An Integrated Learning and Information Environment for Product Innov@tion

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Abstract

"Product Innovation" is a new type of integrated environment, which addresses the learning, exchange of information, training and communication in the field of product innovation. It serves different user groups either for education within the university or the further education or training for people working in industry. The paper discusses the motivation for establishing such an environment. The requirements with respect to didactical, pedagogical and also technical aspects are dealt with. The main focus concerning the learning aspect is directed to the user "students." On the basis of a first evaluation of the environment after using it since autumn 2000, some interesting results with respect to behavior patterns of the users, acceptance of the environment by the users, judgment of quality, availability and functionality are presented.

I. Introduction

Despite the enormous development of the information technologies, information alone is not decisive to assure a competitive advantage. Global communication networks like the Internet enable the almost immediate exchange of information without limits with respect to place and time. However, it is not the information alone, but the knowledge and capability to evaluate, judge and make use of these information in the sense of a learning process.

Knowledge and the gain of knowledge today are the important factors, crucial for being successful within the global competition. Because of this fact numerous companies, enterprises and educational institutions are aware of the importance of knowledge as "the" elementary resource. Several initiatives in the field of knowledge management have been started in the meantime. The objective of an efficient knowledge management is the assembly of specific knowledge to achieve a competitive advantage in the long run. To realize such a knowledge database, the knowledge of individual competence must be made available globally. Moreover process must be defined to efficiently develop knowledge for the knowledge database. The boundary conditions necessary, to support and accelerate such a knowledge building process, must be created. Identification, collection, documentation and sharing of knowledge are the essential elements of the knowledge building process. People have to be enabled, wherever they are in the education system (primary education, secondary education, life-long education), to access globally this knowledge for building up their own competencies.

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II. Motivation for a Network of Competence

Knowledge networks are of high importance in the context of Web-based learning environments. They are formed by groups or communities whose members have a common interest in a certain subject or knowledge area. The utilization of technologies like the Internet, Intranet, search engines, specific knowledge databases, and visualization are essential elements of such knowledge networks. Efficient knowledge networks need state-of-the-art technology platforms to guarantee the exchange of information and knowledge independently and without any restrictions.

Product innovation, which essentially means the definition, development and production of new products and their successful launching to the market, is the driving factor for a powerful, competitive economy and the prosperity of the society. Therefore, the primary education at the universities and the ongoing, further industrial education of engineers in the wide field of product innovation is of central importance.

An analysis of the present education programs and offerings of different universities in the respective area shows the following situation: the specific knowledge is extremely distributed among the different universities, and the curricula have a distinct focus with respect to specific subjects and themes. For instance, there are lots of good courses in innovation management, development methods, engineering tools, engineering and structural analysis, rapid prototyping, and design. However, the subjects are often presented in kind of isolated view, driven by the specific know-how and interests of the teacher. Roughly estimating the expenditure of time and human resources to transfer this broad content of knowledge and courses with a defined high quality into a virtual learning platform using new technologies, it will be immediately evident that the New Technologies can lead to useful synergies by combining the input of different centers of competence.

The learning environment has the final objective to establish a network of competence with its members. It has the potential to leverage this important part of the curriculum to the required sustainable level of quality ensuring a qualified content of the material and appropriate didactics. It also takes into account these aspects by an integrated learning, information and training environment, which utilize the Internet as the communication platform.

State-of-the-art multimedia technology is used to enhance the information and learning process. The system utilizes new forms of teaching and functions as a complementary supply of lectures in a first step during a transitional period. However, as a short-range objective, the system is a replacement for some parts of the classical frontal lectures. A strong component of interactivity supports the use of the system with improved communication tools among students and with the lecturers. One aspects of the system is also the improved equal treatment of students. The system promotes the exchange of ideas and their judgment. The complex decision making processes, which characterize product design and development, is one important focus of the learning scenarios.

Users of the environment can determine independently time and place of their studies and can choose among the courses which correspond to the individual demand of qualification. Other important issues refer to time management for students and as well the support of independent working (individual work). Thus, the self-responsibility of the students is promoted. On-line examinations, tests and as well the quality of the results will be the basis for grading. To shorten response times for the grading will be especially of great value for students. Permanent knowledge diagnosis gives important information either to the students and the lecturers. A high level of transparency both promotes the quality of the learning process and improves the efficiency.

Communication partners are not only students and teachers/professor alone, but increasingly also people from industry (external students). Students receive by means of augmented communication additional information, hints and tips from these new learning partners. Thus, a new quality of learning network is created.

