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Educational Evaluation of an Interactive Multimedia Learning Platform

Computerized Educational Platform in
Heat and Power Technology

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ABSTRACT

Learning materials have multiple forms, such as books, overhead slides, computer files, blackboard notes by teachers, narration to the notes, video/audio tapes etc. Since the forms are highly inhomogeneous, it becomes difficult to collect and practically use them by a particular learner for individual study at home. Such multiple media are also expensive in management, since human resources are needed to keep the material repositories in order. One solution of the problem lies in centralized active digital repositories. Such repositories aim to simplify the learner's work and boost learning efficiency. With introduction of interactivity and live communication tools such repositories become learning platforms exceeding the functionality of "passive" digital libraries. Such learning platforms could be easily used both for on-campus and distance education.

This dissertation presents an evaluation of a digital repository of interactive multimedia content in the field of Heat and Power Technology: Computerized Educational Platform (CompEdu HPT). The platform evaluation consisted of integration of the tool into the university curriculum and then collection of feedback from students and teachers. The evaluation concerned usefulness of the platform for learning, aspects of instruction improvement, collecting observations about how the platform is used by students, as well as their opinions about the IT application direction chosen. The methods included: online feedback forms, questionnaires, interviews, discussions and observations.

The evaluation demonstrated that the main strength of the platform is the integration of learning materials in one portable package. The students appreciated structured and logically arranged information that was available for easy access. Coverage of a broad area of knowledge related to heat and power technology was also pointed out as an advantage with reflection on the very low price of acquisition of the materials. The most popular elements of the content in use included: simulations, lecture notes, the print function, the glossary, and calculation exercises. A major part of the students declared the high value of CompEdu in facilitating home study. Nevertheless, not all the students had a positive impression: around one-fifth of them did not find the platform useful and expressed preference for more traditional learning media. The majority of the negative opinions concerned content quality, which directly related to weaknesses of the content production and review process.

The evaluation emphasized the importance of material quality and amount as the key issue for a good learning platform with relatively smaller importance of presentation forms. The evaluation also considered aspects of functionality from the user point of view. Differentiation between popularity of simulations showed that simulations used by teachers during lectures have higher educational value than those for individual use only. The

popularity of the printing option indicated a need for adaptation of digital materials for paper publishing. The general conclusion for practical use of multimedia tools in education was that high usability and simplicity of information access should be the focus point of any chosen approach in the direction.

The CompEdu evaluation suggested that after thorough content review and addition of an efficient search mechanism the platform can successfully deliver rich learning content. The platform gave an extensive real-case illustration of how multimedia can be used in educational practice. Due to the evaluation, the CompEdu e-learning group has collected rich experience and know-how in the field of active knowledge repositories. The experience will be used for development of a more sophisticated learning platform working in the global Internet environment with major focus on information accessibility by easy search.

PREFACE

The last decade of the 20^{th} century was marked by a boom in the information and communication technology and corresponding business models. There was a promise that the technology could considerably improve efficiency in almost all areas of human activity in short time perspective. This promise also influenced the educational environment including schools, colleges, and universities. Later experience showed that certain aspects of the approach had been considerably overestimated and some underestimated. Different application directions were chosen in the educational environment for testing, but the test cases showed that the modern technology is not a panacea for efficient instruction and quality of human work in general.

The Computerized Educational Platform in Heat and Power Technology (CompEdu HPT) has been under development at the Department of Energy Technology of KTH during the years 1996-2004 as a response to the worldwide trend of the decade. CompEdu is a product of collaboration between several universities in the international context. The platform gathers broad range of interactive learning materials (slides, lecture notes, simulations, videos, quizzes and some other). The software has been used by students and teachers in daily educational activities; and since any kind of new pedagogical tool should be tested from the perspective of fulfilling the educational goals, CompEdu evaluation was conducted. The evaluation concerned usefulness of the platform, aspects of instruction improvement, collecting observations about how the technology is used by students, as well as their opinions about the ICT application direction chosen.

The dissertation results are expected to be useful for teachers applying ICT in their daily work and also for digital content developers. The teachers will be able to correct their attitude towards computer tools for instruction. Developers will be able to reconsider the importance and efficiency of particular instructional solutions. The final users (learners) might benefit from the work indirectly, when their expectations and needs are met in a better way.

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NOMENCLATURE & DEFINITIONS

Distance education	–	a method of teaching in which the students are not required to be physically present at a specific location during the term.
Interactivity	–	the degree to which in a communication process each message is related to the previous messages exchanged (Wikipedia, 2005).
Multimedia	–	the use of several different media to convey information (text, audio, graphics, animation, video, and interactivity). Multimedia also refers to computer media.
Pedagogy	–	the art or science of teaching. The word comes from the ancient Greek paidagogos, the slave who took children to and from school. The word "paida" refers to children, which is why some like to make the distinction between pedagogy (teaching children) and andragogy (teaching adults). The Latin word for pedagogy, education, is much more widely used, and often the two are used interchangeably. Pedagogy is also sometimes referred to as the correct use of teaching strategies.

Abbreviations

ADL	Advanced Distributed Learning Initiative
AICC	Aviation Industry Computer-Based Training Committee
ARIADNE	Foundation for European Knowledge Pool
ASME	American Society of Mechanical Engineers
CAD	Computer-Aided Design
CompEdu HPT	Computerized Educational Platform in Heat and Power Technology
DCMI	Dublin Core Metadata Initiative
ICT	Information and Communication Technology

IEEE LTSC	Learning Technology Standards Committee of the Institute of Electrical and Electronics Engineers
IMS	Instructional Management Systems Global Learning Consortium
LMS	Learning Management System
SCORM	Sharable Content Object Reference Model
TEL	Technology Enhanced Learning

1 INTRODUCTION

Almost all computers of today are electronic devices, which solve man-defined mathematical and logical problems through operations on binary signals. Computer input/output has been from the beginning adapted to interact with humans. Therefore the devices reflect human's vision of the real world through interactive representations of real objects or human mental models (e.g. flight simulators, virtual "live" organisms, calculation spreadsheets etc). Assuming that most of digital content reflects human logic and experience, one might claim that any interaction between a human and a computer is the form of communication between humans. The idea can be partly supported by the fact that nowadays computer interfaces are becoming more intuitive and human-oriented compared to the time of the technology beginning, therefore becoming communication-oriented as never before. This assumption allows shifting our focus from the computers to a technologically enhanced conventional man-to-man dialogue.

How do Information and Communication Technologies (ICTs) influence our human interactions? Among others the following could be mentioned as the most important:

- allowing reuse of once recorded simple or complex messages from other humans. Recorded this way messages are a cheaper alternative to services demanding human presence. Such machine-based services also can be accessible any time in any place,
- improving communication efficiency between people by removing economic and speed limitations of other communication means, such as telephony or post,
- personal assistance by automating "secretary" routines, such as scheduling, reminding, keeping address books, checking the spelling etc.,
- automatic collection of performance indicators corresponding to human activities (e.g. quizzes in e-learning),
- searching, sorting, and classification of messages from other people.

All the factors mentioned above were rapidly recognized as opportunities by the business community and found practical implementations there. Also the academic environment has followed suit and started adapting ICT for education. "In the last few years, schools have been spending millions of dollars on computer technology and rushing to get computers into the classrooms. But all of the computers in the classrooms will be rendered useless unless appropriate software is available and individual teachers change instructional approaches" (Scott, 1998).

The idea that appropriate software and teacher-accepted instructional methods are the keys of successful use of ICT in education found the response among engineering educational staff and different computer programs started to appear in 1980s-1990s. Among the programs there was CompEdu HPT (Computerized Educational Platform in Heat and Power Technology), which tried to integrate previously separated computer instruction elements into a centralized, curriculum oriented software package.

1.1 Problem formulation for the thesis

The CompEdu platform was a part of the curriculum at the department of Energy Technology in years 1994-2004. The experience was collected along those years, several evaluations were done and the platform was improved to meet the requirements of educational process in the heat and power technology instructional field. Another pedagogical evaluation of the efforts was awaited to support or reject initial assumptions made during the development. Such an evaluation was the goal of the thesis work. The results of the evaluation were expected to give preliminary view of how CompEdu is perceived, but did not aim into a pedagogical research, which would demand more resources and a profound scientific basis to perform. The evaluation also aimed towards making decisions for further platform development.

1.2 Objectives

The evaluation objectives were as follows:

- to identify the strongest and the weakest elements of the platform from the perspective of use by learners,
- to identify typical scenarios of platform usage in terms of time and place,
- to collect information and know-how on the subjects corresponding to the most useful platform elements,
- to judge the value of the platform and to prepare the guidelines and suggestions for further platform development,
- to collect information about practical integration of the computer technology into curricula for newcomers in the field of content development.

1.3 Approach

The evaluation was conducted in six steps as follows:

1. Study of the CompEdu structure/functionalities and use-conditions of the platform among undergraduate and postgraduate students at the department of Energy Technology, KTH.

2. Study on pedagogy and state of the art in the area of technology enhanced learning (in the form of a literature review and by gathering practical experience from assistance for courses, which used CompEdu at the department of Energy Technology, KTH).

3. Study on pedagogical evaluation methods (based on the following literature: Krathwohl (1998), Fraenkel and Wallen (2003) and a workshop at the University of Hanover). The clear distinction between educational research and evaluation was recognized at this step with further focus on the evaluation.

4. Selection of evaluation methods for given conditions: questionnaires, interviews, and observations.

5. Conduction of the evaluation in several groups including undergraduate students, postgraduate students and teaching personnel. The following items were evaluated: CompEdu software package, technological/instructional approaches in online distance lecturing, and the remotely controlled laboratory exercise Linear Cascade.

6. Interpretation of the results obtained based upon the teachers' experience at the department (group work).

1.4 Structure of the present work

The work is organized in the following manner:

1. Discussion of general pedagogy principles.
2. CompEdu e-learning platform preconditions.
3. CompEdu instructional solutions and content development process description.
4. Platform evaluation and discussion on platform development.
5. Conclusions and future work.

2 PEDAGOGY AND COMPUTER TECHNOLOGY

2.1 Introduction

Technology Enhanced Learning (TEL) has historically existed for thousands years, since human started using tools in general. According to the Vygotsky's hypothesis, humans use objects from their surroundings to strengthen mental processes[1] (Vygotsky, 1930/1978). Enhancing learning with technology works in a similar way as enhancing our capabilities with mechanical tools, when a tool is an object interoperating between our body/mind and an object we are interacting with. Without a tool such particular interaction becomes less efficient or impossible. The example of a simplest technological enhancement is the paper and the pen, which serve as help for the human's weak memory. Graphical symbols help coding complex issues, for example numbers or concepts, which without such coding are difficult to communicate or to operate with in our minds.

With coming of the computer era there has been an increase in technological enhancement for learning by increasing availability of tools. The broadened possibilities to support mental activities explain the roots of excitement about the information and communication technology development (ICT) in the pedagogical environment. In some decades the term TEL will probably disappear, because computers will dominate our lives as much as books some hundreds years ago, demanding much less attention. Contrary today TEL often signalises certain degree of complexity and difficulty in use. This complexity is partly a reason why more conventional technology (e.g. paper, pens, and blackboards) are still in relatively intensive use.

When it comes to computer tools in the educational context, in 1980s-1990s much overemphasized attention was paid to the role of multimedia and interactive media. It seems that too many resources were spent on simplifying a variety of possible learning tasks in a complex way. The situation was partly the result of an aggressive marketing strategy from software companies with promises of fast educational gains with their "perfect" tools. The tendency could be well illustrated by a retrospective view from the Charlie Chaplin's comic movie about the industrialization times (Fig. 1). In the movie a factory worker becomes a test case for a high-tech and problematic in use feeding system. In the context of TEL the analogy was chosen, because computerization is becoming a kind of industrialization in the educational area. The analogy aims to demonstrate that certain learning tasks can be hardly improved with very complex systems, or even if so, the cost of development and support is usually high.

[1] "The use of artificial means, the transition to mediated activity, fundamentally changes all psychological operations just as the use of tools limitlessly broadens the range of activities within which the new psychological functions may operate. In this context, we can use the term higher psychological function, or higher behavior as referring to the combination of tool and sign in psychological activity."

Fig. 1: Modern Times (1936)

Multiple examples of domination of technology over the educational expediency caused increasing awareness of the issue among educators. As a response there has been a shift from complex-in-use authoring tools to more simple once, also offering simpler interactivity and multimedia elements. The new tools focus more on reuse and sharing of content than on interactivity.

In the rush of the 80s-90s some pedagogical basics also seemed to have been forgotten. Some proponents of the use of media technologies in education claimed that introduction of new media will considerably increase the diversity of instructional methods. The discussion in educational circles between Clark (1994) and Kozma (1994) presented two confronting opinions on the issue. Therefore it might be useful to look again at the commonly accepted pedagogical principles in order to judge about computer technology in education. The next chapter presents key elements of instructional methods in the form of a scientific dialogue, not merely a presentation of pedagogical facts or theories. The dialogue enables showing both the state-of-the-art in pedagogy and the corresponding background of the thesis author. Statements in the quotation marks come from the "Pedagogy" article in the Encyclopaedia Britannica. This source was chosen, because the scientific discussion on the nature of learning has not been finished yet and the encyclopaedia article seems to represent commonly accepted basic "truths" about education, so no further discussion is absolutely necessary for the proposed quotations.

2.2 Realization of basic pedagogic principles using contemporary computer technology

"In the act of teaching there are two parties (the teacher and the taught) who work together in some program (the subject matter) designed to modify the learners' behaviour and experience in some way" (Britannica, 2005). The teacher's role is "making relevant experience available to the student at the right time" (Ibid). This role very much corresponds to certain functions of learning platforms, which aim to provide such relevant experiences to a learner.

“Although each group of subjects has something in common with others in terms of the demands it makes on the thinker, each area has also something quite specific in its mode of development” (Ibid.) Therefore each subject has certain, historically developed and proved teaching methodologies and media. The same media might not fit all needs and all methodologies equally well. Teaching/learning subjects constitute a network of interconnected elements both in terms of knowledge development in time and teaching methodology. Knowledge in the form of concepts is also a kind of network reflected in the minds of teachers and learners.

“A large part of the teacher's role is as a group leader” (Ibid.) This leadership motivator is not very easy to represent by computerized tools.

“The individual pupil also conducts himself under the influence of the group to which he belongs. His achievements and attitudes are subject to evaluation by the group, leading to support or ostracism, and he sets his standards according to these influences”(Ibid.) Group work aspect is also not easily transferable into automated computer interaction. Presence of other students might be profitable for efficient learning. But the issue is not very clear: how positive is the group influence for individual learning? This strongly depends on a learning subject and the learners. Learning playing football in separation from the group would not be the best idea, even thought such learning also includes elements of learning in separation.

“The case for uniformity is that putting a pupil with his intellectual peers makes teaching more effective and learning more acceptable. The case against it draws attention to its bad effects on the morale of those children in the lower streams. This view supports the heterogeneous class on the grounds that the strongest are not overforced, and the weakest gain from sharing with their abler fellows”(Ibid.) The issue of background homogeneity in well-designed personalized computerized learning is not expressed so strongly due to individual approach and certain separation between learning paths of students. Personalization of learning content accordingly to the needs represents one of the strongest arguments for computerized education.

“The school community is housed in a physical complex, and the conditions of classrooms, assembly places, and play areas and the existence (or non-existence) of libraries, laboratories, art-and-craft rooms, and workshops all play their part in the effectiveness of the teaching–learning situation. Severe restrictions may be caused by the absence of library and laboratory services” (Ibid.) Computerized education (CE) resolves certain restrictions of traditional “on site” education. Material digitising, archiving, distribution, and search capabilities of modern information/communication technology reduce certain restrictions of resource accessibility, which could not be accepted in the past. Virtual facilities can help in teaching subjects, where such computerized representation of objects and environments is feasible. The areas, where such representation is not feasible (mainly for economic reasons) define the constraints of computerized education. In such cases blended methods have to be used. Therefore CE cannot be completely free and “innovative” from the major media and techniques of teaching/learning.

“The social forces immediately outside the school community also influence the teaching situation…. The overall neighbourhood youth subculture also sets standards and attitudes that a teacher has to take into account in his work” (Ibid.) Though written about youths, the conditions are probably equally influential for any learner. Universities and schools have particular specificity in terms of intellectual development environment. Such conditions might be reduced if using computerized tools only. Fortunately, with the rapid progress in the communication technologies, the problem solution seems to be relatively close. The progress can even considerably enhance learning due to creation of virtual communities between people, which would not be able to communicate otherwise. Such virtual meeting places have a potential of reducing influences of local social environment and increasing influences of geographically distant societies. Acceleration of global movement towards distance education seems inevitable assuming that communication factor is a considerable factor in education.

“The permeation of emotional learning throughout the whole educative process is not always obvious, in part because very often it is brought about incidentally. Teachers may be self-conscious and self-critical about the deliberate inculcation of emotional responses, which will provide the energy and a mainspring of social life” (Ibid.) Motivation is psychologically close to emotional involvement into certain activities. The role of classmates and the teacher in motivating a learner can be high due to social force of group and authority opinion. Without strong social involvement learning process might slow down. But there are cases when in-class social influences can negatively influence learning performance. On the one hand modern computerized education is limiting social interaction of certain kind. On the other hand it allows controlling such social conditions.

“A person's emotional structure is the pattern of his values and attitudes… as he becomes more mature he is increasingly involved in affairs and causes far removed from his own personal life” (Ibid.) The issue of personal involvement in large-scale activities (geographically, physically, socially) probably plays an important role in personal maturation and rising believes in personal abilities. A person, who is aware of own potential and who applied skills in practice considerably differs from a person, who learned about things in theory. Distance communication aspects of computerized education might enrich value of learner’s personal development by enabling participation in larger projects and intercultural exchange.

“Educational psychologists give much attention to diagnosing preinstructional achievements, particularly in the basic subjects of language and number, and to measuring intellectual ability… There has been special emphasis on the idea of the student's readiness… to grasp concepts of concrete and formal thought” (Ibid.) Testing of preinstructional achievements and readiness had been formalized in the form of quantitative tests long before personal computers became widespread. Standardized test methods of preinstructional capacity diagnosis can be relatively easy implemented in computerized education, for example multiple-choice questions or similar. Nevertheless, the role of teacher in analysis of students’ backgrounds prior to a next instruction step remains important, because certain aspects are not easily measurable by the tests. Therefore, in certain assessment stages teacher's analytic work is necessary. Intermediate computerized tests could help the learner in the understanding of own background "white spots". Also properly developed and fully accessible/searchable digital resources considerably simplify filling background gaps during learning somewhat reducing the need in the intermediate assessment tests. In traditional classroom filling background gaps would cause delays for the whole group. In personalized computerized learning a gap would delay work of one person only. But it could considerably increase the work of teachers.

"The progress of a lesson may consist of a cycle of smaller units of shorter duration, each consisting of instruction by the teacher and construction by the learner—that is, alternating phases in which first the activity of the teacher and then that of the learner predominates. The lesson or syllabus is thus not to be narrowly conceived of as "chalk and talk" instruction. It is better seen as a succession of periods of varying length of instruction by the teacher and of discovery, construction, and problem solving by the pupil" (Ibid.) The cyclic character of teaching/learning process used in higher education in the form of lectures, seminars and laboratory exercises is also transferable to computer environment. By the nature of contemporary computer technology, computerized educational tools are highly personal and therefore, contrary to in-class education, frequent change of activity type is relatively easy, because this does not involve more complex issue of group activity management. Also sequencing of frequent activities in computer environment could be less costly assuming that every lecture, lab exercise simulations etc. could be repeated any time without additional teacher's work. Such flexibility allows overcoming the problem in traditional education workflow, when frequent activity changes call for achievement tests after each teaching/learning unit, but such tests are usually not performed for economic and organizational reasons. In fully computerized workflow such intermediate tests could be done, even though they are not necessary, because if the final tests showed lack of knowledge, then a leaner would actively repeat certain topics without necessity to fully involve teachers in the process of gap-filling.

"Pupils in general are organized by age into what are usually termed grades, classes, or forms… Schools frequently have some kind of streaming or multitracking whereby students are grouped according to ability so that there are separate classes for the less able and the more able" (Ibid.) To large extent the need of grouping by age/ability was dictated by economic reasons, which favour mass education. On organizational level of activities computerized education has a potential for simultaneous support of more curriculum tracks and streams compared to traditional education. In fact properly collected curricula including most learning and assessment objects could be saved for future reuse in individual study tracks. In such use of computerized materials teachers would serve as consultants rather than lecturers. Therefore, the future teachers' role might shift towards learning material production and consulting work. In such case each student might follow relatively individual track with certain intersections with other students in group activities. The group activities could become the milestones supporting learning speed, but major part of learning would be taken individually. Indeed the multitracking idea, in other words the idea of teachers/learners mobility, found a resonance in teaching environment, but “there was not sufficient evidence of its effectiveness when it comes to primary and secondary schools” (Ibid.). Contrary at the university level we could assume there is awareness of self-education importance; therefore such mobility could provide good conditions for efficient studying.

“A teacher spends a disproportionate amount of his time in routine chores—in collecting and assigning books and materials and in marking” (Ibid.) In the context of learning management systems there is a tendency for efficient facilitation of routine tasks like material distribution, evaluation collection, planning etc. Quizzes and standardized tests can be collected and analysed in automatic manner. But there is no considerable improvement of analytic assessment of certain types of assignments like essays, for example.

“In general, instructional media are seen by educators as aids rather than substitutions for the teacher” (Ibid.) The reason of such situation comes from two main directions. One is that teachers often have no time to learn and use new media, especially in cases when the media are easily replaceable by simpler in delivery and use analogies (chalk and blackboard). This is purely economic reason. The other reason is that teacher’s mind represents far broader context description mechanism for majority of presented objects than many existing descriptions could offer. In such exceptional cases teachers are used to recommend further reading, for example. In fact the Internet has started undermining the teacher’s expert position by offering multiple answers to same questions. Therefore natural shift towards computerized education is inevitable.

“In general, pictures and diagrams, fieldwork, and contrived experiments and observations are all used as concrete leads to the generalizing, abstracting, and explaining that constitutes human learning. To fulfil this function, however, their use must be accompanied by interpretation by an adult mind” (Ibid.) The need for interpretation to any presented multimedia object has become obvious with availability of multiple illustration materials in the Internet. But only small fraction of them is offering educational value due to lack of proper description and detaching from semantic context. Computerized media offer more effective contextual association and search mechanisms compared to more traditional media. Semantic networks, which are currently under development and implementation, might dramatically change the situation with information accessibility.

“Visual material by itself may even be a hindrance; a scattering of pretty pictures through a history text, for example, does not necessarily produce a better understanding of history… What is observed rarely gives the whole story and… provides an incomplete picture” (Ibid.) Accessibility of multiple representations and contexts by means of traditional media is difficult. Computerized tools involving databases and the Internet can simplify the task of multiple context illustrations and therefore improve learning efficiency. The tools offer the possibility of sequencing and grouping information for the purpose of easy learning. The major difficulty is actual input of object descriptions and grouping them. This difficulty would be possible to overcome through consequent knowledge object management by students, who will finally become teachers themselves. Efficient knowledge object sharing will happen when teachers themselves start using personal digital portfolios for what they have learned.

