a navigation similar to the Windows Explorer but has some icons of folders added. The screen is, therefore, divided into a navigation bar containing mainly the doors, a content-frame containing texts, diagrams, movies etc. and a tree-frame containing the navigation “tree”. Despite the fact, that some users still do not understand the function of a graphical overview map (sitemap) we decided to offer them in the system as a secondary method of navigation. On the other hand, there are several reasons to include such maps. There is ample empirical research which indicates that graphical maps are advantageous for the learning process (Jonassen & Reeves 1996). In addition to these two navigational concepts we also provided text links and a quick navigation bar known as breadcrumbs because of its benefits of both quick access to superior nodes and display of contextual hierarchical relations (Fig. 2).

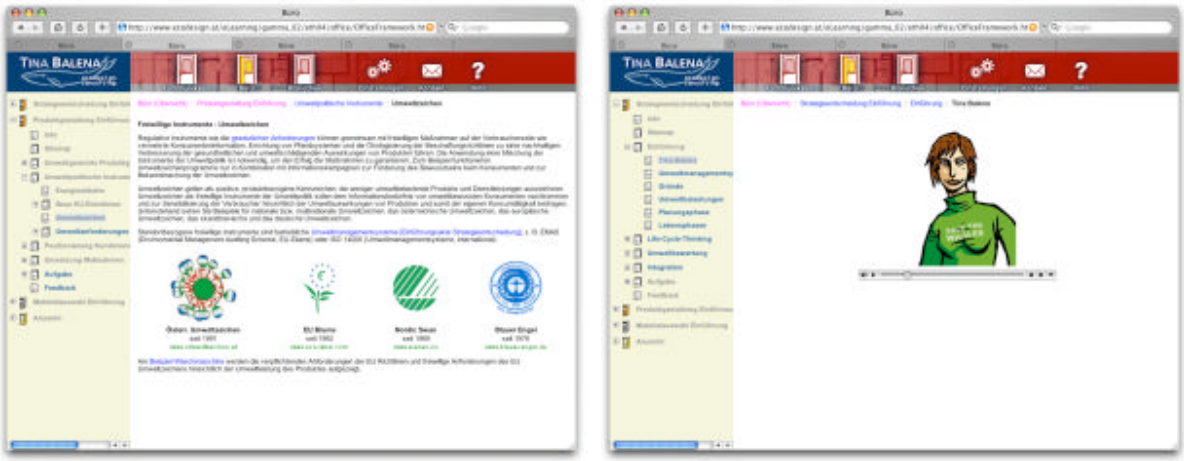

Figure 1: The Ecodesign E-Learning System ("Office"-Part):
Typical Node (left) and Introduction of Electronic Tutor Tina Balena (right)