III. Main Features of the Learning Environment

The main features of the environment as the basic result of the requirements and specifications are:

- the formation of a motivated learning community which is determined by characteristics like feedback, competition and collaboration;
- a formalized explanation and definition of the product development through descriptive process models;
- innovation cases to lead the students to the learning targets on the basis of real world or constructed case studies;
- check lists;
- interactive formulas;
- intensive use of multimedia;
- automated correction of exercises;
- access of study material by a wider group of people;
- better survey for the lecturer over the success of the individual student;
- gaining information about the quality of the course material through the system, improved individual treatment of students;
- continuous control of the learning improvement and success by the student;
- communication and discussion platform among students and professors/experts to motivate students for
- links to secondary information and to selected companies.

IV. Pedagogical Scenarios and Learning Material

Creative processes as well as collaboration and discussions with others are essential for the formation of the ability to perform well on innovative tasks. Innovative achievements result from ill-defined processes and, therefore, it is important to set up appropriate environments for the development and training of this special kind of expertise. To perform well when innovative results are sought demands self-confidence and a situation that allows for a free and unrestricted development of ideas. A trustworthy platform is, therefore, key to support such processes as well as the development of the ability to perform creatively.

Experience has shown that trust increases:

- with the amount of transparency within the system;
- with its reliability regarding the stored data; and
- with the protection of the personal sphere and identity.

Additionally, any technical support and information regarding the task at hand that can be provided is beneficial.

Special features that should be offered to enhance individual as well as collaborative creative work include:

- support of the freedom to explore and expand a possible result space;
- support to narrow down the possibilities at any time;
- easy navigation through the result space;
- access to relevant additional information; and
- features that help to understand past decisions, on the one hand own decisions, but more importantly the decisions of other participants.

Since the creative process itself is very complex and collaboration adds to this complexity, only sophisticated visuals means can provide the information necessary for its understanding. To transform data into appropriate visual representations is a crucial aspect of the platform. Important is the identification of the views that are necessary as well as the implementation of the procedures to produce them on the fly.

Three categories of views are important:

- *Overviews:* These views allow grasping information on a meta-level regarding and show relations among different parts of the data including geometric models, qualitative information, quantitative information or semantic information.

- *Process Views:* These views allow understanding of the dynamic process and to navigate in time and access different states of the developments. They are important to understand past decisions.

- *Focused Views:* These views give access to individual contributions. A sequence of such views is helpful to see the progress of the work as well as progress in the learning process.

Links between different views as well as the same level of views create a navigation network that helps to access information in different ways depending on one's intention. The concept of views is a straightforward strategy to allow for synergies on various levels. A sophisticated set of views that support creative collaboration cannot currently be found in commercial applications, but it has been explored in several research and teaching projects at ETHZ as well as other institutes around the world.

The application of these findings to the context of product innovation can be estimated to be an important feature to provide a visionary Web-based learning environment.
A "course" is to be a combination of certain number of educational units (modules) based on the individual needs and learning targets defined by the teacher.

The existing classical courses have a certain pedagogical structure, most of the time one-third frontal lectures, one-third training, and one-third individual extra work. It is clearly the intention of the learning environment to drastically reduce the effort of frontal teaching in the sense of giving basic information to students. This type of lecturing is a passive process from the students' point of view.

The on-line course system has the function to prepare the students for the adapted lectures, which cover especially case studies, or in a narrower sense, "innovation cases." Innovation cases have the function to demonstrate the practical relevance and the application of methods of the material presented. On the other hand the students spend on-line time consolidating the material presented (Figure 1).

The following pedagogical elements have been implemented (Table 1).

The distribution of hours in a course can differ from course to course and can also vary with the individual student. From today's allocation of 52 hours of direct student contact, we will reduce the "physical" contact to approx. 30 hours and another "virtual" contact of another 20 hours in which the students have the possibility to contact other students or the tutor. As already mentioned, this allocation differs tremendously from course to course, from student to student, and also during our own learning curve and experience with this new form of education. Especially the contact in the classroom is a process of experimenting and evaluating during the next years of introduction. Even though social aspects can be integrated in networked platforms, the face-to-face contact with the staff is still considered crucial to ensure an optimal support of the learner.

Product innovation is a highly interdisciplinary field (Figure 2). Several disciplines are covered like science, engineering, technology, economics, administration, ecology and much more.