“Reading and writing have formed the staple of traditional education…A textbook is essentially a mode of communication between a remote teacher and a reader” (Ibid.) In this context computerized education of today has reached relatively close level to the methods used in the past with widely accessible text materials for reading and efficient tools for writing. Indeed learning in many scientific subjects is very much about reading, because reading/writing is about (effective) communication, as was mentioned above. In the age of digital information the role of text media might diminish to certain extent due to development of other media. Nevertheless relative compactness in terms of symbolic encoding makes text very efficient in to-human information transfer. For example text analysis is easier and faster compared to listening to an audio recording due to the fact that no rewind action is needed for a text material, as well as unimportant text fragments could be easily disregarded.

“Programmed learning is a newer form of reading and writing. The most basic form of programmed instruction—called linear programming—analyses a subject into its component parts and arranges the parts in sequential learning order. At each step in his reading, the student is required to make a response and is told immediately whether or not the response is correct… In another kind of programmed instruction—called branching programming—the student is given a piece of information, provided with alternative answers to questions, and, on the basis of his decision, detoured, if necessary, to remedial study or sent on to the next section of the program” (Ibid.) Programmed learning can be relatively easy realized by contemporary tools used in computerized education. Accordingly to the Definition of Programmed Learning (University of Western Australia web resources, 2005) the advantages of such learning include breaking learning tasks into manageable parts, receiving feedback by a learner and proceeding at own pace in learning. In fact the technique of programmed learning can be considerably simplified (in terms of management) and enriched by usage of multimedia instead of plain text and electromechanical devices as originally developed.

Commenting on computer-based instruction the article is pointing out its disadvantage: “The limitations at the moment centre on the learner's responses, which are limited to a prescribed set of multiple choices. Free, creative responses, which one associates with the best of classroom situations, cannot yet be accommodated” (Pedagogy, Britannica, 2005.) At the point comes the truth about fully automated teaching tools – they must be humanly intelligent in order to perform as well as a good teacher does: including flexibility of responses, large knowledge pool and understanding of psychological processes in the learner’s brain. From this perspective computer-based instruction is as far from truly automated teaching as the computer technology is far from artificial intelligence. This concerns the comparison with a perfect teaching-learning situation when one teacher is instructing one learner. In the reality of mass education such personal contact is not feasible for economic reasons and many routine mass-education activities could be successfully computerized. At this point the statement: “a computer will never replace a teacher”, is contradicting the concept of technology development for education, because the ideal case would be when similar or better learning results could be achieved without teacher's physical presence. Nevertheless, since artificial intelligence is still a field for futurology predictions, the role of teachers is not endangered. At the same time contemporary easiness of access to information has already challenged the role of a teacher to certain extent.

"The (learner)[2] develops inevitably as a product of nature, and the main function of the teacher is to provide the optimum conditions for this development" (Ibid.) This notion is representing the point of view of naturalistic educational theory. Based on the theory, computerized education should focus on providing appropriate experience environment for natural development of a learner.

Apperception theories of education specified a sequence of steps required to carry out a lesson, which aimed at building association between new and older ideas in the mind (Ibid.):

1. "Preparation, whereby the teacher starts the lesson with something already known to the class,
2. Presentation, introducing new material,
3. Association, whereby the new is compared with the old and connected (the stage of apperception),
4. Generalization, whereby the teacher presents other instances of the new idea,
5. Application, whereby the ideas are applied to further material, carried out by the (learner)[3] individually (a problem-solving phase)".

This method, though being criticised for restricting creative learning, has to a large extent been used in both traditional and computerized education. It seems logical to assume that at least steps 1, 2, and 3 are common for many learning experiences, where formal knowledge is a general prerequisite for any next learning step. This includes basic knowledge about an object/phenomenon in a study field. In a case of learning arts, music or sports relating to the background in formal terms might be more difficult, nevertheless this is commonly used, because such knowledge also includes certain formalized concept elements or naturally developed and later named abilities.

Contemporary the computerized enhancements are capable of facilitating steps 1, 2, 3, and 4 of educational methods based on the apperception theories by subject descriptions enriched with multimedia and interactivity. Step 5 in general will require presence of the teacher able to analyse problem solutions submitted by a learner. It seems that the most difficult elements for computer support will be creative problem-formulating and problem-solving. Since conceptual integration and coordination between those learning steps has not

[2] "Child" originally in the text.
[3] "Child" originally in the text.

been resolved in an automated manner, the role of a teacher will focus on such issues. At the same time there are indications that the role of a teacher working purely as a medium between a knowledge source and a learner might considerably diminish, since access to quality learning material is becoming easier with the Internet. Nevertheless the prediction probably discriminates the fact that physical presence of a teacher and class-mates might strongly motivate for learning, therefore the role of the “natural” lecturing forms will not disappear. Another vision of future teaching is that it might transform into pure didactic process organization and planning, when learners will study mostly individually, acquiring theoretical and some practical knowledge, using computer tools and contacting the instructors when necessary, and then attending problem-solving sessions conducted in classrooms or online. From such interpretation follows that knowledge materialization might become increasingly important, because someone has to catch and represent knowledge symbolically for further use in digital form. Also curriculum-object production, meaning creating detailed course plans with links to learning objects, might become a common form of activity in the educational environment.

Conditioning and behaviourism theories do not provide direct methods of training, but help in understanding the reinforcement (e.g., a reward) phenomena. At the university level such positive reinforcement could be achieved by rising satisfaction from successful problem solving, which gives the feeling of power.

The conditioning and behaviourist theories also give a simplified model of symbol learning, when, for example “in the human situation, learning to recognize the name of an object or a foreign word constitutes a simple instance of stimulus learning. Such an event is called sign learning, because, in knowing the sign for something, a person to some extent makes a response to the sign similar to that that he would make to the object itself” (Ibid.) As an example in situation of learning a formula $E=mc^2$, first process would be the memorisation of the equation, and after a sequence of rewards further use of symbol “E” will be enough to cause conditioned association with the full equation in appropriate context. In computerized education such memorization could by easily facilitated by hyperlinked windows, so that no considerable work is needed to refresh the association. Hyperlinks also help protecting against unconscious operation by still-not-well-learnt concepts and latest dissatisfaction with learning results.

“Cognitive theories…assume that perceiving and doing, shown in manipulation and play, precede the capacity to symbolize, which in turn prepares for comprehensive understanding… Cognitive theories of learning also assume that the complete act of thought follows a fairly common sequence, as follows: arousal of intellectual interest; preliminary exploration of the problem; formulation of ideas, explanations, or hypotheses; selection of appropriate ideas; and verification of their suitability” (Ibid.) Therefore cognitive theories call for a reverse of the lecture-exercise learning sequence, making the exercise to precede the lecture. E.g. a practical experience should be put prior to the theory explanation, therefore enabling natural hypothesises creation in the learner’s mind with further verification of the ideas.

“The motivation of cognitive learning depends less on notions of reinforcement and more on standards of intellectual achievement generated by the learner himself” (Ibid.) Cognitive theories aim at higher levels of intellectual activities. The cognitive levels were formally presented by the educational psychologist Bloom (1956), who pointed out that levels of abstraction of questions in tests that were common in educational settings of USA in the 50s often did not require deeper intellectual activities. The only knowledge they were asked to demonstrate was merely information recalling. Fig. 2 (Teaching, IMI Home, 2005) illustrates the classification of cognitive domain called the Bloom's Taxonomy. The classification puts higher priority towards practical aspects of learning where assessment, research and problem solving are put on the top of the pyramid of intellectual complexity.

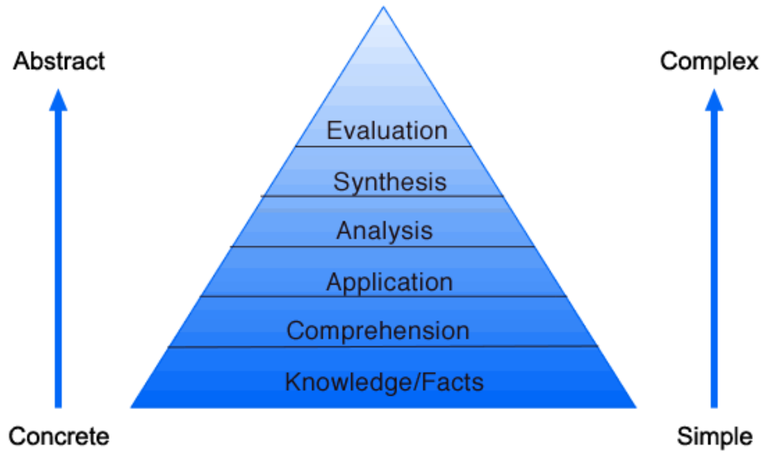

Fig. 2: Bloom’s classification of cognitive domain

Potential value of cognitive approach in education can be development of intellectuals with practical skills instead of persons possessing mainly factual knowledge. In the age of Internet the factual knowledge is rapidly devaluating. Higher-level knowledge and practical skills are becoming more competitive.

“…The second half of the 20th century saw a revival of the concept of the structured wholeness of experience…. A new experience…begins by seeming relatively formless and unstructured. The learner, who does not yet know his way about the material, begins by seizing upon what appear to him to be important features or figures. He then reformulates the experience in these new terms. The insight gradually becomes more and more structured until finally he reaches an understanding or a solution to the problem…” (Pedagogy, Britannica, 2005.) The concept represents so-called structural theories of learning, which seem to incorporate pedagogical theories described above by means of network development and interactions. In such model learning is a process of continuous mental model rebuilding based on old and new experiences. There has not been much success in practical implementation of the structural theories, probably because of their complexity.

Multiple theories have been developed for learning process explanation. High abstract level of the theories implies the necessity of teacher’s presence in both knowledge content creation and learning procedures. Computerized education has simplified organization, presentation and distribution of knowledge, but is not very close to efficient learner modelling and therefore in machine-intelligent response to the learners needs. There are no significant indications that computer technology per se is capable of improving education in terms of core cognitive learning processes. At the moment the much simplified learner models used in computerized education are mostly representing properties of a statistical human, than an individual, because learning theories are relatively imprecise in reflecting the complex nature of human intelligence.

An ideal fully computerized teaching system will sustain a leaner model, comprehensively process different responses from the learner (including verbal, nonverbal and neuropsychological activities), and based on the obtained information will create optimised educational situations using existing semantically described knowledge databases.

There has been a strong trend in pedagogy to follow discoveries of the natural sciences. This probably demonstrates that the natural sciences (especially brain studies) could bring effective explanations of what learning is about. Such reasoning is based on the assumption that general principles of brain work can be explained in purely mechanistic/mathematic terms. Research in the ICT area towards modelling of learning mechanisms has a great potential of influencing the pedagogical science. At the same time the pedagogical theory serves as verification and control of the ICT solutions being proposed.

Until now there have been no profound show-cases when technology demonstrated to change the way we learn, therefore ICT should be considered as a tool extending possibilities, but not changing the basic learning mechanisms. On the other hand teaching seems to be influenced to a larger extent by the technology development. New tools allow presenting information in new ways and involving learners in multiple simultaneous interactions, which were not possible earlier. Probably the best example of such tools is the interactive tutorials and simulations, when problem-based learning occurs without instructor's participation. In such conditions teacher's role as a content developer might become highly important, at the same time the issue of proper intellectual property protection becomes very important as well.

2.3 E-learning today and development trends

Several computer technologies have been proposed for use in education. The ones, which seem to reach a stable position and broad practical application, support the following activities:

- Content exchange and sharing,
- Management of educational activities,
- Audio/video communication,

- Multimedia and interactive content[4] authoring.

Internet-based and offline digital repositories are probably the most commonly used technologies nowadays. The first offline repositories to appear were software packages on floppy disks and CD-ROMs, also working in local networks. The Internet provided broad sharing possibilities and increased information accessibility. Nowadays, online repositories are a competitive alternative to traditional public libraries. A typical repository contains electronic copies of books and journals. Some repositories also offer other objects, such as multimedia, computer codes, software etc.

Problems with digital content compatibility stimulated development of worldwide standards for content presentation. The standards also simplified content development and distribution. The work towards unification has been evolutionary natural, since the Internet-access became relatively common. For example the simplest presentation standards include image formats GIF and JPG. Word and Power Point have dominated content authoring to a certain extent. Interactivity and multimediality in the net is widely distributed by Flash and Java. HTML language became a universal way to present static data for reading online.

Online communication technologies have started to successfully compete with traditional telephony. Text chat, audio/video via IP, and application sharing are the key technologies for meeting people distantly. Internet-based communication platforms enabled virtual classes, web seminars, conferences, online meetings etc.

The next step in the content sharing is sharing database-related kinds of data, and one-way passivity of HTML has been extended by bi-directional and commonly acceptable XML. The latter is a standardized representation of complex data-base like structures in the form of text-tagged files. Whereas HTML served mostly for human-to-human communication, XML offers efficient machine-to-machine communication.

Learning management systems represent the latest trend in e-learning. A learning management system (LMS) uses the technologies above and additional (usually server-based) software to support educational workflows and processes. Since major educational organizations function similarly, the system helps automating typical tasks and data streams. "It refers to a suite of functionalities designed to deliver, track, report on and manage learning content, learner progress and learner interactions. The term "LMS" can apply to very simple course management systems, or highly complex enterprise-wide distributed environments" (Advanced Distributed Learning, 2004). In general LMSs "industrialize" education the same way it happened in other big-scale commercial areas, like aerospace or automobile industry. An example of an LMS is given in the Appendix 1.

The current trend in computerization of learning is to a large extent LMS-oriented, and also distance-learning oriented. Since learning to a large extent is about "learning-object

[4] An example of multimedia interactive platform is given in the Appendix 2.

consumption”, and production/consumption of learning objects is distributed by the nature of the Internet, several standards concerning data exchange and process management have been established and recognized as important for sustainable development of e-learning. The initial purpose of the standards was to avoid “locking in” of content in proprietary commercial platforms, when reuse of it in other platforms becomes difficult or impossible. Some parts of the standards are still under development stage. The main organizational bodies involved into development of the standards, which are actively collaborating to each other, are as follows:

- IMS (Instructional Management Systems Global Learning Consortium),
- ADL (Advanced Distributed Learning Initiative),
- IEEE LTSC (Learning Technology Standards Committee of the Institute of Electrical and Electronics Engineers),
- ARIADNE (Foundation for European Knowledge Pool),
- AICC (Aviation Industry Computer-Based Training Committee),
- DCMI (Dublin Core Metadata Initiative).

Probably the most prominent reference model in relation to practical applications today is SCORM (Sharable Content Object Reference Model) by ADL, which is adopting essential elements from AICC, IMS, IEEE LTSC, and ARIADNE. Accordingly to the article published at the e-learning web page (University of Bath web resources, 2005) in the U.S.A. if online content providers and LMS manufacturers want to be eligible for future government work, they will have to conform to certain aspects of the ADL strategy. The strategy is implemented partially in the SCORM. The SCORM, not being a standard itself, “serves to test the effectiveness and real-life application of a collection of individual specifications and standards. SCORM provides a foundational reference model upon which anyone can develop models of learning content and delivery. For example, systems should be able to "share" data about how learners access courses, their progress in the course, and their pretest/posttest scores. Through the application of the specifications and standards from the various groups, SCORM provides the framework and detailed implementation reference that enables content, technology, and systems using SCORM to "talk" to each other, thus ensuring interoperability, re-usability, and manageability” (MASIE Center, 2003).

“SCORM is a suite of technical standards that enables web-based learning systems to find, import, share, reuse, and export learning content in a standardized way” (Randall House Associates, 2003). SCORM is explicitly oriented towards Web environment, assuming that content, which can be delivered through the Web, can be delivered on CDs etc. as well. The reference model basic structure is presented in the form of a library with books as shown in the Fig. 3.

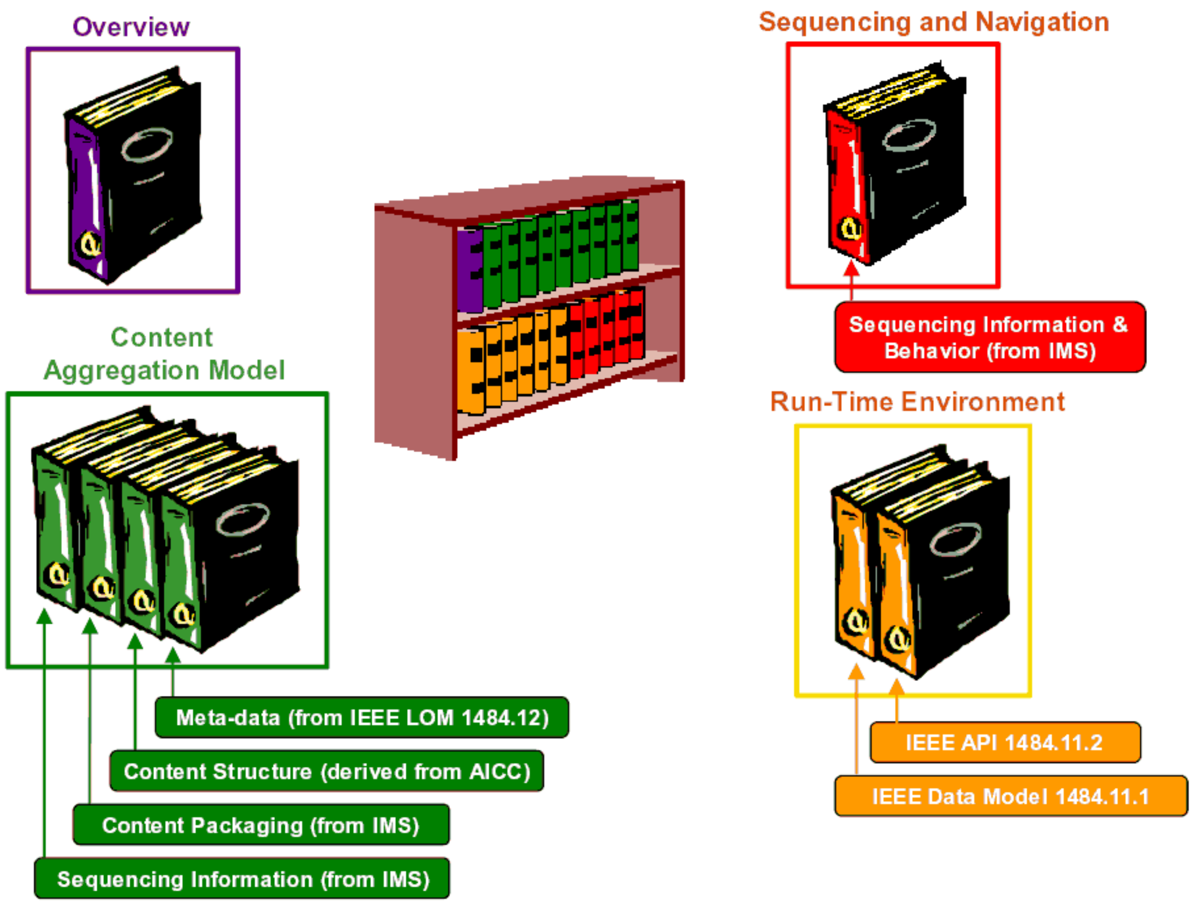

Fig. 3: SCORM specification logic (Advanced Distributed Learning, 2004)

Another promising set of standards (partly reused by the other standard bodies) is the IMS open specifications. The specifications, which are being introduced by LMS and e-content software companies concern: meta-data, enterprise, content packaging, question and test interoperability, reusable definition of competency or educational objectives, digital repositories, learning design, simple sequencing, and accessibility issues (IMS Global Learning Consortium, 2003).

Metadata[5] play important role in the particular standards related to e-learning. LOM (Learning Object Metadata) standard by IEEE LTSC focuses on enhancement of search, evaluation, acquisition, and use of learning objects. It includes some recommendations by the Dublin Core Metadata initiative. Particularly LOM specifies tag vocabularies and tag taxonomy for learning objects. Such tags could be attached to a learning object in the form of an XML file, for example. The metadata include among the others: author/co-author names, version number, language, coverage, interactivity level, property rights, software used to open a learning object etc.

[5] Data about data.

“In e-learning, the key issue is neither the interoperability nor the reusability of content, but rather the support of learning as a cognitive and constructive process.” (Lytras et al., 2005). The future trend in computerized education is the shift from mass-education towards individual education. A new method reflecting the shift is based on individual search/browsing of the Internet learning resources and extracting the most essential and relevant knowledge (in relation to a problem being solved by an individual in the search time-period). This approach was called “knowledge pull” opposing the “knowledge push” that represents the older curricula-based educational approaches (Naeve, 2005). “In the “pull” case, knowledge flows from the selection activity to other knowledge manipulation activities and is essentially triggered by an individual's “knowledge seek” request. Contrary to the above, in the “push case”, knowledge flow gets triggered automatically without an explicit request from any knowledge seeker” (Chandrasekar, 2005). The main obstacle towards active use of the “knowledge pull” method lies in limitations of the search mechanisms. Responses to queries following the natural language properties typically do not offer answers, which are close semantically to a searcher’s query. Using more advanced search mechanisms allows narrowing the search, but still requires material-sieving work from a learner, often with poor output. The reason for such results is that the engines use literally unintelligent way to judge about semantic structure of the documents.

Specialized electronic libraries/repositories use search filters based on metadata sets, but the metadata often have different structure in different repositories. Therefore there are no general search mechanisms, which make sure all relevant documents from the World Internet-accessible content are present in the search results. Such metadata are typically static, e. g. reflecting subjective views on the content at the moment of the content publication.

It has been generally accepted that machines are incapable to judge about documents’ semantic structure, if such structure has not been introduced into the documents by humans in a formalized machine-readable way.

Some researchers suggest that introduction of advanced metadata tagging and corresponding mechanisms of human-like logical inference might change the paradigm of the WWW-content access/share. Accordingly to the model, content metadata will not be a static part of corresponding documents, but will dynamically reflect content access, modifications, popularity, quality etc. Also the model implies there is an “idealistic” knowledge structure, which can be formalized in terms of ontologies describing interconnections between objects in the real world. From this perspective the ontologies would serve to represent “common-sense” logical operations performed by humans when filtering/sorting information. The next generation of the Web, implementing the mechanism, is called Semantic Web that will enable machine-“understanding” of web resources, so that information request from a human could be passed from a machine to a machine preserving semantic structure of the request.

The framework of Semantic Web research is presently supported by development of semantic content processing standards/frameworks such as: RDF (Resource Description Framework), OWL (Web Ontology Language) and UML (Unified Modelling Language).