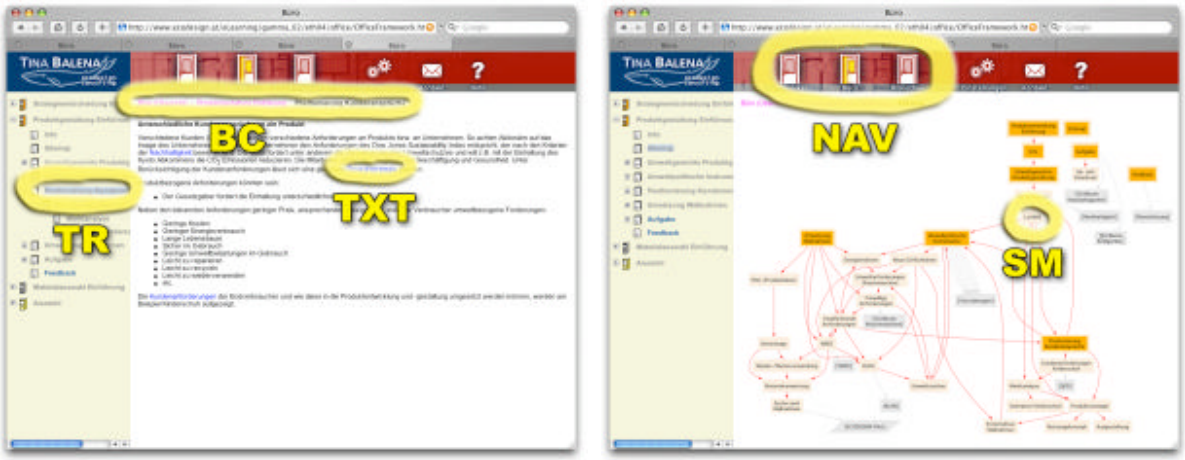

Figure 2: Introduced Categories of Navigational Practices
Tree, Breadcrumbs, Text -Links, Navigation Bar and Sitemap

Its main part is a collection of seven concrete examples. The trainees, for example, have to improve the design of an electrical water kettle according to ecological standards. They get an extensive description of the problem, some hints how to solve the problem and many links to additional material (tables, texts about standards, other solutions,...) which is necessary to complete this task. The learners are supposed to use these materials in order to compute the optimal solution for an "ecological" water kettle. The seventh example is carried out as teamwork of 3-

4 trainees. The examples are presented in a hypertext format. These examples are the main building blocks of the whole course. In addition, the assessment of the learners is based on their work with the examples. The main argument for this approach was that professionals looking for additional training are mainly interested in the practical solution of realistic problems and not so much in acquiring theoretical knowledge. It should be mentioned, however, that this approach is rather time-consuming because it is necessary to support students when they work on the examples and to give them extensive feedback. In this sense, the Ecodesign e-learning system differs from many other e-learning systems in the area of vocational training. The communications section provides possibilities for synchronous and asynchronous communication. Three different technologies are utilized to ensure versatile forms of communication: email, discussion forums (similar to weblogs) and IRC (internet relay chat).

It is well-known that motivation is an important variable in online learning (Simonson et al 2000). Without accompanying measures dropout rates in online learning tend to be very high. To avoid these high dropout rates we adopt two strategies. We use blended learning. The duration of a course is one semester. During this semester there are three face-to-face meetings (one at the beginning, one in the middle, and one in the end), so that trainers, tutors, and trainees can get acquainted and can solve problems which cannot be solved online. Between these face-to-face meetings are online learning phases. Apart from that we use an approach which can be called active tutoring. Apart from the trainers who deliver the lectures in the face-to-face meetings and who provide the content material there are tutors who support the learners online. They organize electronic meetings and answer all the questions the trainees have when they are not in the face-to-face meetings. In previous projects very positive experiences were made with active learner support (Reichl & Vierlinger 2003).

The Ecodesign e-learning system is completed by now. It is being used in a course offered by Vienna University of Technology lasting from October 2004 until January 2005. Participants are employees of companies from various industrial sectors (manufacturing of subways, production of synthetic materials, IT sector etc). The evaluation of the beta versions which we conducted in spring and summer 2004 were very important for the development of a satisfactory system. For the evaluation, we used two different methods: interviews and logfiles. The logfiles yield very rich, objective data but the inferences which can be drawn from these data are mostly restricted to navigational behavior. From these logfiles we cannot derive very much about the use of pictures, diagrams or videos or about interaction between participants and trainers. We, therefore, also used interviews to supplement the logfile data. Data from interviews may be biased because subjects are not always able to describe their experiences objectively. We hope that by comparing data from interviews and logfile data we can get a fairly consistent picture of the advantages and shortcomings of the Ecodesign e-learning system.

3. Interviews

3.1 Theoretical Background and Guidelines

Interviews with users of e-learning systems can yield very interesting and detailed results even if the users often have little meta-knowledge about their own learning processes. Interviews can help to define concrete problems learners have. They also clarify which features of an e-learning system are motivating for the learners and which are difficult to grasp. As motivation is a very important factor in education, such aspects of the learning process should not be overlooked. Nevertheless, it is necessary to plan interviews carefully and to develop comprehensive guidelines for conducting them. These guidelines should be based on learning theory and on previous experimental research about e-learning systems so that it is possible to compare one's own research with research conducted elsewhere. An interesting input in this context could be guidelines for the development of e-learning systems (Clark & Mayer 2003, Pohl 2004) because development and evaluation should be governed by the same principles. It should be mentioned, that the guidelines we used for the evaluation process also influenced the creation of the Ecodesign e-learning system.