The overall learning cycle or process within the learning environment is characterized by three consecutive phases of knowledge gain:

- *Conception:* Tthe student gets a survey about the subject. Relations to his prior knowledge are built thus initiating a first process of interpretation.

- *Construction:* The student is asked to make use of the new knowledge. With respect to the learning goals he

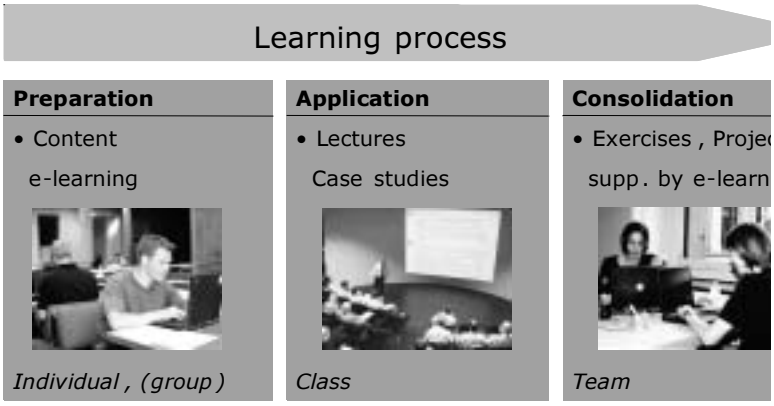

Figure 1. Learning scenarios.

Table 1. Pedagogical elements.

Pedagogical Element	Type	Activities and Objectives
On-line learning	Individual	Basic knowledge transfer, definitions, process understanding, methods
Classroom tutorial	Class	Motivation, discussion and solving of "innovation cases", general discussions
On-line training	Team	Forming teams for certain topics and interests, discussion and solving of "innovation cases" individually or in teams, self tests, discussion with tutors
Practical training	Team	Coached experiments, skills

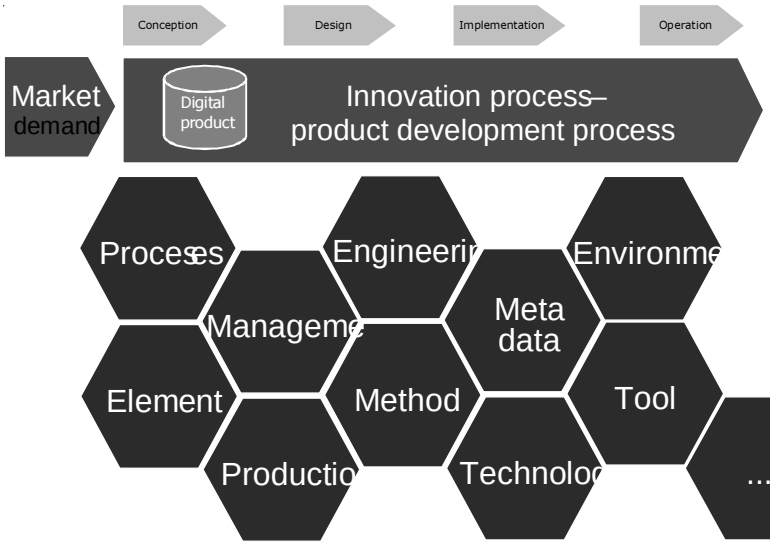

Figure 2. Interdisciplinary field.

chooses the relevant subjects, he relates the learning goals to contents of his memory and carries out a classification of the learning contents. The dealing with meaningful problems results in a consolidation the knowledge.

- *Dialogue:* This is the essential social component of the learning cycle because by exchanging of the individual results with others in discussions, the students go into a process of reflection, thus improving their knowledge.

The dialogue phase within the individual learning cycle of course is supported by online coaches who can step into the discussions between the students as required and can even establish kind of "moderated conferences."

The scope of action for the proposed on-line learning environment fosters the principles of "Internet-based Group Learning," which are creation, communication, cooperation, construction and collaboration (Figure 3).

The pedagogical objectives of the environment are to:

- motivate the student such that he actively works on the subjects;
- impart the knowledge by authentic situations;
- present the subjects from different views and in different contexts;
- stimulate the cooperation and the exchange among students and enable the individual coaching by the teachers at the same time;
- to predict no learning paths to the student, but offers different ways to deal with the subjects; and
- to permit the student to control the duration, time and pace of learning.