Further future and more futuristic perspectives of e-learning could be mentioned as well. Much higher value from computerization might be achieved when the machines are actually capable to learn and teach. If they cannot learn, they will be only able to transfer knowledge copies from a human to a human. The problem concerning automated content production ("extraction of knowledge") could be hardly improved without literally wise machines. This futuristic concept is closely related to the research in the Artificial Intelligence field. At the same time there are certain solutions, which already today allow certain automation of learning-object creation through the use of knowledge-capturing mechanisms. Such mechanisms make use of the synergy effect between human and computer capabilities as shown in Fig. 4. The figure illustrates the emerging technology called "knowledge retrieval", which allows blending computer and human skills through human behaviour registration/analysis by a computer.

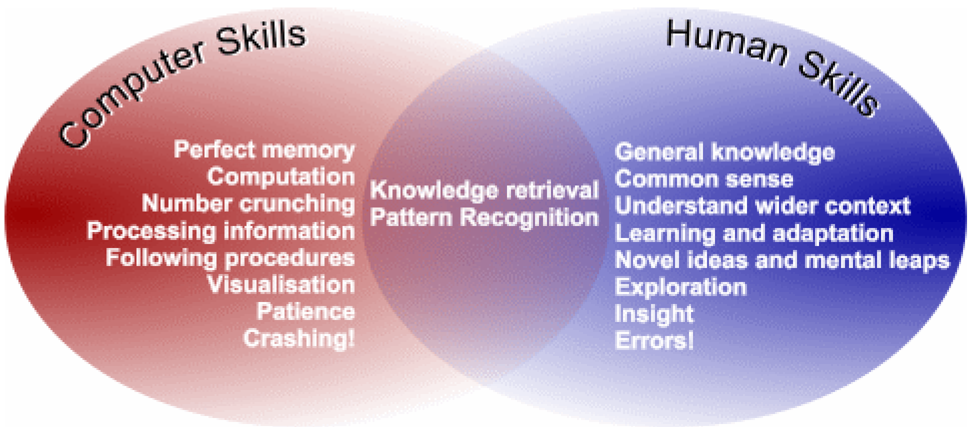

Fig. 4: Knowledge retrieval technological approach (Lancaster University web resources, 2005)

The model of knowledge retrieval is the first step in very primitive machine understanding. In this context "understanding" means time-space pattern recognition as it was suggested by Jeff Hawkins (2004). An interesting example of intelligent behaviour pattern retrieval was lately described in the Mechanical Engineering journal (Thilmany, 2004). The ***Fig. 5*** from the journal shows how best engineering practices in the machine design could be preserved for other users in such a system.

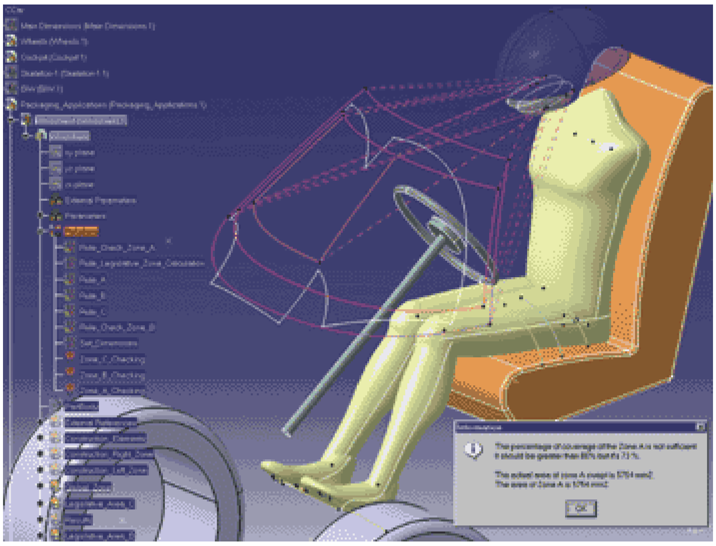

Fig. 5: Several CAD programs include knowledge capture features that archive best design practices and company specifications (Thilmany, 2004)

When knowledge is acquired and saved as a set of behaviour patterns in certain formalized way in such systems, it can be reused for indirect learning by other users, which will be assisted by best-practice hints during their work without need to search for certain problem-solutions themselves. At the moment knowledge retrieval is possible in the areas where major working activities are performed at the computer. This concerns people working with CAD applications, for example. In some areas of human activity, where computers are rather occasionally used, such retrieval seems to be difficult or impossible. But with increasing penetration of the computer technology in our lives, such retrieval and knowledge share methods might become common. In such a scenario a problem solution could be bought or acquired from some open source in the form of "expert knowledge plug-in" similarly how certain problem solutions are can be bought today in the form of software packages.

3 COMPEDU E-LEARNING PLATFORM

3.1 Platform overview

CompEdu HPT is an interactive multimedial life-long learning platform in the subject Heat and Power Technology. It has been developed at the chair of Heat and Power Technology at Royal Institute of Technology (KTH), in collaboration with several partner universities and industrial organizations. The map of CompEdu academic and industrial partners is presented in Fig. 6.

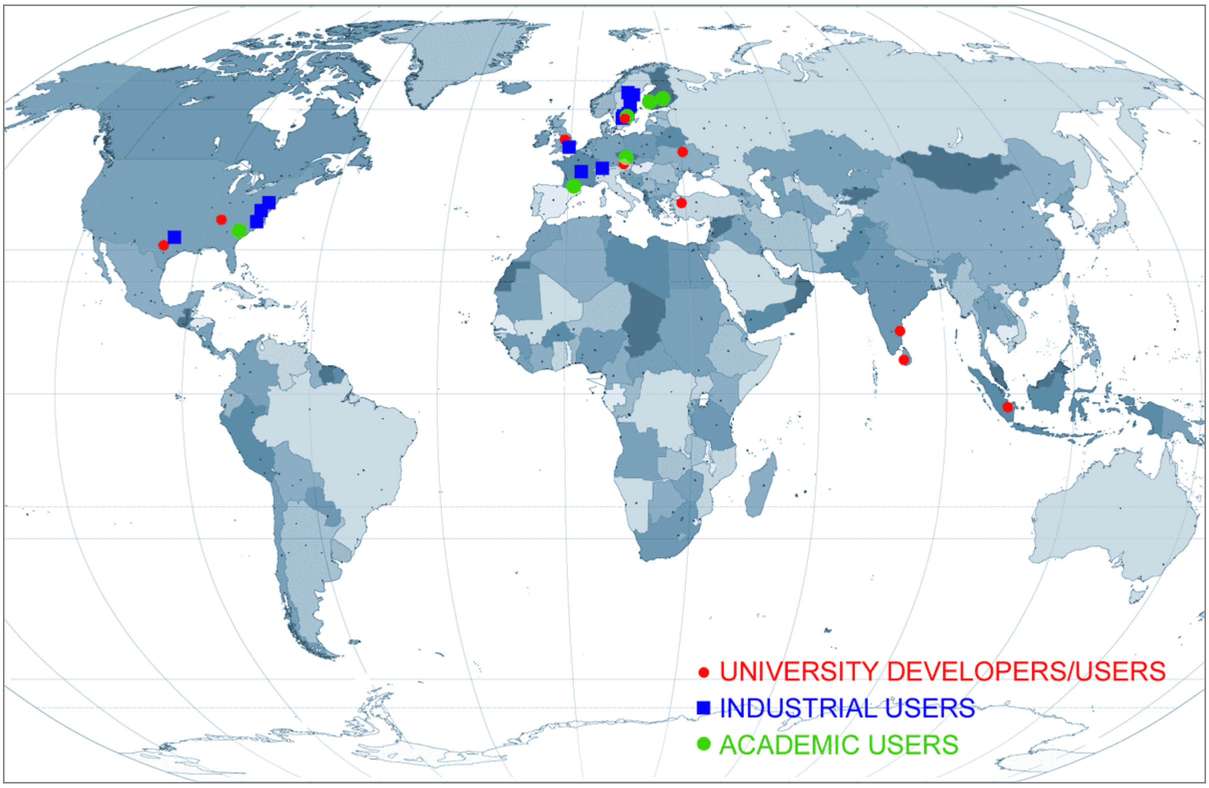

Fig. 6: CompEdu collaboration map (2004)

CompEdu platform was created with the idea of merging traditional on campus teaching and individual learning in one block supporting modern digital technologies for data presentation and management. The platform is a basis for international collaboration for sharing of teaching and learning resources in the field.

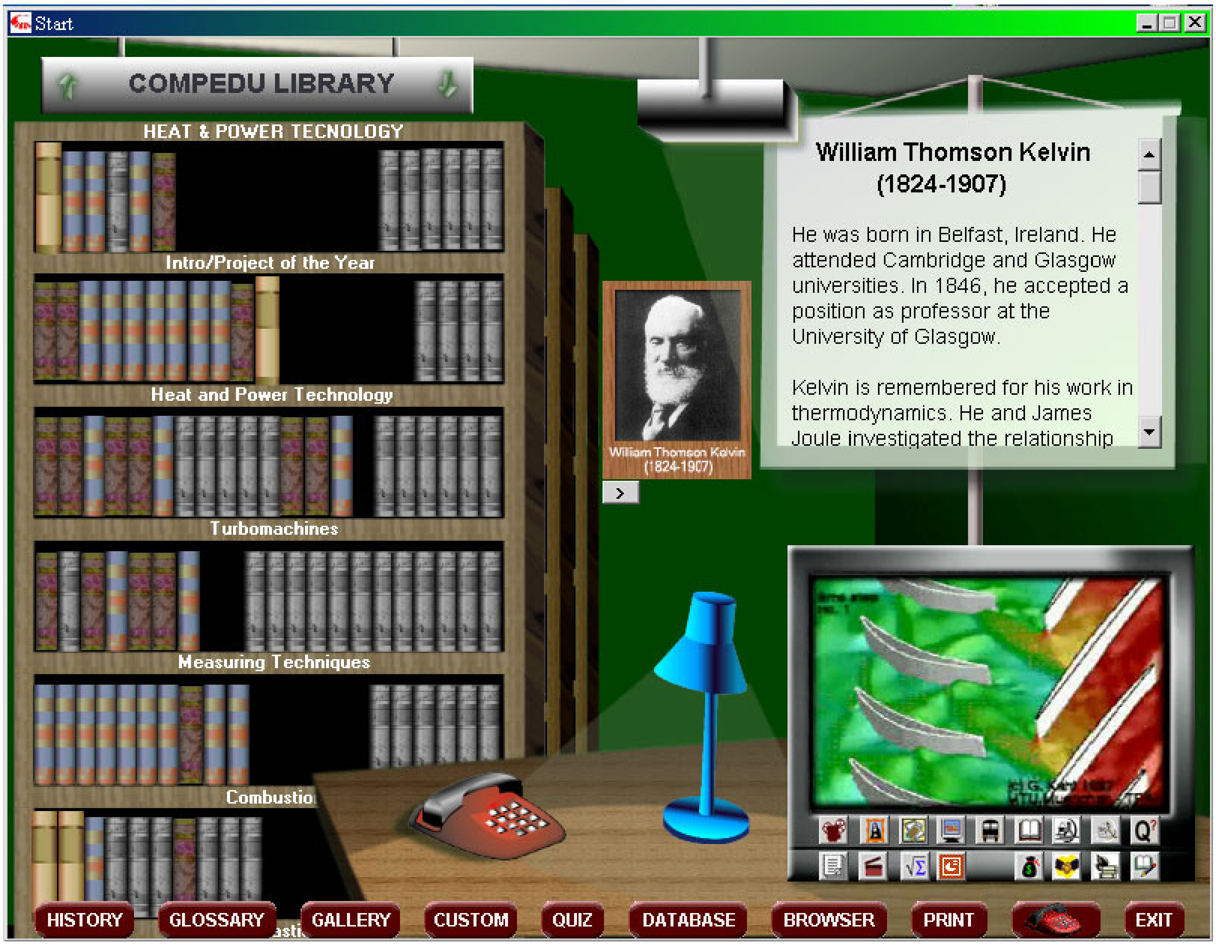

Fig. 7: CompEdu the Main Room interface (version 3.0)

The software is a response to the urgent need to turn the *multi*media into a media unity. The platform is a trial to integrate highly diversified modern learning content in one easily-to-navigate platform, which will help both students and teachers to manage their educational activities, especially learning. CompEdu includes a broad range of tools covering the majority of traditional educational process aspects and allowing students to control their learning with self-assessment mechanisms. The platform was designed for undergraduate and post-graduate level learners both at universities and in industry.

The platform is a collection of course theory and other educational material. OH-like e-pages with hypertext are grouped in chapters. Chapters are grouped in books. Books are grouped in shelves. The shelves are grouped in bookcases in the main menu – the Main Room, forming the characteristic “bookshelf” interface (Fig. 7). This is a clear analogy to traditional paper books. Simple structure of a bookcase is shown in Fig. 8. For navigation purposes both the bookshelf menu and the Browser can be used.

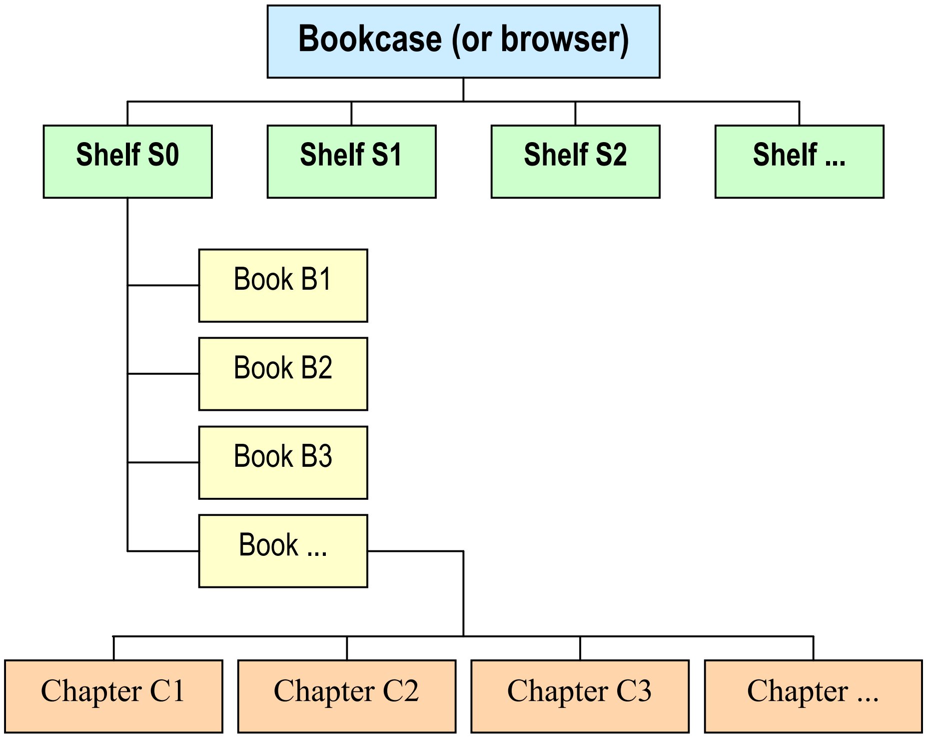

Fig. 8: CompEdu content structure

Theoretical material presented in chapters is complemented with:

- quizzes
- interactive simulations,
- virtual laboratory exercises,
- virtual study visits,
- videos and animations,
- calculation exercises,
- study questions,
- case studies,
- remote laboratory exercises,
- lecture notes,
- glossary,
- virtual gallery.

Quizzes (Fig. 9) and calculation exercises allow making self-assessment of learning progress and pointing out gaps in obtained knowledge and skills. Interactive simulations actively highlight dependencies between described values. They form instructional situations stimulating discovery of the mechanisms of physical processes. Lecture notes are classical notes in the ready-to-print form.

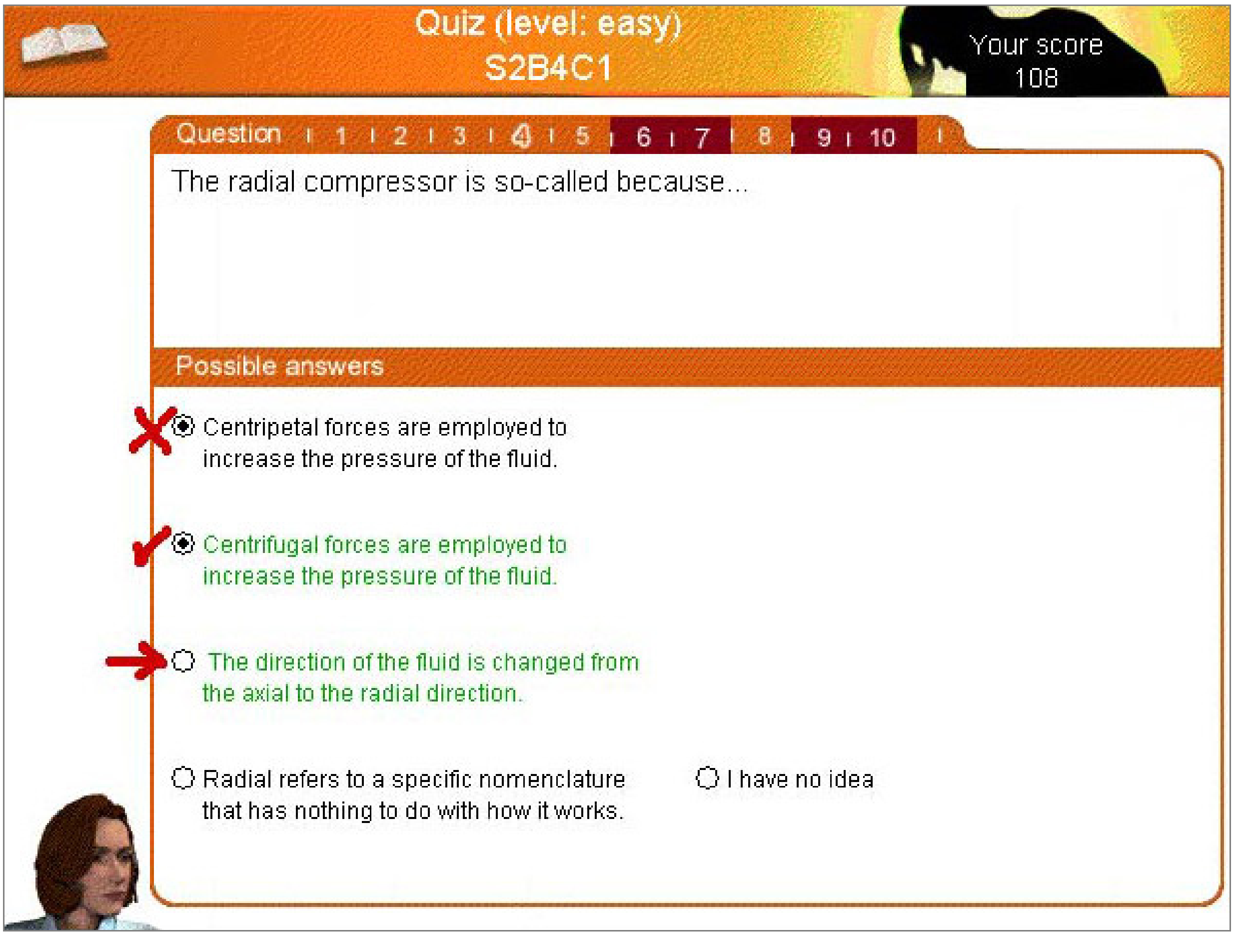

Fig. 9: CompEdu quiz (version 3.0)

Multiple animations attractively illustrate dynamic processes. Virtual study visits (Fig. 10) help learners to feel themselves like visiting real industrial facilities and give the feeling of scale and space relations. The visits are also intended to give an overview of the systems as a whole.

Remote laboratory exercises are a relatively new part of CompEdu HPT platform. They serve for doing real laboratory exercises from distant sites using Internet channels. This allows extending learning possibilities with the very important practical experience.

The toolbar of the CompEdu HPT platform contains significant background information related to historical development in the field, a display of existing components, nomenclature, multi-lingual dictionary and keywords. Questions for self-assessment and exams are also included, as well as an electronic communication group and a database of the user's “successes and failures”.

The possibility to see complex phenomena through videos and animations has been, together with the simulations, the most important feature available to complement the theory presented forming a complete e-learning tool.

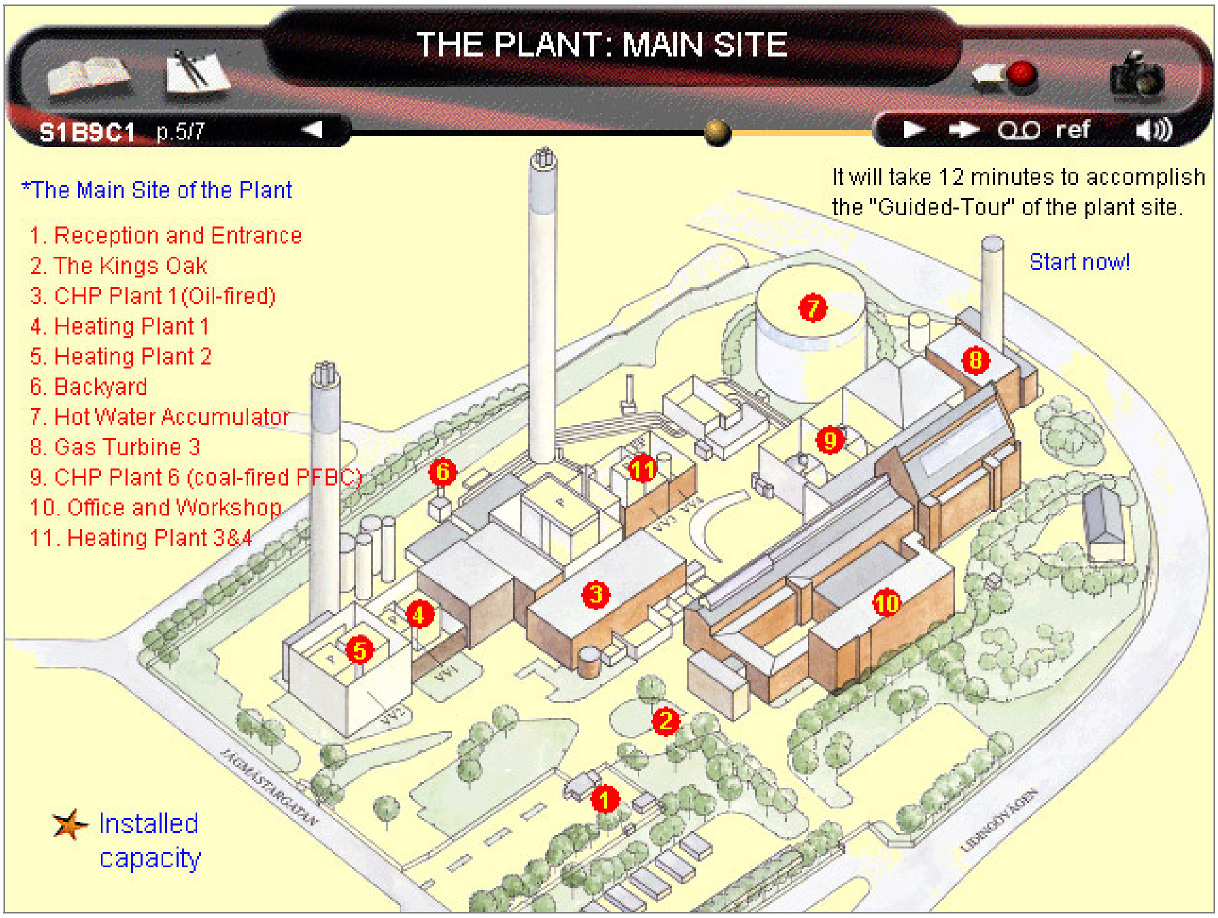

Fig. 10: CompEdu virtual study visit (version 3.0)

As it was mentioned above, the Computerized Educational Program in Heat and Power Technology has been structured in an analogous way as a printed book/library is arranged. Each main subject within Heat and Power Technology is symbolised by a “shelf” in the interface of the program. To the moment of writing the dissertation 6 shelves were present in the platform:

- Introduction and Project of the year
- Heat and Power cycles
- Turbomachines
- Measuring Techniques
- Combustion
- Aeroelasticity

3.2 Platform preconditions

The first precursors of the development of the CompEdu platform were the works of Wilson and Korakianitis in collaboration with the International Gas Turbine Institute at MIT and Bölcs at Swiss Federal Institute of Technology, Lausanne in years 1985-1990. One work was a PC-based computer program “Home Study Course” allowed performing calculations of thermodynamic processes. The other work was a Macintosh-based program with a graphical interface for interactive lecturing of design and calculations of a turbomachine (Leotard et al., 1998). These “classical programs” were often complicated in use and could not be easily employed by undergraduate students for educational purposes. The other important preconditions for development of the CompEdu platform are presented as follows.