The guidelines we used for conducting the interviews are strongly influenced by Clark & Mayer (2003) and Pohl (2004). They cover four areas: structure/navigation, pictures/diagrams/videos, cooperative learning/communication and the use of examples. A clear structure and usable methods of navigation are absolutely essential for good e-learning systems. In the Ecodesign e-learning system all examples have a consistent structure. Several methods for navigation are offered, among them sitemaps and tree navigation. Especially sitemaps (which might also be called graphical overview maps or concept maps) are broadly discussed in the hypertext literature, and there is some

evidence for their usefulness (Jonassen & Reeves 1996). The use of pictures, diagrams and videos is supposed to be one of the most important advantages of e-learning systems. It must be mentioned, however, that the efficiency of pictures, diagrams and videos very much depends on the quality of their design and the way how they are integrated into the system. William Winn (1987) has developed very detailed guidelines for the design of charts, graphs and diagrams and Strittmatter (1994) discusses the use of videos and film in e-learning. Cooperative learning and communication can also play an important role in e-learning. Again this depends very much on the concrete organisation of the communication processes. Allen et al (1996) point out that cooperative learning should be supported by a moderator and well integrated into the learning process. The use of examples is suggested by Clark & Mayer (2003). They argue that learning material is better retained in memory when students have to prepare examples. Examples can enable students to relate the learned material to their practical experience in working life.

3.2 Subjects and Setting

The interviews were conducted in May 2004. The subjects were five students of the Vienna University of Technology. One of the students was an exchange student from Greece who had difficulties with the German language and had, therefore, not worked extensively with the system. His comments were also used for the final interpretation although he could not answer every question we asked him. Three of the students worked at least part-time. Two interviewers were present at every interview and made extensive notes. These notes were then compiled and compared. They were the basis of the subsequent analysis. The students had worked with a beta version of the system which was only half finished. Several of the examples, which are available in the final systems, did not exist in May 2004. The students could only use a simple forum for communication purposes, and there was no support by a tutor. The chat facility was not yet integrated into the system. The students' comments formed an important input for the redesign of the system. They helped us to make the system easier to use and to improve its didactical value. In interviews and questionnaires there is often a tendency towards politeness, therefore, we explicitly asked students to criticize the system so that we could improve the system.

3.3 Results

We first asked the students for general remarks and for the most positive and the most negative features of the system. The students' comments about the positive features were quite heterogeneous. Two of them said that the possibilities for communication were positive. Some navigational features (sitemap, tree navigation) were mentioned as being advantageous by single individuals. On the other hand, all five students had an unanimous attitude about the negative features of the system. They all mentioned that the hypertextual structure of the system was confusing. They said that there were too many links, that they easily lost their way by following textual links and that they did not know whether they had seen all there was to see in the system. This is a well-known problem in the hypertext literature. We asked a student whether he also used the WWW which is structured in a similar way. The student said that what he wanted to achieve in the WWW was something completely different. Actually, most of the students we talked to were already acquainted to the WWW. We tried to find an explanation for these contradictory findings. From the students' comments it is clear that they think they have to read all the material that is presented to them in the "office"-part of the system. We think that this might explain the seemingly contradictory result that students are well acquainted with the WWW and like to use it and still have problems with the hypertextual organisation of the Ecodesign e-learning system. Apparently, it depends very much on the kind of task which is set whether they are comfortable with a hypertext system or not. If their task is to look for material in a seemingly chaotic mass of information (as in the WWW) they are not confused by a network of interconnections. When they get the impression that they have to study intensively a whole document they even feel overwhelmed by a fairly well structured and rather small document.