The didactical model defines the coarse framework of an on-line course. In this context, the proposed learning environment addresses the following aspects:

a. the learning goals, which must be reached by the students;
b. the learning content, which lead to the learning goals;
c. the selection and the preparation of the learning contents using state-of-the-art multimedia technology;
d. the learning measures, which support the learning process; and
e. the learning strategy chosen.

Independent learning offers a lot new opportunities to the student like self-control with respect to schedule, pace of learning or reaching of learning goals. However, there might also be drawbacks with respect to independent learning in the context of learning organization, the learning process itself, or in maintaining motivation.

The learning environment takes these problems into consideration. It is done by the following means.

1. On the basis of a precise description of the learning goals, the student can rate the relevance of the specific course with respect to his demand for education. A survey and as well a short summary of the learning contents are very helpful in this context.

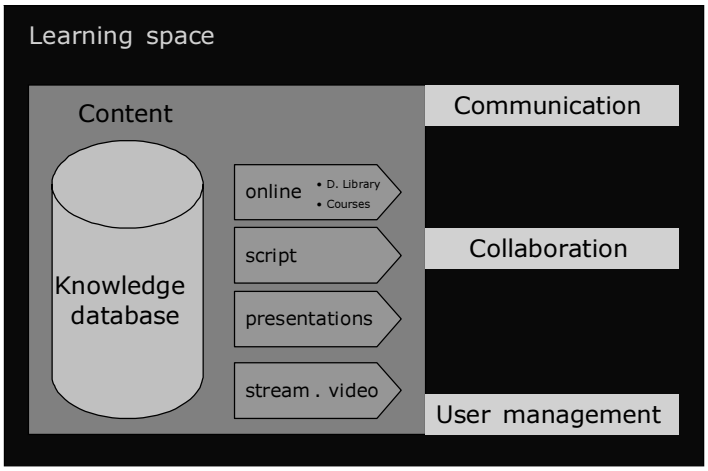

Figure 3. General structure of learning space.

2. A declaration for the work time also is advantageous. The student can plan the learning process effectively and can coordinate it with other activities.

3. The input of the student, especially answers to questions (self-test) are commented on by the system, thus supporting the gain of knowledge.

4. A summary at the end of a learning unit supports the student to built up kind of macro structure of the learning contents.

5. Various kinds or types of exercises support the processing of the new content.

6. Innovation cases lead the student through the content which are relevant with respect to the learning goals and gives him a parallel or complementary path for his own learning preferences.

7. Evaluations of the results that were produced by other teams or individuals enhance the judgmental abilities of the students and in turn can provide them with valuable feedback on their own work.

Motivation deficits of the students can arise due to technical problems or navigational difficulties within the learning environment. Therefore, an intuitive user interface is imperative. Ideally, the learning contents have a relation to the experience or practical knowledge of the students. The learning contents must be variedly prepared. The personal relation and the directly recognizable advantage (benefit) by working on the contents promote the knowledge acquisition and should be evident to the student (by declaring the target and the benefit of each learning unit).

The opportunity to have a competent tutor or coach available has the same motivating effect like the exchange with other students. The social component becomes the scene, the students establish contacts and relationships, which means a stronger integration into the course. Topical hints and tips in the context of the subject assure an ongoing dealing with the contents even after the learning time. The course designer cannot anticipate all problems at the same time. However, the big potential of an online learning environment is based on the fact that tutors or coaches can support the students in this context. Technology offers tools like video-conferencing, chat or e-mail. In this way, the positive effects of independent learning can be optimally utilized for the learning process.

Interactivity is a very important element of an IT-based learning environment, because of its crucial impact on the motivation of the student. Interactivity offers the student the capability the form his personal learning environment by accessing additional interesting information (links), placing marks or notes, and/or defining bookmarks on already processed, or especially important pages. The feeling of responsibility for the learning process is addressed and as well the motivation.

It is the task of the course developer to filter out of a subject the best suitable contents and to structure and to prepare it in such a way that the learning success is guaranteed. The basis is an extensive collection or database of material from which the content of the course are selected. The contents are presented by various media like text, pictures, audio, video, animation, draftings, 3D-models, etc.

The learning goals (targets) describe how the student deals with the learning content after a successful acquisition of knowledge, which essentially is the "target behavior." The formulation of learning goals are essential, because:

- they enable the student to judge the importance of the courses with respect to the own knowledge; and
- they facilitate the control of the learning success (the more precise the expected target behavior is defined, the easier the progress of learning success can be checked).

There are different types of *learning targets*:

a. the capability to use terms correctly;
b. the capability to explain terms with own words;
c. to apply abstract knowledge to real situations; and
d. to reflect facts critically, to arrange, classify and assess them in a wider context.