3.2.1 Multimedia as evolutionary extension of books

In year 1998 Leotard, Roy, Gaulard and Fransson published a paper, where in one of the visions they foreseen untraditional educational settings in which the future student would learn course-basics at home, and then would come to a classroom in order to discuss the most interesting issues with teachers (Leotard et al., 1998). In fact taking into account that asking questions by students during lectures is relatively rare, the scenario implied a situation when instead of a typical lecture one might get a multimedial sequence with dynamic image, sound and elements of interactivity. In the paper there is a statement denying that the new technology will substitute a teacher. The statement seems reasonable: when books were invented, this did not mean a replacement of the teachers.

Nowadays a book is not enough: the global trend worldwide is to extend presentation with multimedia. This trend is reflected by the fairly common theory[6] that learners have individual learning styles and each person has definite preferences for use of different senses/media when learning. For example some learners prefer reading, some listening etc. This means that a modern teacher should be able to refer to, present, or even create richer multimedial documents.

Since the computer technology started offering possibilities to create rich multimedia content in 1990s, there was an opportunity to apply it in the educational practice. This opportunity was realized in the CompEdu project.

3.2.2 Learning content fragmentation when using multimedia in a classroom

Nowadays classroom teaching makes use of many classical and more recent tools, such as blackboards, video, overhead and digital projectors connected to computers. A problem with presenting learning material this way is that learners cannot easily reproduce the lecture content and the lecturing sequence in the same way a teacher does during a lecture (Fransson et al., 2000), because the elements originate from different media sources and some

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[6] 528 Articles found in search on “learning styles” in the Scientific Direct resource. Google found 901,000 web pages with the issue described or mentioned (Mar. 2005).

of the elements are difficult to copy/distribute. Even when the distribution issue is solved, proper cataloguing, search, and “wrapping” into a context are often missing.

At the same time it is well known from the educational practice that repetition of once performed activity is one of the key learning mechanisms. Certain lecture elements are available afterwards in the form of notes taken by the students. But multimedia materials, like videos or simulations, usually are not easily accessible, and colourful slides shown by teachers are often given to the students as black and white paper copies instead. Or if available, the content elements are sometimes given to the students in the form of file sets. Those are the reasons for knowledge object fragmentation, which could make studying less efficient, because content structure and interconnections in such material are often unclear.

3.2.3 Slideshows causing information fragmentation

There is a common tendency among educators to present content in the form of Power Point slides. Notes taken by students during such lectures, are often fragmentary and do not allow to easily reproduce the presentation sequence. This is mainly because the lecture presentations are not done fully in the classical blackboard-based way. When lectures were conducted with all information written down on the blackboard, students had full overview of the content and the sequence (if, of course, the teacher did write down everything important that had been said). Nowadays, when the slide shows have dominated lecture rooms, students have to read lecture notes written by teachers or buy books in order to reconstruct the sequence of the teachers’ lecture presentation. A conclusion from the said above is that the slide shows do not serve as well for students as they do for teachers, because teachers tend to use the slide-shows as a support for their own presentation sequence without much focus on the students’ need of learning about topic details. A typical slide show contains keywords and headlines, and the rest of information is presented orally or on a blackboard. This presentation segmentation constitutes a considerable problem for students when they have to connect all the separate elements in one.

3.2.4 Analogue vs. digital distribution

The energy technology field and especially turbomachinery has been traditionally a high-tech engineering area. Because of high complexity of product-development and production chains the industrial area pioneered adoption of digital data management. Thus a lot of information from the area has the digital form from the beginning. Therefore there is an opportunity for the university environment to extend academic learning resources by reuse what the industry might offer.

Digital distribution considerably enlarges accessibility of resources on- and off-campus learning. But the experience shows that much of valuable material is not digitized or is digitized in multiple non-compatible formats. CompEdu aimed to solve the problem by putting the content into integral digital environment, especially created for higher education purposes. Initially CD-ROMs and lately DVD-ROMs were chosen as reliable and voluminous media for memory-consumable multimedia content. This way the problem of Internet transfer speed limit was overcome.

Obtaining CompEdu DVDs students do not only get material related to their courses, but also reference material from other courses, which they might be interested in. They also get prerequisite course material, so they can refresh their knowledge at any time, having the whole library on one DVD, which otherwise will take a lot of space in paper form.

3.2.5 Integration for efficiency of learning materials production

Content production was commonly recognized as the bottleneck for the progress of the Information Society. The development of multimedia course materials is labour intensive and a costly process. From a certain moment of the development stage CompEdu extended with the concept of a platform for joint educational collaboration in the field of heat and power technology. There was a hope that teachers worldwide would add material, which they consider to be good and unique (Kazachkov et al., 2003). Since then new material has been developed in the international collaboration between universities in Sweden, Switzerland, Finland, France, USA, UK, and Ukraine. Such broad collaboration is benefiting every participant of the network where all the materials are shared instead of being produced with own efforts, even though the experience showed that such collaboration often did not have enough resources to proceed efficiently.

The platform initiators Fransson et al. put an important statement that in a “normal” teaching environment there is hardly any exchange between teachers from different universities (Fransson et al., 2000). Current initiatives by the European Commission towards integration of research activities and increased scientific exchange indicate that the strategy implemented in the CompEdu platform might have promising future. For example in the guidelines to the main instrument of research funding in Europe Framework Programme 6 it was indicated that past FPs did not create a lasting impact on greater coherence of scientific and technological cooperation at the European level (European Commission, Research Directorate-General web resources, 2002). Thus, one of the main objectives for so re-defined Framework Programme was promoting activities designed to have a lasting, “structuring” impact.

3.2.6 Knowledge archiving

CompEdu was not developed as merely a learning material collection. It is a set of courselet portfolios, which aims to protect expert work from being lost in the future. Lecture notes, quizzes, simulations and other material retain in digital form ready to be used at any moment by teachers and students. CompEdu was intended to help teachers to organize and protect the intellectual property. This was done so that scholar’s intellectual efforts were not lost, as it often happens to traditionally provided courses (Bernstein, 2004). This especially concerns tests and examination materials, which are unique and relatively difficult to develop.

Nowadays much of reference materials are prepared in digital form (MS Word documents, for example), and collecting them in one place with systematic classification might have enormous value in teachers future work, because so systemized materials can be easily reused.

3.2.7 Promoting active learning

It has been widely recognized that self-motivation for learning is the key for success in the learning process. Then why do students spend a lot of hours participating slowly flowing lectures instead of fast learning using very carefully prepared electronic materials? For example all information during a conventional lecture in a curriculum is normally related to the students' background. This means that the better prepared part of the students is bored during lectures: they have to listen to the same material once again. Another part of the students cannot follow the lecturer, if not prepared well. There are obviously big losses of man-hours from both sides. That is why using well-prepared chapters might be more effective. Then students can modify the learning process in accordance to their individual needs.

Importance of learning by doing and probable unimportance of lectures in the long run was pointed out by Felder and Brent (2003): "You have roughly 40 contact hours in a typical course. If all you do in them is lecture, you might as well just hand out your notes and let the students find something more productive to do with all that time. The only way a skill is developed-skiing, cooking, writing, critical thinking, or solving thermodynamics problems-is practice: trying something, seeing how well or poorly it works, reflecting on how to do it differently, then trying it again and seeing if it works better".

3.3 CompEdu solutions

3.3.1 Learning scenario and place/time use

CompEdu elements for learning can be used for a self-study in the feedback learning-loop following the methodological sequence:

1. Reading/listening/watching.

2. Performing calculation exercises and simulations.

3. Performing quizzes and answering self-assessment questions.

4. Finishing, if the result of self-assessment is satisfactory or going to the step 1, if not.

CompEdu allows for studying in home conditions, without teacher's presence. The possibility to adapt learning speed to individual needs constitutes one of the main advantages of the learning platform for both on-campus and distance learning. This own-pace aspect of multimedia was highlighted by Davies (2002) as thea key issue concerning multimedia educational tools (Salomón et al., 2003).

Platform interactive content can be also used by teachers during lectures. Teacher can put bookmarks or/and create customized sets of CompEdu slides. The browser with content preview option allows for selection of multimedia elements during a lecture “on the fly”.

3.3.2 Presentation

3.3.2.1 Unified content navigation

CompEdu collects learning objects related to heat and power technology in one software package, where all of them have specific place and are presented in specific sequence. Subject-related objects are grouped in pages, chapters, books and shelves.

Version 3.0 of the platform has extensive navigation mechanisms. It is possible to select content from the Main Room and the Browser. In the Main Room the navigation menus (Fig. 11) allow selection of single pages, videos, quizzes, calculation exercises, lecture notes and some other. It is possible to preview pictures and videos before the actual choice. The Browser (Fig. 12) offers similar functionalities. A search mechanism by keywords is included, but it is still not possible to search through the page text fields. More advanced search engine would be a benefit.

Fig. 11: CompEdu with open bookshelf navigation menu

The content was unified and systematized, with well-defined entrance elements, for easy navigation for both teachers and students. Instructional sequence was simplified and made clear – there is no need for a learner to put learning objects together in order to study efficiently. The platform includes all necessary links to hardware and software elements needed for online collaboration with other students and teachers through videoconferencing and forums. Online support is available in case some problems immerge. Learning about current updates and new resources available was enabled through online information service on the CompEdu project homepage.

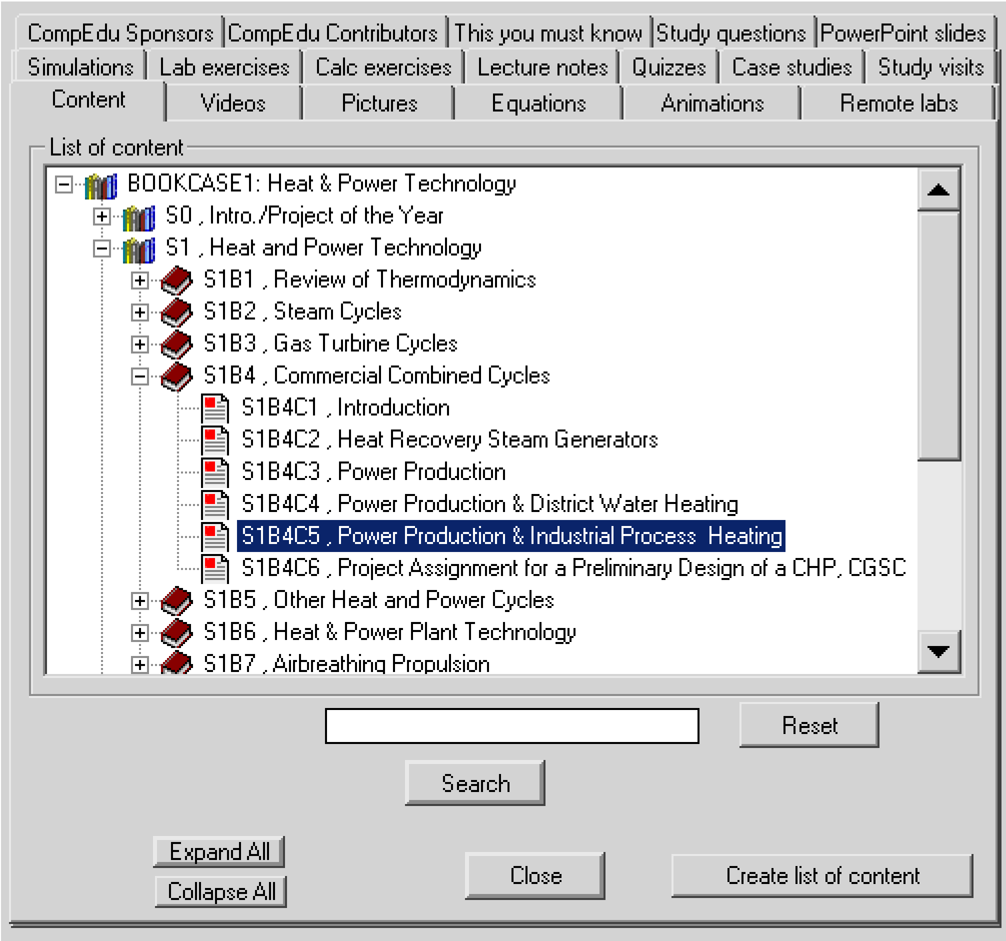


Fig. 12: CompEdu browser

Several different interfaces presenting the same learning objects (e.g. browser views for videos, animations, pictures) were added for giving more flexibility in learning/teaching, depending on presentation context. At the same time logical location of chapters, books, pages and other learning objects is based on traditional "library" philosophy, simplifying content aggregation. Depending on context, material can be used as defined by multiple educational scenarios (e.g. lecture, home-study, search for illustrations etc). The richness of the presentation contexts serves to simplify learning platform usage in multiple situations.

3.3.2.2 Chapter as an axial platform element

Chapter is the key learning element in CompEdu, and might be reused consistently as a part of a learning course. Main slides of a chapter constitute the axis of the chapter, and popups (Fig. 13) are the branches always leading back to the main axis. Chapters have several main slides, which can be followed in the default sequence from the first to the last (mainly when used by students), or in any other freely defined sequence (option available for the lecturers).

Chapters share the same build-up: the first page in each chapter gives an introduction, the second one defines which knowledge the student has to acquire and the last one sums up the key points (Fransson et al., 2000). The introductory page usually contains the title with the chapter's name, related picture, short introduction text on what this chapter is focusing, prerequisites, references to the literature with deeper knowledge and to sources used to build up the chapter, and acknowledgements.

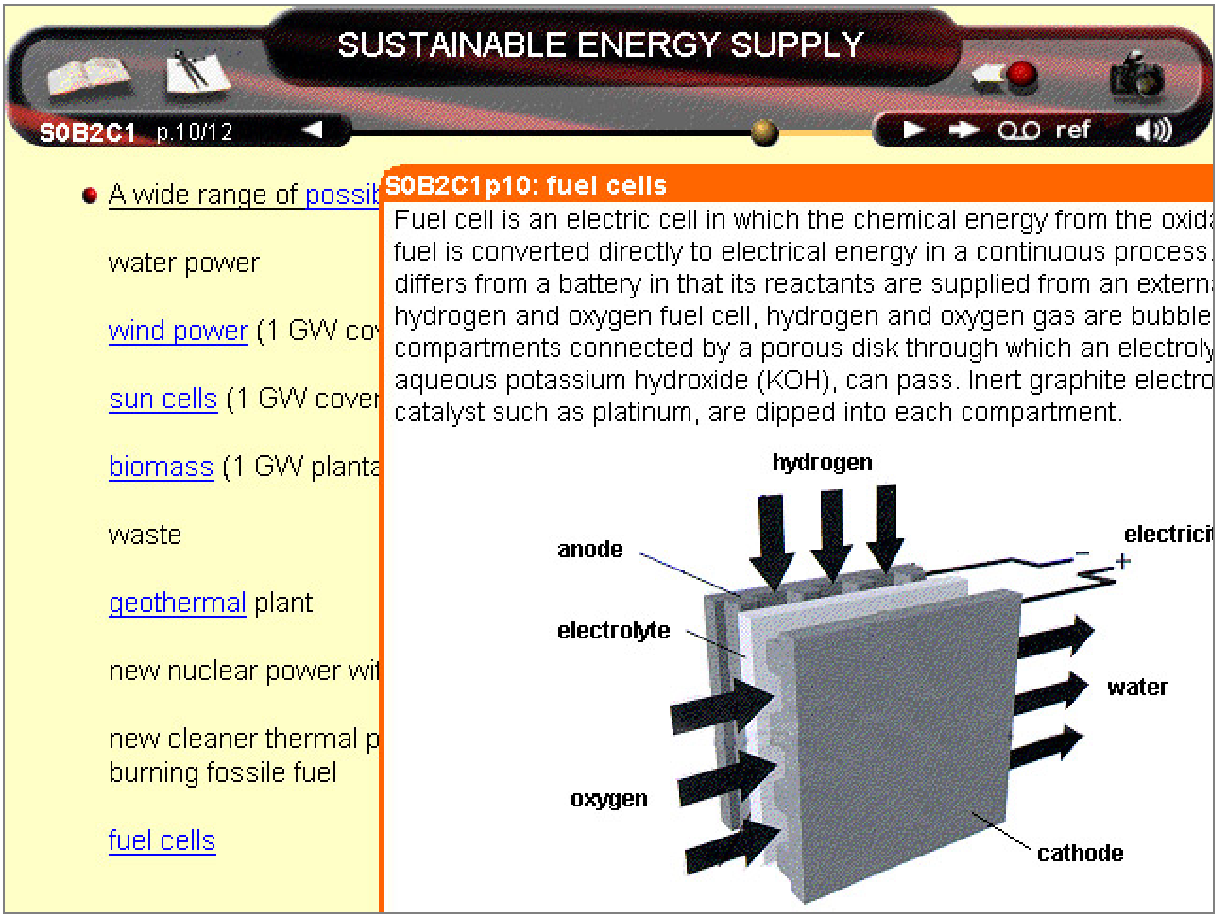


Fig. 13: CompEdu chapter with an open popup (version 3.0)

Prerequisites inform a student about necessary introductory knowledge before they can start to go through the new material. This can be a mathematical concept, a physical law or another learning object in the program.

The educational objectives page presents several points explaining what the student should learn from a chapter. This page also contains “key questions” which the students should be able to answer as a result of their learning. Bullets to emphasize importance of the learning goals always mark the Educational Objectives. Educational Objectives page usually starts with: “At the end of the chapter the student: - should know…, - should be able to…, - have knowledge about…, - should understand, etc.”

Summary is the last page(s) of a chapter where the most important aspects to remember are presented. Summary items are always marked by bullets. The last page of the summary usually contains “next step” hyperlink to the next chapter in the learning sequence. The summary also contains “this you must know” popup. This popup is a part of the general self-assessment strategy in CompEdu. “This you must know” makes learner check whether the key knowledge issues have been learned.

3.3.2.3 Popups

Chapters have auxiliary pages called popups. The popups extend the content of the main slides the same way a teacher would extend content of a power point presentation orally. In order to simplify presentation of the main ideas the popups give detailed explanations for words, symbols, formulas, pictures and so on.

Some (perhaps most) learning theorists have concluded that repetition gradually enhances some underlying process in learning (Britannica, 2004). Chapters with hyperlinked popups make use of this stimulus-sampling theoretical learning model. Popups appear in front of a chapter page when a mouse-click activates a hyperlink. The chapter page sequence represents the main line of information presentation. The popups constitute branches from the main line. Some popups, like the chapters, contain other popups. This way a chapter structure becomes like a tree of links with the main steam, which has to be followed. Such chapter structure makes learners go back to the previously open pages. It is like going back and forth along a tree branches, passing certain elements at least twice. This causes repetition of already learnt material and is believed to help structuring mental models of subject studied. Since the chapter tree has only one entrance, one exit (the first and the last page correspondingly) and no crossing links, there is no risk to be lost in an infinite number of hyperlinked pages as it sometimes happens when browsing the World Wide Web.

Using popups allows presenting material at two levels: the level of main slides, and the level of popups. This gives an opportunity to go quickly through the whole chapter and then read in detail studying also the auxiliary pages included in chapters (Kazachkov et al., 2003).

3.3.2.4 Lecture notes

CompEdu Electronic chapters by definition serve to present the most important ideas in a short and simplified way. Students can find deeper and longer explanations in the Lecture Notes, which are usually added to every chapter. Lecture Notes have Acrobat Reader pdf-file form. Developers are recommended to write lecture notes for each CompEdu chapter.

Written lecture notes, which students can use as classical reading material, are of high importance to many students. It is also a considerable enhancement to the pedagogical concept presented in the CompEdu platform. Writing complete and comprehensive lecture notes is difficult and time-consuming. In cases when a developer cannot do this as a complete chapter, it is suggested that some additional text is written at least for individual pages.

3.3.2.5 Dictionary and glossary

To maintain the connection to students' background, a multilingual dictionary has been introduced (Fig. 14). It gives translations of some words related to heat and power engineering in English, French, German, Italian, Spanish, Hungarian, and Swedish. This way foreign students can use the platform with full understanding of technical terms, which they already know in their native languages.

Fig. 14: CompEdu multi-language dictionary

3.3.3 Active learning and learning progress assessment

"Most importantly, research tells us that students learn more by what they do (and the feedback that comes to what they do) than from what is explained to them. Doing, feedback, and explanation are all important ingredients in the learning recipe. A physics faculty member once tested his students' conceptual understanding and realized for the first time that not even his "A" students really grasped the fundamental ideas of the course, he exclaimed, "I'm a good lecturer. I've been teaching physics for 20 years. And I now realize that you cannot 'tell' people physics. It cannot be done.' So he shifted to a mode of teaching that was driven by what students do: experiments, simulations, exploration, and debate. That doesn't eliminate presentations from the instructor's repertoire. But it does suggest that many faculty members rely too much on clear, compelling presentations and not enough on student action as modes of learning" (Teaching, Learning, and Technology group, 2004). This reflects the problem of some academies, which are very much theory-oriented ignoring practical-skill demand of the industry. In the industrial world there is often no need to know theoretical aspects of why something works or does not work. In the commercial area the knowledge of what works and how it works is often the optimal solution.