To a certain extent this conforms to other findings in the literature. Beasley and Smyth (2004) report that students working with the CBLPET (Computer-Based Learning in Petroleum Engineering) environment preferred to learn in a linear fashion. They argue that if students are provided with clear navigational guidance which is integrated into the system they will be more likely to study the material in an active and hypertextual manner. Still, there are differences between the findings of the CBLPET study and our investigation. The students in the CBLPET study tended to make printouts of the material and study the material offline. This was not the case in the Ecodesign course. All the students said that reading on the screen was no problem for them. One student mentioned that this

had something to do with the fact that the texts were very short. There was a guideline for the authors of the course to avoid scroll fields because the WWW is not a medium for the delivery of large amounts of text for learners of any age group (Wolfe 2000). Some of them made printouts of just a few selected materials (the sitemap or pdf-files from the "library"-part of the system).

These results somehow contradict the structure of the whole system which is built around examples. The examples as such were accepted by the students, and some of them also looked for additional material on the Internet because they were interested in the topic. Some of the students complained that example 1 was a little bit confusing. It is apparently necessary to use unambiguous text for the description of the examples. This sounds very trivial but is often difficult to achieve.

We also asked the students what kind of navigational tools they used (see Fig. 2). There is a kind of navigation tree on the left side of the screen which is well-known from the Windows Explorer. It is also possible to use the breadcrumbs (a line of text on the top of the text window which represents the hierarchy of the search path) or the links in the text. As for the beta version used in this course, the sitemap already existed as a picture but was not clickable. We, therefore, asked students whether they were interested in such a form of navigation or whether they used sitemaps in any other context. All five students said that they predominantly used the tree navigation on the left side of the screen. This is rather plausible because many people are used to this form of navigation. In addition, the tree is a rather obvious metaphor for the contents of the material and it is always visible. As far as the sitemap is concerned, the attitudes were very contradictory. Two students said that the sitemap was great and that they loved to use such a form of navigation. One student even printed the sitemap out and put it on his desk beside the computer to have an overview of the material at hand. The other two students said that they did not like sitemaps and that they never used such a method of navigation. The breadcrumbs were only used very seldom. Some students even said that they had not noticed them at all. The links in the text were not found attractive because of the confusion they produced. Most of the students mentioned that they found it irritating to follow a link and find themselves in a completely different chapter of the material. In general, it can be said that the tree navigation seems to be the most attractive form of the navigation for the students.

The pictures, diagrams and animations which can be found in the system were also an interesting issue in the interviews. The students' attitudes were rather diverse. Especially the animations were rather controversial. At that time, there were two animations in the Ecodesign e-learning system. One of these videos introduced Tina Balena (Fig. 1) as a kind of electronic tutor. The other animation was about the product life cycle of a shoe for children. Two students explicitly said that they found these animations childish and that they reminded them of kids' cartoons on TV. It was quite obvious that they found these animations not motivating and e-learning programs containing such animations not professional. The other three students apparently enjoyed the animations and found them rather nice. It is very difficult to derive any guidelines from such results because there are such mixed attitudes towards the animations. These findings contradict the popular idea that any animation or video will be beneficial or motivating for learners. All the five students found the pictures and diagrams good. Some of the students said that they even enjoyed those pictures which did not provide any additional information.

Despite the fact that the communication features only existed in a rudimentary form the students were rather fascinated by the idea of exchanging ideas in an electronic form. In principle, the students were willing to spend some time for the interaction with trainers and other students. Two of the students had used the electronic forum to ask questions.We also asked students about several technical features of the system and got quite a lot of interesting information for the improvement of the system. These results are not reported here because of their very specific nature.

4. Logfiles

4.1 The Data: Courses, Users and Observation Periods

The users of the first course who used the beta version received their logins on April, 2 2004. By April, 22 2004 four out of five subjects have uploaded and submitted their assignments of the Ecodesign e-learning system concerning the first two introductory examples. Accordingly these two dates mark the observation period of the first course. Although the size of this group was not too big, one user (the mentioned exchange student) was excluded from the