The learning strategy determines the sequence of educational measures with which the student is able to reach a specific learning goal. Learning is an active and dynamic process. The student works independently on the subject which is assembled in the individual cognitive structure. The student adopts and processes the content which have been prepared by experts in small, successive learning units. A positive feedback after a successful completion of a learning unit encourages one to go on in the course. The basic approach is based on the phases of preparation, acquisition and evaluation.

Preparation Phase:

- A central element is a kind of introductory kick-off meeting for all students. This event is necessary to introduce the students into an new learning situation.
- Learning goals inform the students about the benefit which he will have after completing the course.
- A short video could be a very useful information source to demonstrate how the new knowledge will improve the individual capabilities.
- A clear and obvious advantage promotes the curiosity and the positive attitude (motivation) of the students.

Evaluation Phase:

- Regular small exercises support the active acquisition of the material.
- Comprehensive learning checks (self-test) at the end of each learning unit require a concentrated dealing with the material in its complete complexity.
- Meaningful feedback are very important either for small exercises or more difficult tests. Students read comments and tips for the correct solution with more interest.
- Case studies or so-called innovation cases demonstrate the benefit of the new acquired knowledge. The practical relevance is proven by these examples from industry. They can visualize the subject in different ways.

V. Pedagogical Benefits

Further pedagogical benefit in this context can be summarized as follows:

- Learning takes place more and more online and substitutes at least partly frontal lectures. Therefore more time becomes available for individual coaching.
- Knowledge, which is globally available, is integrated into the learning processes.
- The learning environment offers several guidelines or learning paths, the student learns within a system without restrictions, lead by own preferences.
- The requirements with respect to the student's capability, to organize themselves within the learning process, increases.
- New relations of communication are integrated into the learning process, which approach the work process more and more.
- On-line courses support the "start-up" of the learning process by stimulation the student to construct (assembly) the knowledge independently.
- Students are trained to work over electronic networks, which increasingly corresponds to their future professional working situation.

The long-term perspective of the learning network is the increase in efficiency for the educational establishment because of the:

- integration of documentation and education within the intranet;
- better utilization of staff with respect to required time for coaching;
- higher level of relevance of the material;
- flexible and easy to use educational environment;
- consideration of interested people from industry for ongoing education;
- integration and embedding of corporate universities; and
- integration of industry partners into the network to profit from current professional experience offer academic themes and research results for on-site continuing education.

As already mentioned the result is a Web-based information and learning platform for continuous use with respect to learning, training and consulting in the sense of providing specific, certified information and knowledge about the whole product innovation process. Partly it is a replacement for knowledge by heart and a support for making decisions within the product development process. Moreover it serves as a reference book and as support the process of compiling new knowledge for various user groups serving their specific demands and requirements. The platform provides support for making decisions during the product development process, reducing the application of fixed and aim for flexible, creative attitudes towards the tasks at hand.

This integrated environment enables both the education and training for product innovation. As one aspect, students can form virtual project teams which work on specific projects, addressing also the social component of the learning process. The forum for the teams are the virtual environment itself using specific discussion groups, e-mail etc. Thus, students are confronted with the type of realistic working situation which will become more and more important in the industrial practice.

VI. Courses Implemented

The whole environment will have approximately 10 courses with a total number of approximately 650 hours learning time in the various disciplines around innovation. The whole system will have a modular concept to compile specific courses with different levels (undergraduate and graduate) for technical universities and further industrial training.

Within the existing curriculum the following courses will form the base version of the learning environment:

Course 1: Product Innovation 1-Methods and Processes

Marketing (market segmentation, market analysis, trends and projection, strategy), core competencies, product and service requirements, team organization, presentation techniques,

moderation techniques, reporting, cost structure of products, conceptual design (broadening of the system, function structure, working structures, finding partial solutions, combining solutions, selecting and evaluating solutions) creativity methods, design basics (fundamentals and principles of design, administration, concurrency), patents.

Course 2: Product Innovation 2-Materials and Processes

Materials for products and their properties, manufacturing processes and the corresponding design rules (design for production), rapid prototyping, industrial design, engineering first part, machine elements (part 1).

Course 3: Product Innovation 3-Engineering, Structural Analysis

Machine elements (part two), engineering (stress-strain and failure analysis for fundamental problems, application to mechanical components and systems, fatigue), discussion of engineering cases.