Probably many people experienced the feeling of internal persuasion that they had learned a lot, but then inability to demonstrate the knowledge during exams or tests, and thus frustration. The learning progress assessment gives an opportunity to check if the feeling was correct. It is the basis for feedback in education. Actions are a part of learning processes happening in nature, where every learned concept is practically tested. Without application of theoretical skill a learner cannot be sure, if the learning has occurred. A practice test is the final exam of theoretical knowledge. "There is a great difference between imagining that we have done the problem and actually doing it. No matter what ideas our front cortex has created, we cannot know if they are true until they have been tested in a concrete and active way. Until we do that, as Sophocles said, our knowledge is 'fanciful" (Zull, 2002). Research in education shows that the most appealing aspects of well-programmed instruction may be those that generalize to practical application (Treanor, 1998). Accordingly to the Active Learning principle of Cognitive Psychology (Alessi, 2001) one of the essential features of interactive multimedia, in contrast to more traditional media, is its capacity to require learner actions and act on them. At the same time designing interactions that are frequent, relevant, interesting, and have an appropriate level of difficulty, is more difficult than even some experienced developers believe.

There is a tendency in certain kinds of training that students are following tutorials in their own pace and any time they prefer. Practical seminar training is needed after such tutorials, when a teacher can control learning conditions and respond to unpredictable situations. In fact nowadays there are tools allowing preparing interactive narrated presentations in front of a computer with a headset on a head[7]. Such a presentation would be richer than a traditional lecture by offering self-check tools, for example. Then once prepared such lectures could be reused by students the same way as course manuscripts are reused, but with bigger pleasure for added interactivity, videos and audio in one. Afterwards instead of lecturing, teachers could spend more time conducting seminar activities or online conference support for practical work with students as they are using the "digital manuscript" presentations.

Elements of practice and self-check in CompEdu were introduced as a response to the need of active learning. The elements include calculation exercises, simulations, computer

[7] For example the Macromedia Captivate software (2004).

codes, quizzes, “this you must know”-section, virtual and laboratory exercises, virtual study visit and some other.

3.3.3.1 Calculation exercises

Calculation exercises (Fig. 15) are equivalent to classical calculation tasks. The difference is in possibility to check not only the final result, but also intermediate results. Getting the intermediate solutions is realized in CompEdu by “buying” hints from the interactive animated person in the calculation exercise window. The hints represent parts of the solution stimulating further self-reliant work. When a learner uses hints, he/she loses score points, which are automatically counted by the platform as positive or negative feedback for quizzes, calculation exercises etc. It is also possible to “buy” complete solution for a task. Then the solution is shown in the form of a pdf-file.

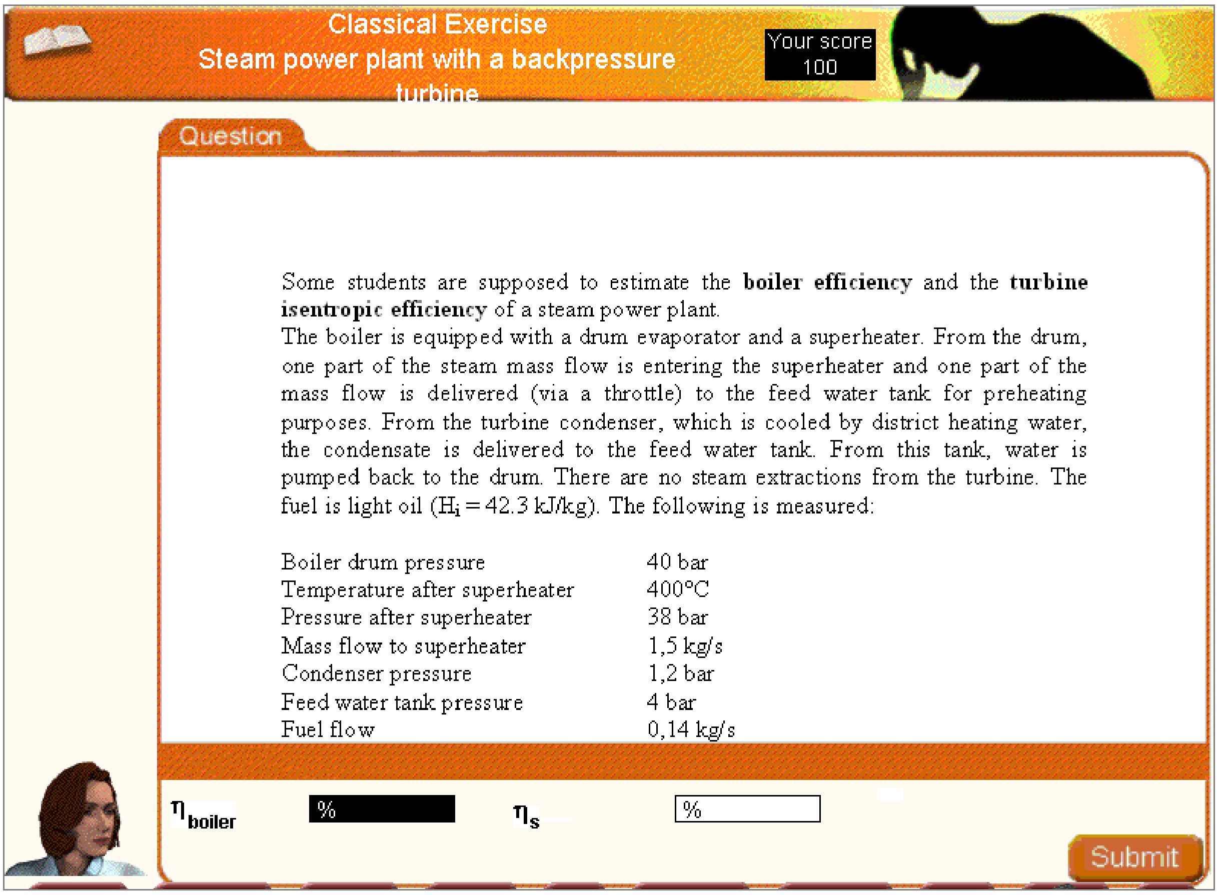


Fig. 15: CompEdu calculation exercise

3.3.3.2 Simulations

Simulations constitute an alternative way to learn, which is based on discovery and experience (Salomón et al., 2003). They are interactive programs presenting complicated phenomena in an easy way. Simulations have an important role in facilitating learning process in situations and places previously not available or possible. They represent the model of a “laboratory in a classroom” and this is a unique feature ever available taking in account how difficult it is to organize and conduct live lab exercises.

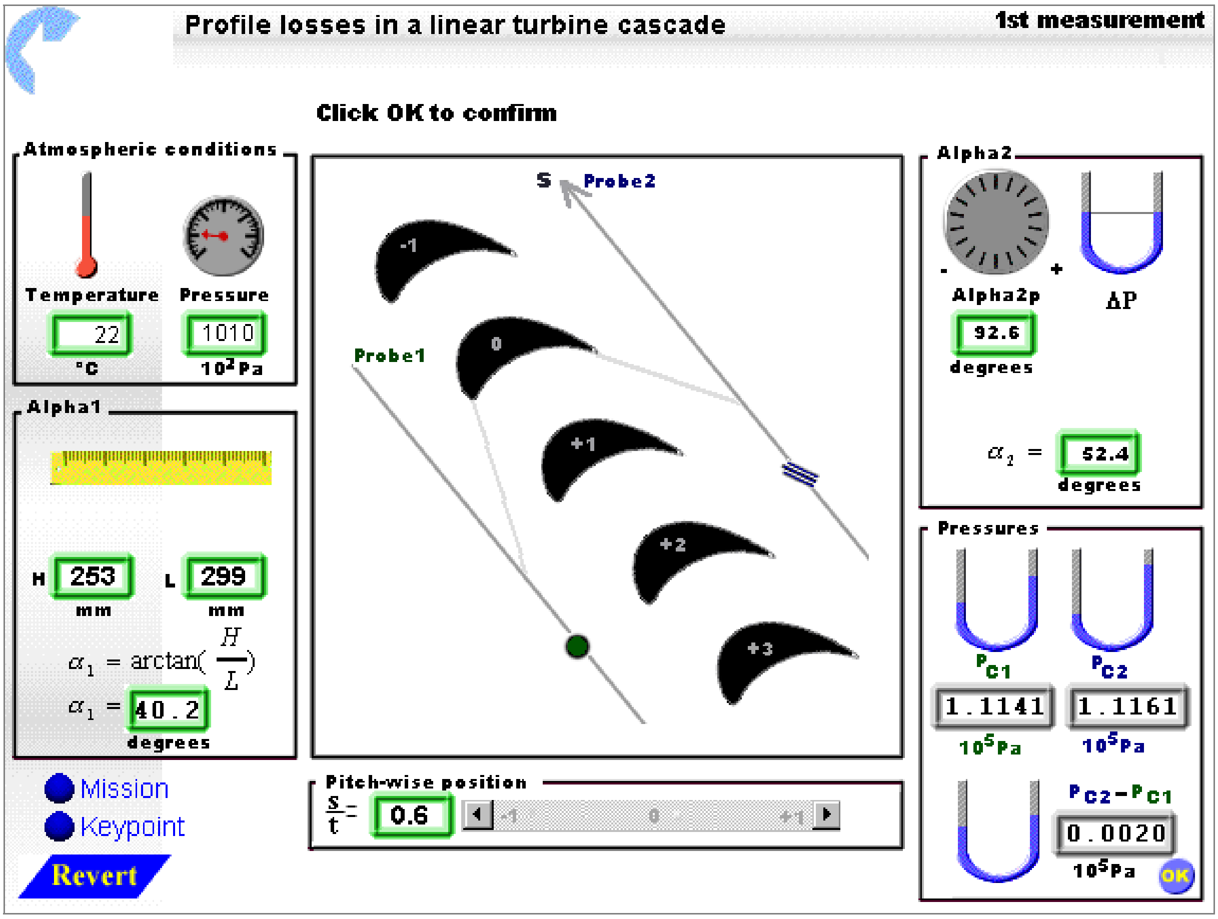


Fig. 16: CompEdu simulation (virtual laboratory exercise)

The programs have inbuilt mathematical models of physical processes and behave as they were actually the physical objects to study. The user can change parameters of such process and can observe effects following the changes. In the platform simulations there are message guides how to proceed, so that the user does not get lost. The messages still give some freedom for making certain mistakes having educational value as well. Outputs of simulations usually have graphical form for easy perception and analysis. Simulations are parts of chapter content and this way are directly used in the theoretical context.

Virtual lab exercises are a subclass of simulations. Virtual laboratory exercises simulate real lab exercises, giving learners possibility to control/measure operation parameters without touching real equipment. Such simulations might be useful in preparation to real lab exercises (Fransson et al., 2000). The difference between a simulation and a virtual lab is that the latter aims at demonstration and training of measurement techniques applicable to the simulated environment or phenomenon.

Though simulations do not give possibility to have contact with reality, they, if well programmed, serve as a "story retell" about processes. If simulations are accompanied with real photos and videos they can be very efficient, since many facts we believe in, come from the other sources than our own experience. For example almost all lecture material is a form of retell, but we seem to believe it.

3.3.3.3 Computer codes

Computer codes accessible through hyperlinks have been introduced into the platform in parts concerning numerical methods. The codes help students comparing between symbolically described algorithms and practical computer language codes. If students are interested they can apply the elements of code in their work and try it. This way certain parts of engineering knowledge could be obtained in practice.

3.3.3.4 Quizzes

True/false questions and multiple-choice questions (quizzes) are typical in computerized knowledge assessment. The learners' progress self-assessment is an important stage of major pedagogical practices. The quizzes serve to check if the knowledge was assimilated. Thus every chapter devoted to learning should have at least one quiz, which helps learners to control their memorization and understanding the material presented. Teachers use quizzes for flexible material adaptation during consequent instruction phases. CompEdu e-learning group designed overall quiz structure and development methodology; so that all new quizzes are homogeneous with previous versions and the CompEdu platform overall structure, and developers spend less time on quiz preparation activities. Quizzes are developed as tables of questions and answers with difficulty grades.

Quizzes in CompEdu are related both to theoretical parts and also to main issues of simulations, animations, etc. The quiz tool offers possibility to analyse check-up results in the form of feedback pointing to the places in chapters related to unlearnt parts.

CompEdu quizzes can be printed out and used by teachers before or after lectures in order to get feedback about how well students progress. This also makes students focus more on studying, if the results are not satisfactory.

3.3.3.5 Laboratory exercises

Laboratory exercises constitute an important element of engineering education. Physical contact with objects of study allows filling gaps between descriptive theoretical knowledge and sensory knowledge. Experiments allow testing idealized theoretical models as well as triggering interest in explanation of certain observed phenomenon. This interest helps mastering the models on deeper level of understanding. Lab exercises together with the theoretical training are parts of a full-value educational process.

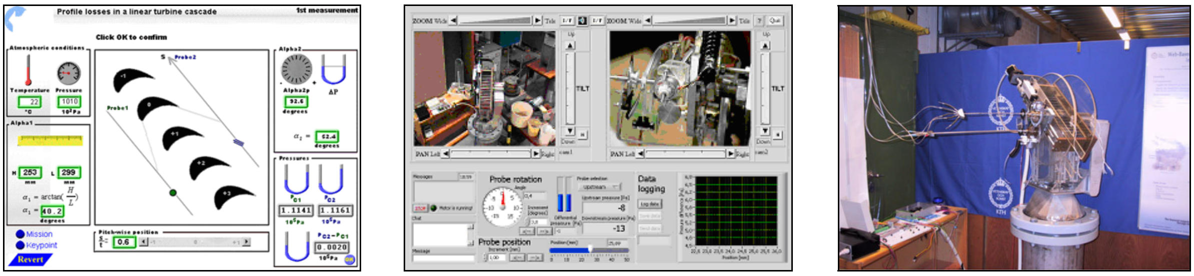
In the field of turbomachinery, laboratory exercises are often large dimensionally and expensive. Not every educational institution can afford having a desirably rich set of experimental facilities. This constitutes a problem, when students finishing their engineering education do not have sufficient experience with real equipment. They might also miss large portion of theoretical understanding as a result of poor association with the reality of the knowledge obtained. As a solution of the problem of insufficient experimental experience several alternatives to direct access to real laboratories have been offered worldwide. The alternatives include computer simulations of real labs and sharing of existing labs with internet-based remote control interfaces.

At the division of Heat and Power Technology at KTH a real Linear Cascade lab has been extended with internet-based remote control and a software simulation. Therefore there are two alternatives to the real lab available at the institute.

At KTH the Virtual Labs have been internally defined as computer simulations of real labs. Measurements are simulated by a pre-recorded set of real data or/and through involving mathematical models reflecting aspects of real experiment uncertainties, errors etc.

Local Labs are defined as real labs operated in the traditional way.

Remote Labs are defined as real labs operated distantly, access to which is enabled from the Internet. Measurements are done remotely. Remote labs (as well as local labs) are necessary for illustrating processes, which can not be calculated accurately in a simulation. Such laboratory exercises enable students to see the difference between existing models and experimental results. Also, since in the energy technology field measurements are very important, students can practically learn what kind of measurement techniques are used for different applications. For example the Linear Cascade lab illustrates how to use aerodynamic probes for establishing certain physical parameters. Due to remote (or local) labs students can get a feeling for measurement accuracies, possibilities, and limitations.



Virtual lab ***Remote lab*** ***Local lab***

Fig. 17: Three types of laboratory exercise "Linear Cascade"

The three lab exercises are a part of CompEdu platform. The exercises are blocks consisting of a theory chapter and a simulation. The description of the laboratories and evaluation results were presented in several publications (Appendix 6).

3.3.4 Other elements supporting active learning

Other elements of the platform, which support active learning, are virtual study visits, case studies, a keyword search option of the browser, elements of assessment tracking, bookmarks, a note-taking option, and support of web-communities and communication.

3.3.4.1 Virtual study visits and galleries

Virtual study visits of industrial objects and galleries of industrial machinery are intended to give learners the feeling of physical scale, proportions, spatial layout, and process connections. They present sequences of active maps with described photos/videos of real objects and their parts.

3.3.4.2 Personalization options

Personalization by creation of personal profile with individual password/login was developed to serve for individual tracking of learner's successes and failures. Results of performed quizzes, calculation exercises and time spent reading theory are recorded in the personalization files for subsequent learning quality control and learning strategy modification. The files can then be sent to teachers for further processing.

Another personalization function helps teacher pre-select page-sequences in advance. The new sequences then can be presented during a lecture in a certain sequence without need to search through the chapters during the lecture. Due to the option, lecturers do not have to follow the default sequence of chapter slides, but can create customized sequences (Fig. 18).

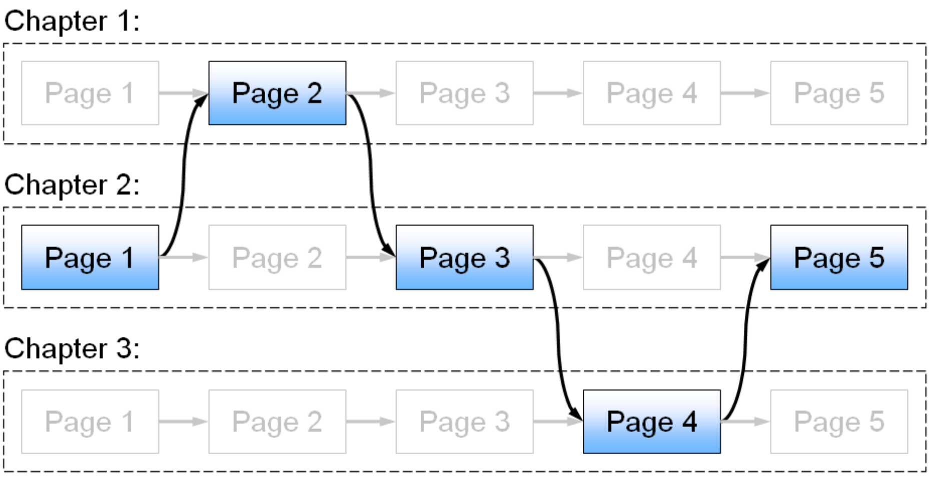


Fig. 18: Page sequence customization using material from several chapters

3.3.4.3 Supporting web learning communities and communication

A web-based discussion forum is available for CompEdu users. Students can also easily run Internet-based audiovisual conference software programs directly from the platform (programs: E-pop, Centra, ViaVideo, NetMeeting). The programs extend usage of CompEdu for the needs of distance learners, who cannot attend educational activities directly. In such cases CompEdu can be used as a substitute or addition to Power Point presentations.

3.3.5 Interactivity and dynamics

In order to shift the position of a learner from passive observation to active participation, CompEdu was enriched with animations, videos, and narrations. The concept of active participation was one of the main driving forces behind introduction of multimedia elements into the platform.

CompEdu platform incorporates elements of interactivity with focus on several learning methodology aspects:

- Giving extended illustrations of dynamic content elements,
- Guiding through the differentiated and rich content,
- Providing feedback during learning progress assessment,
- Increasing interest and thus learning motivation by attracting attention with elements of multimedia.

3.3.5.1 Animations, videos and sound narration

Animations and videos extend static images with dynamics. They are perceived by CompEdu developers as more valuable compared to the static pictures when illustrating changes of object states or properties. In the platform animations and movies can be parts of chapters and chapter pop-ups. The movies can be opened directly from these electronic pages. Movies and animations can be also parts of any other CompEdu element, such as the glossary, a virtual study visit or a gallery.

Sound narration added to bullet-by-bullet presentation of chapter content is another solution added to some CompEdu chapters to facilitate learning for visually impaired students or students having a learning style predisposing to listening.

3.3.6 Number of main elements present in the platform (version 3.0)

Table 1 gives the number of key elements available in the platform in the end of year 2004.

Table 1: Number of elements present in the platform (version 3.0)

Chapters	157
Lecture notes	35
Simulations	49
Quizzes	4
Calculation exercises	25
Animations	2
Videos	34
Remote labs	1
Virtual labs	1

3.4 Content development process

The platform development started in year 1996 with major interface changes in 1998. Five conference and journal publications have been published. Several master thesis works have been done based on tasks related to the platform content development. To a large exptent the CompEdu has shifted from software development towards content development, which included many activities triggering integration between universities and industries in several countries. Practical support of users helped to modify and adapt CompEdu for the learners' needs.

3.4.1 Development phases

It was agreed that structure of learning material should be clear prior to development. Classification of processes, mechanisms, and phenomena is the key for efficient learning. The content should be classified before putting the material into CompEdu chapters, because well classified material seems to simplify knowledge assimilation in many cases. Badly classified material forces learners to classify it themselves, what might reduce learning speed and cause frustration (at the same time certain classification tasks given to students may have learning value). The same classification rule concerns active elements such as simulations: they are to be developed by teachers to fulfil educational objectives and to fit overall material structure.

The Main phases of chapter development include deep understanding of described aspect and key concept formulation, review of already available in CompEdu material, discussions between teacher(s) and developer about chapter's content, chapter preparation in Power Point program, and incorporation of the chapter into CompEdu platform[8]. The development steps are usually performed in an iteration loop, which enables continuous improvement of every element to be introduced (e.g. chapters, simulations etc).

3.4.2 Copyrights

It is ethically and scientifically unacceptable to use materials from any source without the explicit acceptance by the originator. Copyright violation might lead to legal prosecution, thus all figures, videos and other materials prepared for CompEdu must have clear copyright status. Standard forms for copyright requests are available at the CompEdu team. Each material item from an external source used in the platform must have references given in a description document. The document, for example, can have a form of an accompanying popup with appropriate information about the source. Copyright statements are also a part of the references.

3.4.3 Conventions for unified content structure, outlook and description

There are several content presentation conventions, which must be followed. Predefined chapter templates help to remember about the conventions during development. The templates also allow keeping homogeneity of the chapters' structure.

It is recommended that text in chapters and pop-ups should form short paragraphs. A paragraph length should not exceed 3 lines of text. This rule is based on the assumptions that smaller parts of material are easier to read and understand. Such rule also forces content developers to build shorter and more "to the point" sentences. In case of need to present more information a developer should use pop-up windows. Lecture notes are not the subject of the 3-line rule. Bullets are used for accenting and separation of ideas, and not only for presenting lists of items.

[8] Macromedia Director was used for all versions prior to 3.0. Chapter Creator was used for v.3.0.

Presentation of long and complex equations in main slides is limited. Only the very basic equations should be presented this way. Longer equations should be put in popups. Such approach aims to motivate developers on describing dependencies in a non-mathematical way first.

Blue colour in text and picture frames is reserved for popup links. This is intended to clearly indicate active elements. Without this convention it is often not clear which elements are active, and which are not.

Equations, pictures, videos should have explanations underneath. All parameters in equations should be described directly on page. The descriptions can be also given in pop-ups or by links to the nomenclature pages.

It was agreed that chapters should contain only the key concepts concerning learning subject. Longer explanations should be given in the lecture notes or separate chapters. Number of pages for the theoretical part without introductory and summary pages should not exceed 12.

3.4.4 Review process and criteria

To assure good scientific quality, learning material to be included into CompEdu platform is reviewed by specialists in the field. The reviewers are selected by the Editorial Board of the CompEdu e-learning group based on existing network of contacts with other universities and industry. The review process helps deciding whether the material is acceptable for introduction or needs further modifications. The review process is kept confidential. Formal aspects of the review are based upon the official ASME review forms.