logfile analysis. The difficulties he had with the online course's language not only led to a rather moderate use of the system but also to a very unusual navigational behavior: text links were hardly ever used. He furthermore did not hand in any assignment like the others did. So we decided for the smaller group size of 4 instead of risking corruption of the findings. The consecutive gamma system was thoroughly tested by 35 users of a course held in Zürich, Switzerland. They had their first meeting on April, 26 2004, an intermediate get-together on May, 10 and the third and last face-to-face meeting on June, 6 2004. The deadline for submitting their essays was extended by a few weeks and so the last submissions happened on June, 28 2004. Therefore the observation period for the gamma system is marked by April, 26 2004 and June, 28 2004. The first and the third introductory example were submitted by 34 users, the second by 33 and the forth extensive example by 27. There were 2 persons who showed very little activity compared to average, nonetheless one of the two handed in all 4 examples, so there was no need to exclude anyone from the analysis.

4.2 Technical Details

We used the Z2.log produced by Zope in combined log format. The fact that the server running Zope resides behind a firewall caused us to alter the servercode to include the x-forwarded-for header in the logfile entries. In order to distinguish the different categories of clicks we introduced query values to respective URLs. So every link followed from the explorer-like tree on the left ended with "?TR=1". This query was not evaluated or processed in any way but only used to tag the log entries. Breadcrumbs (BC), sitemap (SM) and navigation bar (NAV) were labeled similarly (Fig. 2). The naive assumption that we would be able to count the one and only remaining navigational category, namely the following of 'real' hypertextual links within the text (ie. clicks in the content-frame), by process of elimination turned out to be the crux of the matter. Due to the complexity of the e-learning system, especially because of the re-designed behavior of and interaction between tree-frame and content-frame according to the feedback in the interviews with the users of the beta system, simple user interactions triggered complex server reactions which were reflected in the respective log entries.

In short, the Perl program (which was implemented from scratch to meet this special task of analyzing) quickly exceeded a thousand lines. The primary input to this program was a logfile of 450 MB. After splitting and cropping the valuable data was condensed to 4 files of overall 10642 lines (4.2 MB) for the first course and 35 files with a total of 167759 lines (70.2 MB).

4.3 Results

The labeling of URLs via queries has the side effect that for a browser two URLs leading to the same content are seen differently (eg. asdf.html?TR=1 and asdf.html?SM=1). Both have the same result when followed by the user but when the browser's history is used to determine which links have been visited by then, nodes accessed previously via the sitemap are rendered unvisited in the tree-frame by the browser. This may seem like a terrible weakness of the system but on the other hand also has its advantages. It makes perfect sense when learners access the same material through different contexts: whereas the tree gives a rather clear linear sequence, the sitemap shows much more of the interrelations (ie. all the edges in the graph, which are lost in the tree view of an example).

When it comes to the question of activity of different users, one has to take into account that few log entries do not essentially mean low activity. In the interviews that are undertaken right now with users of the final e-learning system we learned that some of these users did not stay online the whole time when working with the system. In fact they loaded many pages into the cache of their browsers, disconnected from their Internet service provider and made their way throughout the system with back and forward buttons of their browsers.

The navigational behavior was analyzed for each user. The click count of the user who utilized a given category least is mentioned as min for this category whereas max shows the click count of the user who had the most clicks in the given category (Tab. 1). Mind that the mentioned min values for the various categories do not originate necessarily from the same user. This applies to the max values as well. Calculated values (ie. the average click-count for each category and the relative distribution amongst these) were rounded to 1 decimal place. The differentiation between the 2 courses was introduced not for showing major discrepancy but to account for the progress made from beta to gamma (eg. in the beta system there were sitemaps but at that time they were not clickable). In addition to

the obvious 5 categories shown in (Fig. 2) we introduced three more: the count of links followed for viewing a posting in the "communication"-part (VP), the count of links followed from the "office"-part to "library"-part (O2L) and the count of downloaded pdfs in the "library"-part. All of these three could be interpreted as a variant of the TXT category but we think there are conceptual differences to text links.