Course 4: Design Skills–Technical Documentation

Skills for drawing and sketching, reading and interpreting of drawings, standardization, tools (CAD,CAE).

Course 5: Managing Innovation Projects

Advanced know-how for processes, methods and enable students to manage complex innovation-projects (new course, not already existing).

Course 6: Information Technologies Used for the Digital Product.

Course 7: Engineering Tools for the Product Development Process.

Course 8: Visualization of Technical Objects.

Course 9: Visualization and Simulation of the Digital Product.

VII. Evaluation and Experiences

To evaluate the use and the level of acceptance, the users of the first course were interviewed by an independent evaluation team.

A. Behavior Patterns

It turns out that 50% of all users prepared in advance the next lecture. At the beginning of the course, the student had been informed that the preparation of the "next lecture" would be a prerequisite in order being able to follow the lecture. The content of the lecture does not reflect the material presented in the on-line course or the printed lecture notes. The lectures are focused on discussing innovation cases together with the students. Although a printed version of the lecture notes was available also, approximately 65% of all students used the on-line system for the preparation. The "post-processing" of the lecture was only done by 30% of all students.

B. System Rating

The didactical elements (motivation, self-test, innovation cases) were only available to the students through the on-line system. Forty percent of all students rated these elements as useful and made use of it (Figure 4). Sixty percent used of the communication tools. Most interesting the bulletin board was highly accepted and substituted the e-mail to a great extent. Thus, the whole course community was involved, which lead to a very intensive discussion with respect to selected topics or subjects, either related to the learning contents or to "every day life." In a certain way we have the impression that the increase of quality of communication was supported by the formalism of the bulletin board.

From the learning process point of view, 80% of all students agreed that the lecture concept in combination with the on-line learning system effectively supports the learning process. More than 55% of all users used the on-line learning system on a regular basis. One has to keep in mind that the students had several possibilities to have access to the relevant information. The graphical and textual quality of the contents pages were rated "good" by more than 80%. As pointed out earlier, this is absolutely necessary for a high level of acceptance and use of the content presented. It must be noted that the presentation of the material on Web pages must considerably differ from the presentation in a printed script. Especially the textual content must be compressed to a permissible limit to reduce the amount of on-line reading.

The functionally and user friendliness of the system was rated as good by approximately 75% of all users. The settling-in period was short for most users. Most users (80%) rated their skills in using computers at the beginning of the course as "average to high." Neither during the work with the learning environment over the intranet or the Internet most users (90%) experienced substantial problems.

Contrary to the speed of the intranet, the speed over the Internet was rated as not satisfactory.

VI. Summary

A first evaluation indicates a successful introduction of the learning environment. Nevertheless, these limited set of information does not allow a final conclusion of the quality and value of this new learning environment and concept. However, further

evaluations, comparisons of corresponding years on a longer period of observation should not leave a lot of questions unanswered.

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Author's Biography

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1995 –1998	Head of research group for visualization, analysis and simulation in product development (virtual reality)
1994	Habilitation on Active Structures and Materials
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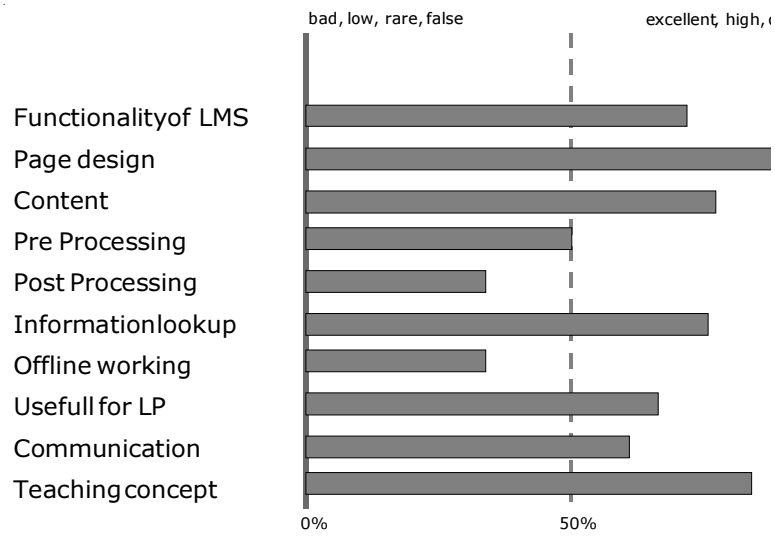

Figure 4. System Rating.