In the review process the two following aspects are taken into consideration: educational and presentational. The educational quality aspect includes material completeness, exactness, relevance, presentation simplicity, clarity, proper structural organization, motivating variation, acknowledgments/references, and illustrative richness. The presentation aspects include screen design quality, easy access to learning objects, proper headlines and titles, unified use of symbols and units, quality of illustrations, length of material, and style. The criteria are evaluated by five quality ratings: poor, marginal, acceptable, good and honour. Based upon the ratings a reviewer gives final recommendation concerning further development stage of the proposed content. The full criteria list is given in the Appendix 5.

3.4.5 Visual tests of content presentation

CompEdu platform serves for both individual learning and classroom teaching. Sometime it is difficult to predict how well pictures, text or other content will look in a classroom. A common mistake done by CompEdu content development beginners is putting pictures with too small fonts or graphic details in chapter pages. Therefore it is important to test ready chapter pages in a classroom using a video projector. This will make sure that all the information is easy readable from the back of a lecture room.

3.4.6 CompEdu project management

The CompEdu HPT platform contains several types of objects and operational layers: chapters, simulations, animations, quizzes, virtual laboratory exercises, virtual study visits, videos, sound tracks, calculation exercises, remote laboratory exercises, lecture notes, glossary and virtual gallery. The integration of the elements and functionalities inside the platform is a relatively complex task, which is realized by the CompEdu HPT e-learning group.

General overview of activities at the development and support stage is given in the list below. The overview gives an idea about resource engagement and task distribution. The indicated activities are delegated to appropriate developer in an organized manner:

1. Management (general project management issues of the CompEdu platform, development strategy, team task responsibility distribution, platform content lists and structure, report collection, analysis of comments and bug reports).

2. Integration, communication and promotion (communication with partners, preparation of newsletters, organization and conduction of reference group meetings, organization and conduction of CompEdu international cluster meetings, platform home page, downloadable versions of the software, demo versions, collection of comments, CompEdu HPT web-forum for developers and users, support of the Remote Lab).

3. Content development (training and support of developers, supervision of chapter development, sending, collecting and storage of copyrights, preparation of case studies, calculation exercises, quizzes, preparation of computerized exams).

4. Production (scanning, edition and drawing of pictures, video encoding, glossary updates, keywords updates, introduction of new chapters into the platform, modifications of platform content accordingly to existing comments, preparation of content lists and keywords for pictures, animations, equations in existing chapters, introduction of case studies, calculation exercises, quizzes, fixing software bugs, modifications of the appearance).

5. CompEdu CD/DVD production, distribution and user support.

6. Quality control (platform evaluation process, comment/bug reporting web system, review process organization and supervision, review and comments analysis).

The main tools for development of the computerized platform (in version 3.0) are: Microsoft Power Point and the Chapter Creator. The Creator is a special software tool, which was developed for facilitating introduction of new material into the platform. This tool was intended to help teachers at different universities to follow predefined data structure and interface. It was expected to reduce time and costs of edition by the CompEdu developers. The tool aimed at simplifying input of learning objects into the CompEdu platform. The Chapter Creator can be used as the only tool if necessary. But since Power Point program is well known in other universities and industry, it was decided that both tools can be used. Moreover there was a specific reason for using Power Point, because it is relatively difficult to export data from the Chapter Creator to other multimedia formats. The need for export is predicted in the nearest future, when the new web-based version of CompEdu is planned to be developed.

Other tools for picture/video/audio preparation are usually needed. Graphic editors are the most used programs during development process. Adobe Photoshop, Illustrator or their equivalents can be used at this development stage. Typically there is a need for both vector and bitmap graphic editorial tools. Vector graphics is typically developed in Microsoft Word. Adobe Acrobat is used for creating portable document format files, which are the basic form of the lecture notes. Animations are mainly realized using Macromedia Director and Adobe Image Ready. Videos are usually edited in Adobe Premiere program. Specific filters available in the program enable considerable improvement of quality of older VHS records, for example. This includes contrast/colour boosting and noise cleaning.

4 COMPEDU PLATFORM EVALUATION[9]

Leotard et al. (1998) defined two main objectives, which Multimedia Education should fulfil: it must improve pedagogical quality of teaching in a classroom and it must increase learning speed/quality when used by a student at home. In order to validate fulfilment of the objectives an evaluation of CompEdu platform was conducted. The evaluation covered practical usage of the platform elements in the context of heat and power technology courses at the Energy Technology Department of KTH. This concerned teaching and learning as mutually dependent but different processes. Opinions of students and teachers were collected during 8 years in the form of statistical data. The expertise of platform developers was an important part of the evaluation too, since the developers often get immediate response from students and teachers concerning problems, therefore giving suggestions for improvement.

The latest evaluation of the platform included two surveys conducted in two groups of 94 and 91 students each, with a time-span of about a month. The second survey was an evaluation iteration after processing the results from the first one. Both surveys included questionnaires. The questionnaire data were collected from the students before active preparation to the exam phase. Both groups included totally 128 different students attending the following courses during autumn 2004:

- Sustainable Power Generation,
- Measurement Techniques,
- Numerical Methods in Energy Technology,
- Fluid Machinery.

Every questionnaire included multiple-choice questions and open fields for comments. The questionnaires included an assessment of CompEdu usage frequency by each student. This was important to validate the evaluation quality in terms of actual learning time spent by a learner with the platform. Accordingly to the results 68% of the students used CompEdu more than 4-5 times before the survey, 26% used it 2-4 times.

The questionnaires questions and the summary statistics are included in the Appendix 4.

[9] The evaluation concerned version 3.0 of the platform.

4.1 The most used platform elements

To facilitate expansion of the platform in the direction of the most urgent learners' needs, one evaluation part concerned collection of data about the most used and the less used elements (apart from the chapter text elements). The percentage of the 91 students, who used corresponding elements, is presented in the table below.

Table 2: The most used platform elements

Nr	Element name	How many students used
1.	simulations	85%
2.	lecture notes	84%
3.	print	73%
4.	glossary	71%
5.	calculation exercises	62%

The results show that the two most used elements apart from the chapter text content are simulations and lecture notes. The print function is also commonly used, what indicates the importance of printed documentation for comfortable reading in any place and any time. Also the reason for the frequent use of the print function could be that not all students had computers at home. The frequent use of printed materials was found disappointing by the CompEdu group, because one of the reasons for "going digital" had been to reduce paper use.

Students, especially those who are not native English speakers and wanted to know meaning in their own languages or more extensive explanations of words, extensively used glossary. The majority of students which took part in the evaluation were not native English speakers. Also a considerable part of the course terminology was new to the learners for the educational novelty reason. Calculation exercises were also used extensively, even though their number in CompEdu was limited at the moment of evaluation, but the exercises were accessible as part of course web pages. This also reflects students' need and understanding of importance of active learning by problem-solving (independently from the learning tools used).

Quizzes did not appear among the most used platform elements. One reason could be that students did not find them useful. The other reason, which seems to be more probable in the evaluation context, is that there were only four quizzes available in CompEdu in year 2004.

4.2 Value in learning

From the general perspective the CompEdu platform value for individual learning was found high by 52% of the students. This means that a half of the students was relatively satisfied with the platform content. At the same time the number also reflects the fact that about half of the population was not satisfied with the platform content for learning.

When the improvement of learning due to use of CompEdu was assessed in the relation to traditional learning approach, the evaluation showed that about half of the students observed certain improvement of their learning effects due to the CompEdu use. At the same time about one fifth of the population observed the efficiency diminution.

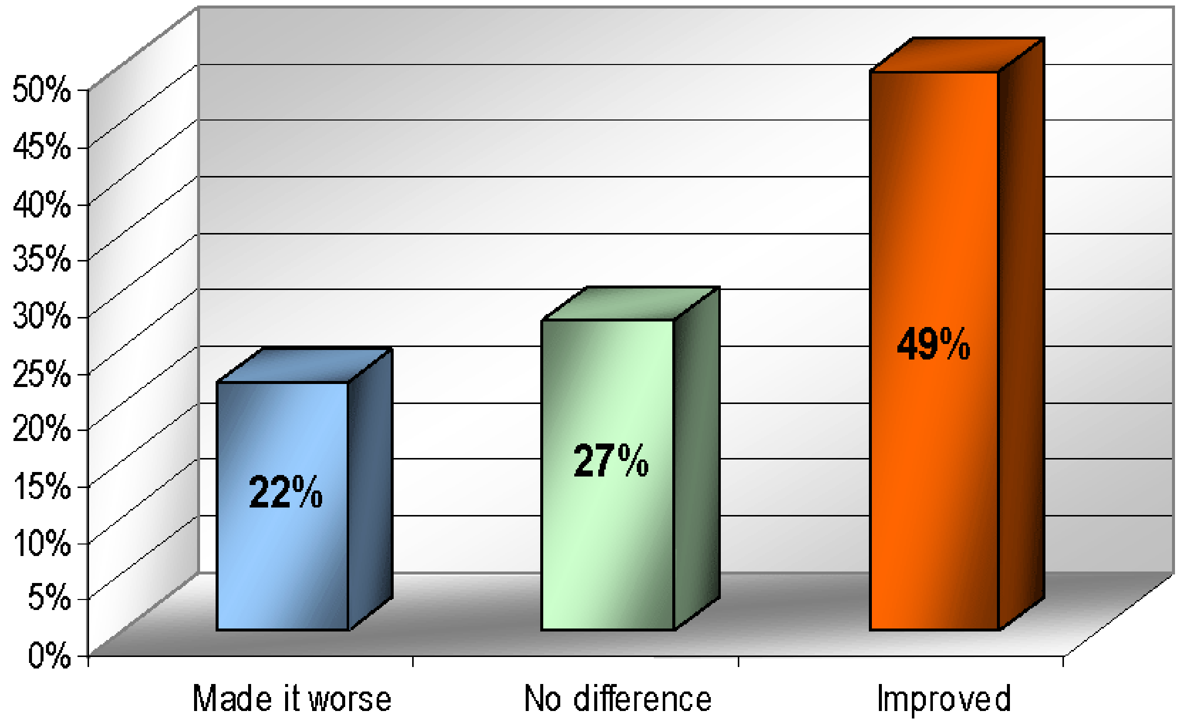


Fig. 19: Opinion on improvement of learning results when using CompEdu

The results suggest that the general trend towards improving learning efficiency due to CompEdu is positive. But there are certain aspects that need a deeper analysis in order to explain and possibly minimise in the future the negative effects on the smaller group of the 22% students, who felt the platform caused their learning efficiency to decrease. Probably the students had different expectations from the material quality and presentation level/form.

In order to identify the problem, the questionnaire results from the group claiming negative learning effect had been analysed again. The analysis showed that all (!) of the students in the subgroup preferred learning using paper materials (books, scripts, etc) vs. digital media (the Internet, CompEdu etc). Also 90% of them for reading preferred the material having linear structure and not the tree navigation structure like in CompEdu. From this perspective it seems that their learning style and habits did not allow for using the new media efficiently. Also CompEdu did not offer all necessary lecture notes, which were found desirable by the majority of students, who took part in the evaluation. Some information was missing in the platform chapters as well. Increased availability of lecture notes might considerably reduce the negative effect for learning with CompEdu in the future.

Further analysis of the group, which had expressed the negative opinion, showed that they appreciated interactive elements (particularly simulations). At the same time they did not find sufficient number of solved examples, and experienced certain search problems when trying to find particular items of the platform content.

4.2.1 Simulations

General statistics on the most used elements of the platform in the evaluation of 2004 demonstrated very high popularity of simulations. The results are close to the evaluations of CompEdu conducted in 2000-2002 (Salomón, 2003). Then a group of 49 students expressed a positive attitude towards the role of simulations in their education. In the simulations the students especially appreciated the guided help. They also liked the theoretical context of simulations in the form of CompEdu chapter pages.

Salomón pointed out that the simulation objectives must be congruent with the objectives of a learner. Some simulations were originally created for research purposes and then adapted for learning. In the CompEdu platform the harmonization of the two different objectives (the research objective and the learning objective) is not always done perfectly. On one hand simulations contain help information, guides, and are parts of chapters. On the other hand the descriptions do not always contain enough information to perform the simulations efficiently. Therefore some interesting learning aspects of simulations might be missed.

A relatively common exception from the educational context usage of simulations was observed, when not all teachers used the CompEdu simulations during lectures/seminars, even though the simulations were available as part of the study material. One of the main reasons for this is that simulations are often demanding from the navigation/control point of view. Not all teachers are fluent in working with interactive content. Thus simpler simulations would be more beneficial for active use by teachers in lecturing.

One of the evaluation findings was that CompEdu simulations could be easily used by engineers in companies for performing basic calculations concerning performance of their energy equipment. For example one Swedish industrial company was interested in using a CompEdu simulation for performing a preliminary gas turbine project study. Therefore well-collected and described set of simulation tools in CompEdu might also be used in some commercial applications.

4.2.2 Virtual and remotely controlled labs

Contemporary information and communication technology offers much broader possibilities of information transmission than ever before. But still the flexibility of computer-mediated perception is relatively limited compared to what can be observed within physical proximity to an object of study. Since the alternatives to a real lab (e.g. a virtual/remote lab) might not be equally valuable for learning, there is a need to compare them with each other. Comparison results can suggest new ways to learn same aspects of experimental work using different approaches. The comparison might also show if the different laboratory forms are feasible as far as educational quality factors vs. economical factors are concerned.

To meet the comparison objectives, the CompEdu remotely controlled lab and virtual laboratory “Linear Cascade” were evaluated in years 2003-2004. The results of the evaluation were presented in several articles mentioned in the Appendix 6.

The findings from the lab evaluations indicate that diversified interfaces of virtual/remote labs increase learning motivation by inducing interest. The motivation to perform the remote lab was very close to the motivation for doing the real laboratory exercise. The evaluation also showed that remote labs might offer increased comfort of learning activities due to reduction of disturbing sensory information (such as compressor noise, for example). At the same time the labs did not assure efficient learning of spatial/dimensional aspects of the equipment/phenomena and adequate hands-on experience. Nevertheless depending on the learning objectives the virtual and especially the remote labs showed to be full-value alternatives to the real laboratory exercises in a similar way as flight simulators serve for preparation of pilots.

4.2.3 Hypermedia

Popups represent the hypermedia implementation in CompEdu. Hypermedia is an important aspect of computer tools for learning by integration “graphics, text, sound, animation and video in one educational resource, with the addition of the capability to freely navigate between and within concepts, being a broader term that the multimedia concept” (García et al., 2005). The goal of using popups was to make learning easier by clarifying chapter structure. In such arrangement the key issues are presented on the main slides and detailed explanations/examples are given separately in popups. The goal was partly fulfilled, because students, which took part in the evaluation, underlined the platform material clarity in their comments. In a separate question asking if they liked the idea of popups, 85% of the students answered “yes”. At the same time, in a different question, 69% of them claimed that a linear (conventional) presentation form is better than the tree (popup) form. It is highly probable that the clear preference for having linearly arranged material represents reading habits of the students and the physical convenience of using paper content. Some students pointed out that some chapters contained too many popups. Therefore for better information structuring it would be proper to optimize content tree structure, so that popups are used when it is necessary for clear presentation.

4.2.4 Prerequisites

Prerequisites and literature sources necessary to learn using specific chapters should be carefully specified including material, which is not present in the platform. Otherwise a learner might be lost, if he/she is planning to start learning from the scratch. Certain parts of

CompEdu were criticized for this mistake by one of the platform academic reviewers. Also the available references mostly correspond to whole chapters and not to certain chapter parts. Such reference method is probably not detailed and concrete enough.

4.3 Value in teaching

There were several discussions among teachers at KTH about CompEdu value for lecturing. The CompEdu platform was used both for in-classroom lecturing and extensively tested as a content database for online distant lectures.

It was found out that CompEdu simplifies lecturing and increases reliability of online lectures due to integration of all media in this unified content platform. Without CompEdu a teacher would have to open several separate programs to present slides, animations, videos or simulations. Besides such all-in-one material can be easily accessible before/after lectures without need to download separate files. Also use of single content software instead of several might reduce the risk of causing software errors or operation mistakes during lectures.

The platform showed to extend and simplify teachers' presentations. At the same time it was discovered that, when used slide-by-slide (as a Power Point slideshow), the platform caused certain limitations of the presentation freedom by means of predefined chapter structure. In such scenario a teacher opened the first page of a chapter and started explanation. The teacher followed certain internal logic and when he wanted to continue with some unexpected ideas, the next chapter slide offered something different compared to the lecture's intentions. This means the teacher had to adapt to the predefined chapter structure during a presentation, what did not usually happen with his own slide presentation. The problem described was partly solved in the platform by the possibility to predefine personal page sequences and putting bookmarks, but this option also might limit teachers in creative improvising, especially when the students ask some unexpected questions.

Since textual information on chapter pages is not very useful for presentation during lectures, the other solution in the form of choosing from a list of pictures, videos etc. from the CompEdu browser could give some freedom to teachers, so they could actually choose different slide sequences on-fly. Nevertheless the search for a particular picture from the whole chapter picture list during presentation might take some time and could discontinue the lecture flow. In such situations, for content presentation flexibility the present platform version has to be mixed with other programs during presentations; otherwise teachers would feel bound to predefined presentation sequences. A better solution for the search of pictures/videos on-fly could be arranging the objects in annotated taxonomies (tree structures) in similar way as computer files are arranged in folders.

Evaluation results also showed that students did not appreciate when teachers extensively used CompEdu in their presentations as a kind of substitute to Power Point slides. This dislike was especially profound when a teacher was actually reading the slide text. The main reason given in the students' comments was that they did not want to be presented exactly the same information, which they could get themselves from CompEdu at home. This way it becomes clear what additional value, in general, Power Point slides gain from lecturers' narrations and comments: many Power Point presentations are useless without a narration or could only be used in the form of reminders about topics introduced. Compared to Power Point slides, CompEdu has shown to cover the need of narration to a larger extent through use of broader explanations in chapter text.

The evaluation of use by teachers showed that CompEdu offers convenient content integration for lecturers and enriches explanations, but rather should not be used directly as a substitute for Power Point presentations. It can be used as reference material stock during lectures instead. And probably the best use of CompEdu is for individual learning at home.

4.4 Time/place situation and group use

The platform evaluation showed that students most commonly used the platform when preparing to solve some particular task. This included preparation to exams and doing homework for exercises. Some students used CompEdu as a reference book (e.g. PhD students).

One question in the evaluation contained choice of the most important activity for exam preparation during students' educational experience. The question concerned their life experience and did not focus on CompEdu in this context. The exam preparation was chosen, because it is one of the most tangible targets of a typical goal-oriented student. 94 students, who took part in the evaluation stage, could choose between: home work with books/scripts/exercises, attending lectures and attending exercises. 74% of the students claimed that homework was the most important. Only 14% chose lectures as the most important for exam preparation.

The evaluation results might suggest that lectures are not the most efficient way of learning anymore, when learning content distribution in digital form is becoming easy. Certainly lectures help creating a framework/skeleton for further learning, but they do not typically adapt the "learning by doing" approach present in the exercises/homework. On the other hand there is the very important social aspect of attending lectures for internal conviction about learning goals. As it is known from the sociology research, group opinion and action have high motivational power for an individual. The phenomenon of Social Validation describes "one fundamental way that we decide what to do in a situation". The way "is to look to what others are doing or have done there. If many individuals have decided in favour of a particular idea, we are more likely to follow, because we perceive the idea to be more correct, more valid" (Cialdini, 2001). Therefore attending a lecture could motivate for learning and help focusing on the subject of learning. It might also help students in socializing.

One question in the evaluation assessed the importance of learning from colleagues during the courses and 55% of the students claimed they learn much this way. This means that lectures and exercises play important role in facilitating social contacts and therefore indirectly improving learning efficiency.

It could be assumed that, in general, students try to minimize learning efforts and to maximize learning effects. Since individual work is so important for meeting the students' learning goals, it would be appropriate to provide them with good quality learning materials for homework. This is one of the purposes of CompEdu platform. In the evaluation students were asked if CompEdu helps to study at home after lectures. 83% of the population claimed that it does.

The only practical feature enabling group work in CompEdu was the Internet Forum. Unfortunately it did not become widely popular. The most probable reason for this seems to be that in relatively small groups of local students they can communicate directly or contact teachers to answer their questions. Forums are used in the Internet mostly for communication between people who do not have direct contact. Also the number of participants is critical in forums. If the number is low, there are not many new messages appearing in a time unit, therefore there are not enough information-profits to join such a forum.

4.5 Structure, navigation, and usability

In the question relating to overall CompEdu concept 94 students were asked if the platform is a good example of a software product. 80% of the group answered that it is good (the alternative was "not really"). In the positive comments about the platform it was pointed out that one of the strongest platform sides is the good material structure. For example one of the comments was: "CompEdu is well-structured, goes directly to the point, and explains things clearly, easy to read".

Evaluation indicated relatively good level of navigation simplicity except obvious full-text search limitations. When asked about easiness and intuitiveness of navigation, 79% of the students claimed that the platform is easy to navigate. At the same time some students reported annoying software instabilities and some mentioned not working media clips. One of students suggested having a table of contents for the introductory page to each chapter.

Concerning the platform structure some interface inconsistencies were found. For example the history element in the bottom menu is purely content-oriented, so it should rather be located in one of the shelves as a set of chapters instead. Otherwise it might be functionally mixed with the page-browsing history menu. The bottom menu appears in every chapter and is supposed to be used often. That's why the elements of the menu should be those the most used only.

There were several comments from the students pointing out that number of bullets used for paragraph division was too high. Some students wanted to have a better note-taking tool. Two students complained that the interactivity level is not high enough. Lack of sound was indicated as a drawback by other two students.

4.6 Content amount and quality

The majority of negative opinions concerned content amount and content quality. Considerable differences in quality between different chapters were indicated. Mistakes in some formulas were found. Bad English was also reported by some students. Tendency to present Sweden-related energy technology solutions was pointed out. Quality of some pictures was reported as low, some figures were unclear to the students. Some students did not find enough derivations of formulas presented in CompEdu and more formulas to explain how equipment works.

Some students pointed out that more calculation exercises with solutions, quizzes, and simulations are needed. Extension of the number of words in the CompEdu dictionary was suggested. There were some complaints concerning the difficulty of understanding certain quiz questions and choosing right alternatives in the multiple choice questions. At the same time quizzes were found desirable in general. One student expressed the need to have more real life engineering problems available in the platform.

Many descriptions were found not deep and detailed enough compared to the textbooks. The need in more references was expressed. Students strongly demanded more information for certain platform chapters. Contrary some of the students were lost in the information amount already available, so that they did not know what to focus upon. One student commented that he needed only the information presented during lectures (no more). The latter suggests better curriculum integration between study programs and CompEdu and richer personalization functionality. In the evaluated groups not all material used in the courses was in CompEdu, so there were also requests for having the whole course material in the platform.