		SUM	NAV	TR	BC	TXT	SM	VP	O2L	PDF
beta	min	256	19	120	0	65	-	4	4	3
	max	485	54	277	14	102	-	19	8	37
	avg	332.8	33.5	177.5	6.2	84.5	-	9.8	5.2	16.0
	%	100.0	10.1	53.3	1.9	25.4	-	2.9	1.6	4.8
gamma	min	43	2	23	0	3	0	0	0	0
	max	718	101	534	18	141	3	11	17	47
	avg	418.5	47.7	279.6	4.3	69.5	0.4	2.3	4.1	10.7
	%	100.0	11.4	66.8	1.0	16.6	0.1	0.6	1.0	2.5

Table 1: Usage of Various Navigational Practices.
Navigation Bar (NAV), Tree (TR), Breadcrumbs (BC), Link Within Text (TXT),
Sitemap (SM), View Posting (VP), Office To Library (O2L), PDF Download (PDF).
For Categories See Also (Fig. 2).

The main result of the logfile analysis showed that the tree navigation is clearly favored by all users (53.3% and 66.8%). This corresponds with the interview results mentioned before. One could expect that the reported aversion to hypertextual links would be reflected in a much lower percentage than the observed (25.4%). The reduced percentage (16.6%) in the second course could originate from the fact that on the one hand the amount of nodes has more than doubled (there were 4 examples instead of 2) and on the other hand link-lists to subsequent pages were eliminated from many nodes (they duplicated the tree navigation in the content-frame). Perhaps the most important reason for the marginal use of breadcrumbs (BC) is the nature of structured examples. With the introduction of superordinated and subordinated nodes and the restriction for the content providers to limit the amount of nodes in a given area to not more than seven the tree stays manageable for the user. It is possible to see most of the superordinate nodes. So as long as the tree does not become very flat and therefore one would have to scroll to reach superordinate nodes the breadcrumbs give only a subset of the tree's capabilities. A disappointing finding is the refusal of all users to utilize the sitemap for navigation. The users simply did not click on the graph drawing to reach certain nodes. This does not mean that it was useless to the users. As pointed out above, one of the four users of the first course printed out the sitemap for overview purposes. Similar to that a user in the ongoing interviews reported that he opened the sitemap in another browser instance and placed it on his second monitor. This would be another case wich cannot be accounted for in logfile analysis. As an experiment we counted the requests of the sitemap (how often it was looked at). If counted separately and treated like a category of its own the percentage would climb from 0.1% to 0.7%. Obviously the sitemap is at one big disadvantage: it is big. It requires almost the whole screen or at least the whole content-frame whereas the tree is small and omnipresent. Therefore it is by definition no competitor to the tree.

5. Conclusions

A considerable amount of the results described above concerns the navigation in the Ecodesign e-learning system. In general, it can be said that the students prefer more conventional forms of navigation like the tree navigation on the left side of the screen. Even the students in Zürich who had access to a clickable sitemap did not use this map extensively. Both the data from the interviews and from the logfiles support this conclusion. The students usually first read all the material and then worked on the examples. When working on the examples the students also predominantly used the tree navigation. Only very few students see the potential of the sitemap for giving them an overview of the system. Several explanations are possible for this phenomenon. Many content providers still have difficulties to develop hypertextual structures and the students themselves are used to learning linearly. The structure of the Ecodesign system which is centered on examples could support a more hypertextual approach but a careful redesign of the material in the “office” section would probably be necessary. The examples as such were found to be engaging by the students although a careful explanation of the tasks is necessary. Pictures and diagrams were

appreciated by the students in the interviews. The attitude towards animations was very mixed. Possibilities for communication were seen as advantageous by most of the students.

Presently, we are conducting a second evaluation of the Ecodesign e-learning system. The first results are quite encouraging. The students have a fairly positive opinion about the system and especially the communication via chat and forum is seen as very motivating and interesting. It must be mentioned, however, that we have not overcome the problem with the hypertextual structure of the system completely. The Problem is twofold and for both sides we think that there is no immediate solution. One the one hand it is necessary that content providers get used to the idea of hypertextual organisation and that the example-oriented approach is more pronounced during the whole course. On the other hand, we expect that learners will get used to hypertext as they use the WWW more and more in their private lives. We hope to be able to achieve some progress in further research studies.

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