4.7 The place of CompEdu in relation to other e-learning platforms

In the chapter “E-learning today” it was indicated that the major e-learning trend of today is content management, share and reuse in the Web environment by means of standardisation. In order to judge about CompEdu place among other e-learning platforms, the package functionality can be compared with the LMS functionalities defined by the SCORM model as shown on Fig. 20 (Advanced Distributed Learning, 2004). In this comparison the aspects of content amount, quality, and multimedia interactivity will not be considered.

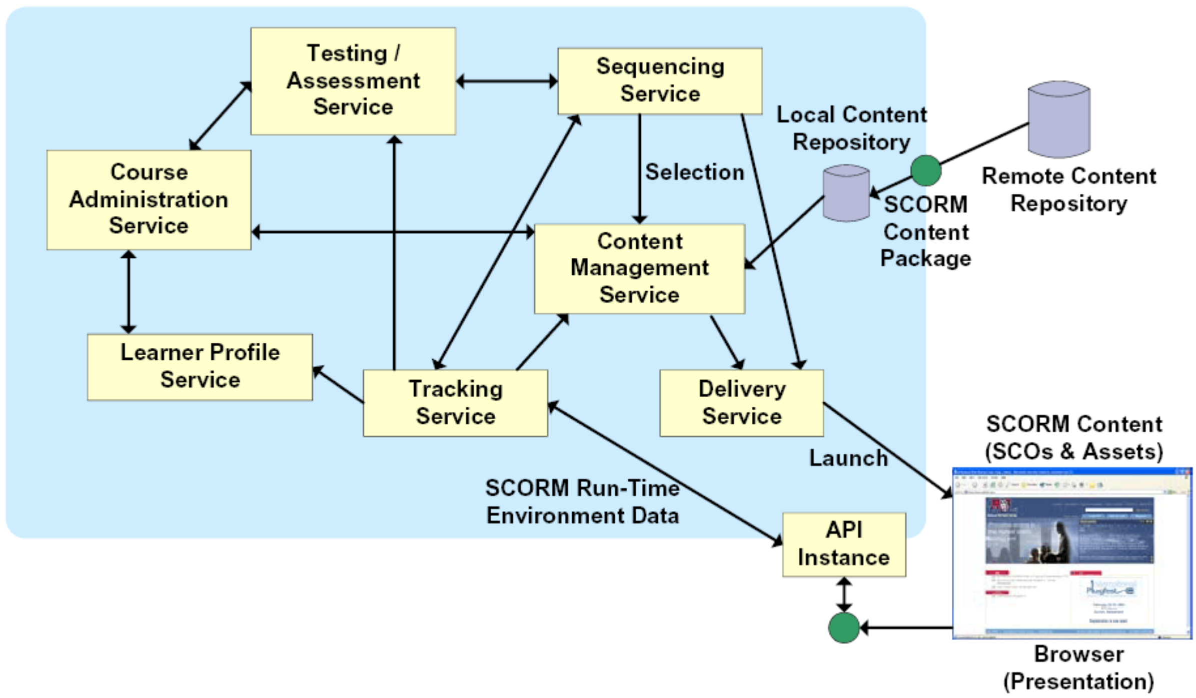


Fig. 20: Generalized model of LMS (based upon the SCORM model)

CompEdu was developed using Macromedia Director, and major elements of the content were encapsulated without flexible possibility to share, manage and reuse in the Internet environment. Nevertheless it can be recognized that the general concept of CompEdu has been aiming at the LMS level of interactivity/functionality. For example such elements of LMSs as testing/assessment and tracking services are present in version 3.0. To some extent sequencing and content management services (aggregated within the quizzes in CompEdu) are also available. Additionally the multilingual dictionary available in CompEdu reflects one of the internationalization issues specified in the e-learning standards.

At the same time such elements as course administration service, learner profile service, content management service, and delivery service are rudimentary or absent in the platform. The platform does not comply with requirements concerning content share/distribution, because it is not web-oriented and the content is making use of the internal Director formats. External resources can only be consumed by opening web-page links from the platform. Content export for external reuse is very limited in CompEdu version 3.0. Practically no metadata are retrievable from the platform.

As far as the internal content structure and methodology are concerned, CompEdu demonstrates similarity to what is described in SCORM specifications. Content rework and adaptation for compliance with the SCORM model will not considerably change the general CompEdu concept. Since presently CompEdu mainly represents the content side of an LMS, further adaptation work might bring fully functional and valuable e-learning product.

5 DISCUSSION ON CONTENT DEVELOPMENT: LESSONS LEARNED

Considerable amount of time during CompEdu platform evaluation was spent on issues related to development and existing content improvement. Since many of the critical comments about platform use experience concerned content quality, there was an opportunity to explain why it is often difficult to develop high quality educational material. The retrospection gives a chance to modify certain steps of the material development process to make them more efficient in the future. The chapter below presents the experience collected by the CompEdu group in years 2002-2004.

5.1 Production costs

About ten years of experience in multimedia content development for the platform showed that the “cost vs. quality” economic performance criterion can be reformulated into the “cost vs. interactivity” criterion for the case of CompEdu. In terms of resource/time consumption, development of interactive elements is much different compared to development of plain text and even pictures. Development of interactivity also demands relatively advanced for many engineers special skills. Many successful simulations and animations were created, but not all of them fitted the category of economically feasible. Sometimes too much work was spent on preparation of a certain interactive tool compared to learning effects possible to achieve from simpler tools or presentations. In general all programming tasks, which demanded creation of non-standard interface elements, non-standard interactive behaviours and advanced 3D-graphics were very time consuming. It was found out that creation of advanced computer effects for illustrating a scientific concept should be carefully compared to the learning effect expected. Audio and video materials are often very demanding in terms of production costs as well. Therefore interactive/multimedia elements should be carefully planned and justified prior to the development.

A wish to compete in presentation level with the TV-companies or other mass media organizations should be compensated with clear understanding about development resources available, which are often very limited in the educational area. Collaboration with public mass media companies might be a solution for reduction of certain production costs. One example of such collaboration is the case between the Open University and BBC in the United Kingdom (mentioned in the paper of the Instructional Technology Global Resource Network, 2005).

5.2 Multimedia and interaction quality

To some extent the term multimedia has become a buzzword for audiovisual computer presentations. There have been several (if not multiple) illustrations of poor quality educational material fully devoted to multimedia in hope for better learning results. But should it be understood that certain learning situations do not become considerably improved by introduction of multimedia? It seems the biggest gains from reach multimedia are possible to achieve when teaching children, who's abstract and symbol interpretation abilities are low and additional media (e.g. audio/video) can considerably improve the process.

Indeed, the illustrative value of multimedia might be high in many cases. At the same time in many cases explanations of highly abstract concepts do not considerably benefit from using other means than text or speech. Probably a classical illustration to such situation is the drawing lesson given to Alice by the Dormouse in the Lewis Carroll book (1865):

> `They were learning to draw,' the Dormouse went on, yawning and rubbing its eyes, for it was getting very sleepy; `and they drew all manner of things -- everything that begins with an M --'
>
> `Why with an M?' said Alice.
>
> `Why not?' said the March Hare.
>
> Alice was silent.
>
> The Dormouse had closed its eyes by this time, and was going off into a doze; but, on being pinched by the Hatter, it woke up again with a little shriek, and went on: `-- that begins with an M, such as mouse-traps, and the moon, and memory, and muchness -- you know you say things are "much of a muchness" -- did you ever see such a thing as a drawing of a muchness?'

In general, every time someone is thinking about adding some multimedia elements, the question should appear: how relevant, necessary, and feasible it is. This issue becomes very clear when we recall that historically text appeared as a more efficient substitute to pictures (e.g. Egyptian hieroglyphs).

Simplicity in use of interactive and multimedia elements is also important. For some reasons developers unconsciously tend to make "interactive" elements too complex in use by learners. But successful projects, for example in consumer electronics, suggest that people prefer ergonomic products (i.e. products increasing productivity and convenience of use). In general the automation is about simplifying everyday activities and not about making life complex. The same probably concerns interactivity. One of the most popular and very simple in use search engines Goggle[10] has only one search field to type in, but quite good results are shown rapidly and search mechanisms behind are probably complex.

One of the strongest positions of multimedia is to illustrate time-dependant phenomena. Dynamic processes demand additional imagination work if having static images or written description. Videos and simulations open a possibility to underline time-

[10] www.google.com (2004)

dependence, which was often neglected in the past due to mathematical complexity and presentation limitations. Nevertheless, some recent videos and simulations still have tendency of copying illustrations of static models presented in the older scientific resources for simplification reason, whereas the true value of the multimedia lies in dynamics.

Another aspect of quality relates to relatively simple visual design issues, such as visibility of picture elements, harmony of colours etc. The material for CompEdu is prepared by specialists in engineering fields. Most of them are not very well familiar with graphic and publishing techniques. The knowledge material is often unique, but visual quality is often not sufficient. On the other hand digital material, which might be accessible by many people, puts higher demands on quality. It was observed that some students felt frustrated and were unmotivated using content of poor quality. Therefore additional support from media staff might be very helpful to achieve accurate and consistent look.

5.3 Knowledge assessment quality: quizzes

Preparation of good sets of multiple-choice questions is a complex issue. The typical simplification in the quiz creation is mistakenly done by focusing on checking basic knowledge about facts, names, etc. and ignoring the importance of actual intellectual efforts for knowledge application. Putting the idea in another way: there is a difference between a person who has learned the Britannica Encyclopedia by heart and an intellectual able to apply the knowledge. The issue of intellectual efforts for learning has been described by Bloom (1956). Preparation of quizzes reflecting the principles indicated by Bloom might be a difficult task as teachers tend to ask questions in the "factual knowledge" category 80% to 90% of the time (OfficePort web resources, 2004). Such approach might also distort student's understanding of science as a continuous democratic debate, forcing acceptance of any new opinions presented by an authority as absolute facts.

5.4 Development of simulations

Availability of simulation tools does not always improve the learning process. In fact use of simulations in an inappropriate way can lead to insignificant or negative effects in the training if the learning environment is not adequate (Salomón et al., 2003). This includes learner's level of theoretical preparation prior to performing an exercise and complexity of a simulation exercise.

Too sophisticated interactivity might decrease efficiency of navigation and learning due to longer time needed to perform tasks leading to relatively simple results and not associated with the actual learning objectives. Some present simulations tend to have too narrowly integrated navigation mechanisms, e.g. too many parameters influencing one graph, too many active elements. For future improved simulations it could be suggested to have multiple simple simulations instead of more complex ones. The number of active elements should be optimised towards reduction of control complexity with increased learning value. Simplification of simulations and breaking them on smaller simulations will be also beneficial for learning object reuse for other courses or other lectures in the same course. Complexity reduction also serves for more cost effective simulation production and easy error corrections. For the purpose of CompEdu platform integrity it might be useful to define common data interchange standard between small simulations, so that a set of simulations could be used in a learning sequence, where output data from one simulation could be used as input data for another simulation.

Another aspect concerning developing simulations concerns linearity in use. The ideal situation would be when simulations allow following linear learning path. All kind of loops and deviation from the path between the beginning and the end might cause difficulties. This does not concern situations when simulations are intentionally programmed this way.

Embedding of simulations into educational context is seen as one of the success factors for their use in teaching. Simulations placed apart from theoretical background and explanations have small or no educational value. This is a general rule for context integrity and the core idea behind CompEdu content elements.

Adding quizzes to existing simulations could be a way to extend their educational context. Without this form of assessment certain issues for learning could be missed. Quizzes (or other assessment methods) would allow focusing learner's attention towards points of the major importance in the simulations. Simulations (and other interactive elements) could have short quizzes before and after. On one hand this could motivate students to actively prepare to such exercise. On the other hand this might increase motivation during the simulation exercise.

Not only quizzes can be used for simulation assessment context. Including short simulation reports sent to the instructor by e-mail also can be beneficial. The reports are the result of analysis and might answer the teacher's question if the educational objectives have been adequately met.

5.5 Weak knowledge of graphic tools among content developers

Practical experience of working with chapter developers shows that many of them often have insufficient knowledge about digital formats of graphical data. Also illustration skills of the developers are generally weak.

Apart from the typically poor quality of graphics delivered, one typical problem is that developers tend to paste pictures and formulas as bitmaps into final documents without preservation the original vector graphics. This makes further edition of the document-elements without retyping/redrawing almost impossible. Sometimes even whole parts of text are delivered as bitmaps. This, although obvious for computer graphics specialists, is not obvious for typical developers, who are more concerned with the content, than the archiving/distribution form. This often creates quality problems, when certain changes are needed, for example if font sizes have to be changed or certain formulas have to be corrected.

Good practice during development of electronic chapters is to keep all elements, which have been created as vector graphics or text as archives available for further edition. The easiest way to create simple vector graphics is to do it in MS Word or PowerPoint, for example. The file formats are commonly used and can be easily converted to bitmap form, if necessary. The files can be easily archived too, since it is possible to have multiple pictures on different pages in one document.

Another common problem concerns graphic size optimisation, for example when BMP format is used in documents instead of compressed formats, or GIF and JPEG formats are not used properly.

6 CONCLUSIONS

The CompEdu platform test cases at EGI KTH gave the real-life illustration of how multimedia can be used in the educational environment. CompEdu demonstrated that interactive multimedia integrated in one software package can moderately improve learning experiences of students offering more interactive and better-structured content in the digital format. The platform was found valuable as a knowledge collector and repository. In terms of media types and instructional methods, the evaluation indicated high importance of simulations and text materials. CompEdu offered additional value in terms of mobility, access and compactness. It also served as a tool for promotion of computer media solutions and IT-related skills among teachers at KTH.

When it comes to the learning gains the evaluation demonstrated certain improvement compared to traditional media (ca. 50% of the learners observed improvement). But about 20% of students claimed that CompEdu made learning worse. The interpretation of the data obtained from the 20%-group learners indicated their definite preference for using paper materials instead of digital ones and their preference for having materials with linear content structure instead of the tree structure (hypermedia type). At the same time some of the students were not able to easily access CompEdu, because they did not have personal computers at home, so they had to print the materials for home study.

Evaluation demonstrated that it is important to maintain proper balance between resources spent on development versus scientific quality of content. It was concluded that certain chapters did not contain enough reading material, but instead they contained interactive elements, which, without proper contextual descriptions, had relatively small learning value. Some interactive features did not assure high learning value due to complexity and non-intuitive interfaces. Interactivity of the platform itself was found not to be of primary importance, except where it was absolutely necessary, like in simulations or calculation exercises, for example. At the same time active use of the platform by teachers in curriculum activities was found to be one of the key factors for gaining better instructional results by the students during the courses.

The evaluation showed that some topics in CompEdu referred to prerequisites not presented or mentioned in the platform. Therefore broader context integration of the platform with other reference material is necessary, for example linking to external documents, such as books and especially the Internet. The search mechanism of version 3.0 and the older versions was found very limited.

In terms of time/situation use, the CompEdu evaluation indicated a high potential for home-work and a moderate potential for use during other learning activities (e.g. lectures and seminars in the form of reference material).

The most popular elements, apart from the platform chapters, were found to be: simulations, lecture notes, calculation exercises and the glossary. Unfortunately in many platform parts the general content quality and amount were found insufficient. Therefore the importance of properly organized development and review process is high, if CompEdu is to continue development in the future. Further merge of the platform with learning management systems and adaptation of the content structure to comply with the e-learning standards would be highly advisable.

7 FUTURE WORK

The global revolution in information technology was to a large extent conditioned by the development of the Internet. Computers on their own probably had considerably smaller influence on the World's economy and integration. The earlier Internet did not allow sharing bigger amounts of data easily, and the previous CompEdu platform versions, based upon compact disks, perfectly served for solving the problem of the slow Internet connection speeds. Since the Internet speed has considerably grown, and the urgent need for content production/sharing is becoming commonly recognized, CompEdu should follow the trend of knowledge distribution though the Internet, orienting primarily towards learning object demand in the distance education area.

The main future **development aspects** of the highest priority concern:

1. Extension of platform accessibility and interoperability by means of web technologies. Reconsideration/change of platform development tools accordingly to the most critical ADL/IMS recommendations.

2. Rework/export of CompEdu content into a web-media format (HTML/XML). Introduction of metadata descriptions for the platform learning objects (LOM).

3. Improving the search-function for full coverage of the text content in the platform by implementation of indexing mechanisms.

4. Extensive scientific content review and rework where necessary.

5. Optimizing of content production, review, and management process with respect to cost and educational efficiency. Setting up a simple toolset for the CompEdu content development.

6. Strengthening of the platform information structure by introduction of object/subject ontologies in the energy technology field. The ontologies are expected to give the overview of technology state-of-art and indicate areas of development for the CompEdu learning material.

7. Development of quiz creation pedagogic guidelines and simple data-base oriented tools for quiz/feedback delivery.

8. Development or adoption of pedagogic simulation-creation guidelines for adequate learning interactivity and applicability in industrial engineering situations. Finding an economically effective and sustainable solution for simulation-delivery via web and choosing efficient programming languages/environments.

9. Integration of CompEdu with existing commercial or open source LMS, alternatively development of a LMS layer in-house.

10. Adding statistical/trend analysis for CompEdu content use for optimization of learning object supply based on demand, when available via web.

11. Adaptation of CompEdu content for web access from portable/handheld computers.

12. Involving more partners for content production and directing CompEdu to become a portal for international e-learning resource exchange centre in the heat and power technology field.

CompEdu web version currently has been under development. Several chapters have been already published online and the rest is in the input process. General development vision of the platform for years 2004-2005 is presented in the Appendix 3. The strategy was first presented in October 2004 with some vision corrections introduced lately.

Research aspects deserving particular attention in the future include:

1. Evaluation of platform usability when published as online web-based version.

2. Influence of availability of the heat and power field ontologies for improving learning efficiency (assuming the ontologies will be linked to CompEdu pages in the form of graphs in the next version).

3. Analysis of possibility to establish energy technology research communities through ontology-mapping of current research trends. Selection of social networking mechanisms and tools to support the development of ontologies.

4. Practical tests of knowledge objects' production "on demand" based on the statistical reports of the search frequency.

5. Practical tests on metadata marking of the CompEdu learning objects and tracing mechanisms to enable search/cataloguing using commercial search engines (such as Google, Yahoo etc.)

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APPENDIXES

APPENDIX 1 Learning Management System example

This example of a Learning Management System (LMS) comes from European Gold Seal of Excellence in Multimedia 2004 awarded by European Multimedia Forum[11], for 'best use of Information and Communication Technology in education' (Fig. 21). The system includes several important e-learning elements mentioned in chapter "The place of CompEdu in relation to other e-learning platforms" (page 73) of the work. This example might serve as a reference for adding new functionalities to the CompEdu platform.

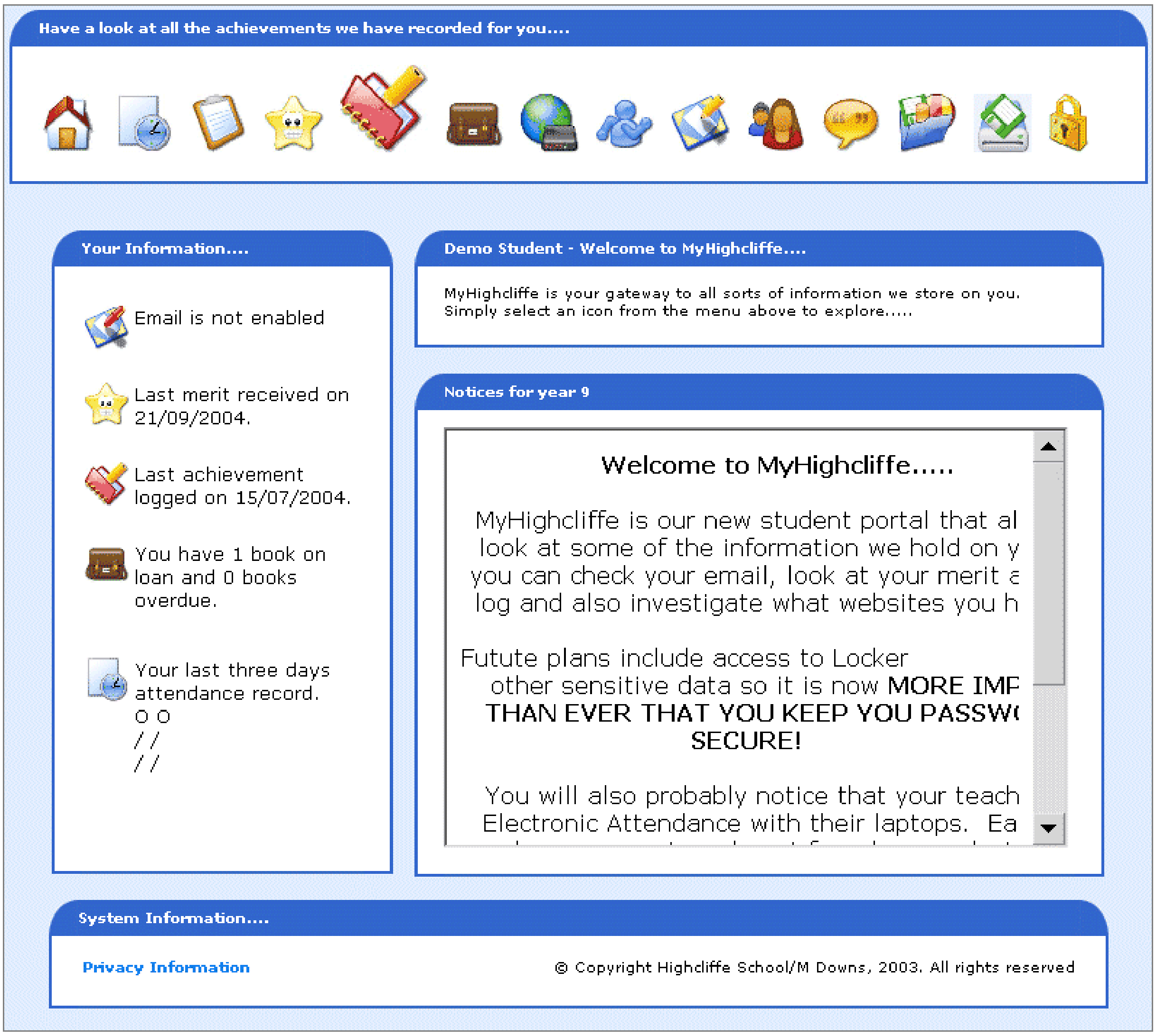

Fig. 21: Example of a LMS system

MyHighcliffe is a web portal that allows students and parents to keep track of progress while studying at Highcliffe School[12]. Accordingly to the authors of the portal, the system

[11] http://www.elearningawards.eun.org Retrieved 2004-12
[12] http://www.myhighcliffe.com Retrieved 2004-12

was born from a desire to involve students in their own learning and to know their own potential and present situation. The system allows controlling following issues depending on the role (student/parent):

- Attendance details
- Assessments
- Merit log
- Achievement log
- Library loans
- Website log
- Timetable
- School email account
- Personal activities/groups
- Personal statement
- School social activities tracking
- Intranet file management system
- Other personal information for school activities (e.g. locker code)
- Account settings

The CompEdu platform does not include majority of the items mentioned above. But all of them seem to play important role helping students managing their school activities. Thorough evaluation of the exemplary learning management system and adding the most important items from the list to CompEdu might increase its value considerably.

APPENDIX 2 Educational multimedia platform example

This lively educational platform from Universal Curriculum by Young Digital Poland SA[13] was developed for K-12 curriculum (educational levels served by the public school systems). The platform makes use of advanced multimedia to teach through interactive dialogue between a learner and a machine. The learning objects resemble a mixture of CompEdu quizzes and simulations, and therefore realizing the idea of learning by doing.

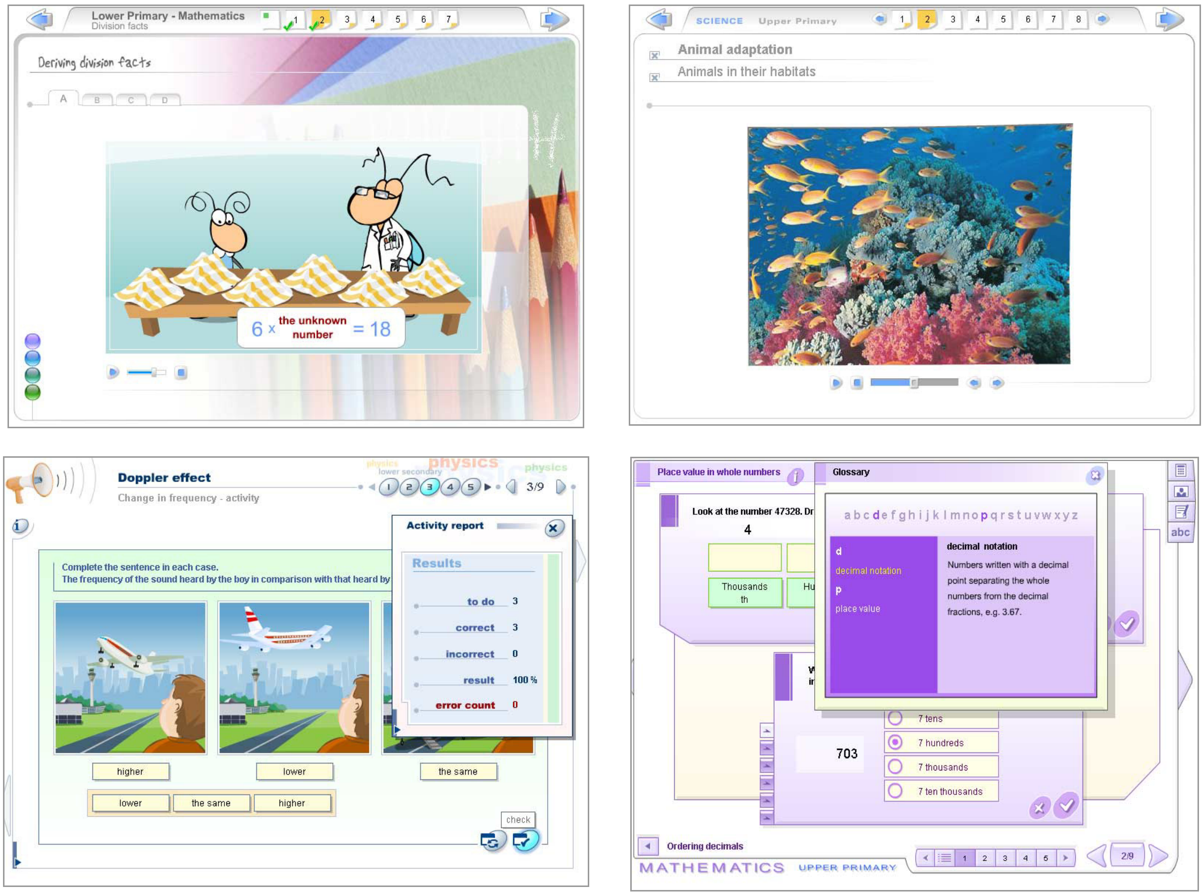

Fig. 22: Example of an interactive multimedia learning platform

The self-study materials are designed to support learning processes through:

- decision making, comparisons
- rich multimedia (interactive, sound, image, video)
- accessible web-based environment (Macromedia Flash)
- feedback (knowledge assessment)

Considerable part of the content is presented in the form of TV-like movies in the form of videos, narrated animations etc.

[13] http://www.universalcurriculum.com/universal/index.jsp?category=30 Retrieved 2004-12

APPENDIX 3 WebCompEdu vision

The document gives the outline of the learning platform extension program in years 2004-2005. This is an introductory concept document for specification preparation phase. Some parts of the document were removed or updated, because certain development steps had been accomplished to the date of the thesis finalizing.

Introduction

The goal of the CompEdu HPT platform is to transfer knowledge from more traditional media to the PC environment and allow for full use of multimedia and modern pedagogy in heat and power technology education. The CompEdu HPT platform was initially developed for collection, standardization and distribution of learning material in the field of heat and power technology.

Presently CompEdu is standalone software operating on separate computers. The platform can be also run in local networks inside companies or organizations. When speeds of Internet communication were limiting direct access of the platform elements like videos and simulations, the optimal way to distribute the learning package were the compact disks. Nowadays the Internet offers relatively high speeds of data transfer and there is an opportunity to offer CompEdu HPT as an Internet-based version. The CompEdu HPT development group has identified the chances and project initiation process is presently on. The project aims for creation of Web-based Computerized Educational Platform in Heat and Power Technology.

The transition from the standalone version to the Internet-based one will assure simplification of learning material distribution, promotion, content contribution and evaluation. The Internet-based CompEdu will allow distributing smaller learning objects independently of other ones for the purpose of personalization. Going to the Internet will make the platform more competitive towards other emerging knowledge repositories. The transformation might help to integrate CompEdu with a broader Semantic Web[14] model that allows data to be shared and reused across application, enterprise, and community boundaries. The transition from standalone version to Internet-based version will create an opportunity to spread the platform on non-Windows platforms, which become quite popular nowadays.

Currently the development group has been identifying the platform functionalities necessary and possible to be realized in the web-version. The group is also selecting server platform for the educational package. Additional resources and time will be needed to implement the vision. This includes programming of the platform framework and data

[14] Definition by W3C at http://www.w3.org/2001/sw/

conversion from the previous version. The works will also involve integration activities with other e-learning networks and probably search engines.

WebCompEdu vision

The basic CompEdu concept of existing chapter tree will be preserved. The changes will concern the form of content archiving, filtering and accessing. The main difference compared to the standalone version will be the capability to access it from any distance location. Additional value will be the possibility to introduce changes into CompEdu knowledge repository from distant locations. Previously existing limitations of access to the platform from local area networks will be overcome.

Software solutions existing in the standalone version will not be directly reused in the web version. This will not concern standalone simulations and other similar elements existing in the previous version. But in general the web version will be a completely new product from software point of view. The content will remain the same with some improvements and corrections. Due to limitations of existing web tools certain interactivity functionalities will not be implemented in the prototype. But there will be a possibility to add them on a later development stage. After comparative analysis ASP.NET was selected as a web-technology for implementation of the LMS side of the e-learning platform. The content side will contain HTML/XHTML pages including some optional Java Script code. Navigation mechanism will be realized using Macromedia Flash technology in the beginning. In the later stage ASP.NET will be used for adding more flexibility.

Following the logic of distinguishing between content and its presentation form we are aiming for creating separate database of learning objects of relatively high granularity and a set of views on the database content. In the standalone CompEdu version one of the views is presently called Main Room. Another view is the chapter window. The distinguishing serves for easy management of content, when different presentation forms are needed. For example if a user would like to customize fonts or backgrounds, the deeper content structure will not be influenced. Or when an unusual sequence of chapter pages is necessary, the only change will concern the view structure, but not the content (separate pages in the database, for example). This is very similar to applying style sheets (CSS, XSL) to existing structured data elements (XML).

A basic content element will be the marked up text. The text will contain special tags corresponding to formatting in a chapter for visual presentation (headline1, headline 2, paragraph, bullet1, bullet2, etc). Some tags will indicate auxiliary information (comments, copyright statements). Other tags will indicate presence of incorporated multimedia content (image, video, audio) and their show-on-page format with links to the files and their preliminary presentation form in chapters. Certain tags will serve as hyperlinks to www-pages and pop-ups. Additional role of tags will be to identify key elements for search engines and for automatic table-of-contents generators. Special tags will define breaking a chapter on separate pages, if found feasible and useful.

Pop-ups, which are typical subpage elements in CompEdu, will have similar structure to the chapter pages. In a different approach they could be parts of chapter marked-up text unit. The main difference between chapters and pop-ups will be the visual form and limited popup navigation functionality.

Chapter content production and marking up with the tags described above will be done using a well known and commonly used text editor, probably the MS Word.

Multimedia content elements (images, videos, simulations, etc) will have metadata descriptions. The metadata will have simple XML structure for easy search and filtering by tags. The descriptions will contain extended picture names, information about copyrights, owners, keywords, chapter/page names where the pictures were used before and some other information. Location of the metadata tags in the content database will be defined.

Five database blocks will constitute the content source:

1. Marked-up text chapter and pop-up elements.
2. Multimedia files.
3. ID and link net descriptor.
4. View formatting descriptor (chapter outlook).
5. View navigation descriptor (outlook of tree structures of shelves and books etc).

In the standalone CompEdu version there were two main content access mechanisms: 1) Main Room, 2) Browser. In the CompEduWeb version they will be just clients accessing the Content Database on common rights. The idea behind this is to make it possible to access the content database from any other platform or any possible client with only limitations by access and modification rights. For example Personal Learning Portfolios[15] or the Prolearn Competence Centre[16] will have possibility to mine certain parts of CompEdu content database. Some part of database information will be available for global search engines, so that CompEdu resources could be easily located and promoted.

The range of operations possible for CompEduWeb users will correspond to predefined roles. The roles will reflect user's access rights, security settings and place in general hierarchy (students, teachers, groups, administrators, editors, reviewers etc).

The personalization mechanisms will enable personal settings, tracing of individual activities and teaching/learning results. The personalization will help to gather and process statistical data on usage frequency and typical information search paths. Personalization will

[15] http://kmr.nada.kth.se/proj/folio.html
[16] http://www.prolearn-online.com

allow for creation of own views/filters of the content database elements, for example setting up individual page sequences by a teacher or putting structured bookmarks for further study of selected fragments by students. The browsing tracing will be based on recording of activated content elements (pages or pop-ups, for example). Personalization for users will incorporate registration of time and resource access paths. This will help to optimize certain frequently used resources for faster access. This will also give clear view about the most successful resources and indication for efficient development directions.

It often happens that a student reading text doesn’t understand certain words, sentences or whole paragraphs. In the CompEdu presently there is Glossary, where many definitions are collected, but if they are not, there is no explicit tool to add a new definition to the glossary or a new pop-up. In the CompEduWeb such tool could be added. It would work similar to mechanisms for content extension in the Wikipedia, for example[17]. A good solution could be automatic informing a teacher about a problem with understanding of certain word/sentence by sending a “request for a broader explanation”. The message in such a case could be also sent to the CompEdu discussion forum, so that other students could answer the question.

New simulations will support extended work in groups, when each person sits at a different computer. It will use the same principles as the ones used in Internet-based group games. Such simulations will assure that everyone is actively involved.

Main content elements will have unique IDs. If an element is totally removed from a database the name will not be reused to make sure there will not be any problems with reference links in the future. Accordingly to the description above chapters will be identified by unique ID numbers, which will not change ever (even if removed). For search purposes their extended names can be used. Position in the Main Room tree structure will be arbitrary with changes possible at any time. Hyperlinks from one chapter to another will relate to the unique chapter IDs. The same unique identification will concern pop-ups, images, videos etc. Since the content and tree representation will be two separate things, the unique identification of objects will make any changes of catalogue structure possible without causing any collisions in linking. But, there will be probably links related to elements of tree structure.

[17] It might be interesting to look at the definition of Aeroelasticity at http://en.wikipedia.org/wiki/Aeroelasticity

APPENDIX 4 CompEdu evaluation questionnaire summary results

Questionnaire set I

This set was given to 94 students. They were asked to mark one answer in each question. Nevertheless some of them selected more than one. Some of them did not choose any. The exceptions caused minor discrepancies in the final sums, which did not influence general trends.

Question	Answer	Total
From your life experience the main thing in preparation to exams is:	home work with books/scripts/exercises	**70**
	attending lectures	**13**
	attending exercises	**9**
What proportion of lectures in your life was worth attending?	0-20%	**5**
	21-40%	**8**
	41-60%	**28**
	61-80%	**38**
	81-100%	**16**
Do you have enough personal contact with your teachers in the SPG/RET course?	yes	**50**
	no	**45**
Do you learn a lot from your colleagues for your courses in general?	yes	**52**
	no	**42**
What is more important in the Internet from the two?	amount of information	**47**
	easy search	**47**

Quizzes in the SPG/RET courses are:	valuable for learning	**60**
	not valuable	**24**
CompEdu for learning is:	very useful	**47**
	so so	**45**
Do you think CompEdu helps to go through learning material at home after lectures?	yes	**77**
	no	**16**
In CompEdu there is a possibility to track points in quizzes and calculation exercises for self-control. This option is:	useful	**48**
	not useful	**21**
	I didn't know about the possibility!	**23**
Is the "Educational Objectives" page in CompEdu chapters useful for you?	yes	**56**
	no	**18**
	I haven't noticed the Objectives	**18**
There are simulations in CompEdu, did you find them valuable for your learning?	yes	**43**
	no	**20**
	I didn't try them	**30**
Is CompEdu good as an example of software?	it is good	**73**
	not really	**18**
Have you ever used the Glossary in CompEdu?	yes, many times	**20**
	no or once/twice	**73**

Do you use the Print option in CompEdu?	yes	**48**
	no	**46**
Is it good when lecturers use CompEdu for lecturing?	yes	**55**
	no	**38**
Is navigation in CompEdu relatively easy and intuitive?	yes	**74**
	no	**20**
Do you want to use the sound/media recordings of lectures we made in the SPG and RET courses?	very much	**36**
	not very much or not at all	**49**
	which recordings???	**8**
Do you like the idea of popping up windows when clicking on underlined words in CompEdu?	yes	**82**
	no	**11**
The scientific value of material presented in CompEdu for the SPG/RET courses is:	high	**51**
	moderate or low	**44**
The value of CompEdu for your learning is:	high	**49**
	moderate or low	**45**
How many times have you used CompEdu for learning?	5 or more times	**72**
	2-4 times	**21**
	once or not at all	**1**

Questionnaire set II

This set was given to 91 students. 57 of the students had filled the Questionnaire set I two months before filling set II. Those 57 students did not have to answer some questions repeated in the new questionnaire again. Students were asked to select only one answer to each question with one exception. If some of students chose more than one answer the points were counted as fractions of unity. This explains why some sums are not integer.

Question	Answer	Total
Do you think using CompEdu improved your learning efficiency compared to traditional way of learning?	Improved a lot	**6**
	Somewhat improved	**39**
	There is no difference	**25**
	Made it worse	**20**
Do you like when lecturers use power-point slides in their lectures?	Yes	**38**
	Probably yes	**24**
	Probably no	**14**
	No	**14**
In a good quality learning material more important for you is:	Optimal amount of information	**18.5**
	Clear and logical structure	**67.5**
When working with CompEdu you prefer:	to read from the computer screen	**39**
	to print and read from paper	**49**
You prefer when lecturers use:	CompEdu	**23**
	Power-Point presentations	**58**
You prefer to learn from materials, which have:	linear structure (page by page, like a book)	**60**
	tree structure (pages with linked pop-up windows, like in CompEdu)	**27**

Quality of pictures in CompEdu is:	Very good	**9**
	Good	**43**
	Acceptable	**29**
	Bad	**9**
In general you prefer to learn using:	paper materials (e.g. books, handouts)	**73.5**
	digital materials (e.g. web pages, pdf-files, CompEdu)	**17.5**
Please select features of CompEdu that you did not use:	other logins/passwords than "guest"	**41**
	red phone	**66**
	glossary	**26**
	gallery	**41**
	quizzes	**41**
	database	**39**
	browser	**31**
	print	**25**
	search in the browser	**43**
	slide show autoplay	**45**
	chapter history list	**37**
	bookmarks	**48**
	option of taking notes	**56**
	calculation exercises	**35**
	Introduction to CompEdu chapter	**28**
	lecture notes	**15**
	simulations	**14**
Do you like CompEdu program in general?	Yes, very much	**5**
	Yes	**34**
	It is acceptable	**34**
	No	**15**

There are simulations in CompEdu, did you find them valuable for your learning?	yes	**22**
	no	**2**
	I didn't try them	**10**
How many times have you used CompEdu for your learning?	5 times or more	**17**
	2-4 times	**13**
	1 time or not at all	**6**

APPENDIX 5 CompEdu review criteria[18]

Suggestions for the reviewer

After you have studied the chapter (including lecture notes, quizzes, calculation exercises etc.), and made a judgment, please complete the Reviewer's Form following the suggestions below.

A. Every chapter to be included in CompEdu HPT must be reviewed prior to introduction and re-evaluated regularly by competent specialists selected by the Editorial Board of the CompEdu HPT Group. The purpose of the review is to determine whether the chapter is acceptable for introduction, needs further revision, or should be rejected. Recommendations should be supported by specific and critical comments. Reviewing is a confidential process involving only the reviewer and the Editorial Board. Chapters, which went through the review process with positive result, will be introduced at the earliest possible time into the Platform.

B. Reviewing a CompEdu chapter is an intellectual process that includes both subjective and objective elements. The reviewer must be objective in the sense of eliminating any personal or corporate bias he may have toward the author, the author's organization or the subject matter. At the same time, the reviewer must evaluate the chapter in terms of his own experience and knowledge of a specialized technical field. This involves more than merely checking a list of possible impressions.

C. CompEdu editors gain a lot from informal statements expressing personal approach of a qualified specialist. Confidential comments are welcomed and should be included in the Review form or on an additional sheet, if required.

D. The CompEdu HPT Review form is designed to stimulate thought so that the reviewer can evaluate the merits of a chapter and fit this evaluation into recommendations conforming to educational practices of high technical quality.

E. If rejection is recommended, please keep in mind that you should set forth reasons for proper documentation and further contemplation of the rejection.

The following are the definitions of characteristics to be evaluated:

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[18] To a large degree based upon the ASME Review Form No. 1257 and Reviewer's Summary Form (version 98/99). The CompEdu project has obtained the right to include these review forms in the project from ASME.

Educational aspects of the review

- **Completeness:** Whether the chapter includes all-important aspects of the subject area.

- **Exactness:** The reliability of information provided.

- **Relevance:** whether the information provided is considered to be pertinent in the chapter.

- **Presentation simplicity:** This means that it is easy for a beginner unfamiliar with a topic to understand the presented material.

- **Clarity:** This aspect refers to the clarity of the information in text or schematics. It answers the question: Could a learner easily grasp the content? A good chapter should always remind the user about the key concepts needed to understand a chapter.

- **Proper structural organization:** Is the material organized in way that facilitates the understanding of the overall content of the chapter? A good chapter should evolve from easy to more advanced. It should always refer to previously explained knowledge in sort of spiral. Explanation in a chapter should follow organization logics, for example: problem description, problem solution and the summary.

- **Variation:** variation is related to maintaining student's interest and motivation throughout the chapter by varying text, pictures, animations etc.

- **Acknowledgment of the work of others by references**: The references should be both adequate in number and accurate in content. Such documentation shows the author's familiarity with the subject and also serves as an aid to the reader, who may desire to learn more of the subject being discussed.

- **Illustrative richness:** The biggest value in CompEdu HPT platform is static and dynamic illustrations to text explanations. The factor decides about fast and correct understanding of learning material. Illustrative richness concerns images, videos, animations and simulations.

Presentation aspects

- **Screen design**: This aspect concerns element placing on a page (text fields, pictures and diagrams). The learner should easily see every element on a page. The learner should not be distracted by the design.

- **Accessibility**: Are videos, simulations and other important elements easily accessible by the learner? An example of bad accessibility is showing a video or highly important information from a link placed in a popup.

- **Titles**: They should be brief and descriptive.

- **Symbols and units**: Symbol formats and units shall comply with definitions of the International System of Units (SI). The symbols being in use in formulas should be properly explained in the chapter.
- **Quality of illustrations**: Figures, drawings, graphs, photographs and other graphical objects should be of good quality (size, contrast, level of detail etc.). Graphs should be free of not essential elements.
- **Length**: Typical length of a chapter is 10-12 pages. Additional information should be presented in pop-ups.
- **Style**: The chapter should be well-written, complying to scientific literature standards and be easily understandable by students in relevant fields.

Definitions of quality ratings

The quality rating scale encompasses a range of evaluations from “not acceptable” to “honors” quality.

Honor: There are very few chapters whose characteristics will merit the rating of honors quality.

Acceptable for introduction: Chapters falling in this category are acceptable for introduction in the Platform or/and remain in it. No changes are necessary.

Acceptable for introduction with minor revisions: Minor changes must be performed before the chapter can be introduced into the Platform. No further reviewing is necessary after the changes have been introduced. The reviewer should provide a description of the suggested changes.

Acceptable for introduction with major revisions: Major changes must be performed before the chapter can be introduced into the Platform. New review will be necessary after introduction of the suggested changes. The reviewer should provide a description of the suggested changes.

Not acceptable: Unacceptable chapters are those having a superficial approach or superficially descriptive of widely accepted engineering practice.

Table 3: Quality matrix

	Poor	Marginal	Acceptable	Good	Honor
Comprehensiveness					
Exactness					
Relevance					
Presentation simplicity					
Clarity					

Proper structural organization					
Variation					
Acknowledgment of the work of others by references					
Illustrative richness					
Screen design					
Accessibility					
Titles					
Symbols and units					
Quality of illustrations					
Length					
Style					

Table 4: Recommendation for further action

Honor	
Acceptable for introduction	
Acceptable for introduction with minor revisions	
Acceptable for introduction with major revisions	
Not acceptable	

APPENDIX 6 List of publications associated with the dissertation

Navarathna, N.; Fedulov, V.; Martin, A.; Fransson T. H.: 2003

"Design of a Remotely-Controlled Laboratory Exercise in Aerodynamics"

J. Mekanisten (Svenska Mekanisters Riksförening), No. 2, p.58, 2003

Navarathna, N.; Fedulov, V.; Martin, A.; Fransson T. H.: 2004

"Web-Based, Interactive Laboratory Experiment in Turbomachine Aerodynamics"

Proceedings of ASME Turbo Expo 2004, 14-17 June, 2004, Vienna, Austria

Salomón, M.; Fransson, T. H.; Fedulov, V.: 2004

"Interactive Teaching and Learning Platform in Energy Technology"

CAL-laborate Vol. 12 November 2004, UniServe Science, University of Sydney