ABSTRACT
An interactive learning platform which sets a new standard for electronic learning of gas turbine technology in a global life-long learning perspective is presented (Fig. 1). The platform contains a theoretical section in the form of several pages for each chapter available, with a significant number of related interactive simulations, movies, animations, virtual laboratory exercises, virtual study visits and realistic case studies. A significant background information related to historical development in the field, a display of existing components, nomenclature, multi-lingual dictionary and keywords, as well as questions for self-assessment and exams, an electronic communication group and a database of the user’s “successes and failures”, enhance the learning process in a significant way.

The program is intended as a platform for an international collaboration on learning heat and power technology. It can be used both in the classroom as well as for self-studies and is as such well adapted for both university and post-university learning, both on and off campus. Tools to facilitate the introduction of new material exist. It is thus hoped that teachers at different universities can join forces in a non-competitive way introduce material which can be shared, instead of developing similar simulations with somewhat different interfaces.

The long-term goal of the learning platform is of course that users worldwide will have the possibility to access the best teaching material available from any specialist, and that this material will contain supplementary pedagogical information which will enhance the learning both at a university and a post-university level.

INTRODUCTION AND OBJECTIVES
The classroom is at many universities today almost like it was in the beginning of the 20th century. The teaching is often done the same way and the students are supposed to learn the same way, although much more material is today presented to them. Of course, some technical issues have been changed with the appearance of the slide projectors for photos and overhead slides, as well as with movie- and video-projectors and with computers. Teachers often enhance the teaching with illustrations using these media, and then the students are expected to grasp the full implications of the shown material immediately, as they do not have the possibility to repeat the
experience at their own learning speed (mostly while studying for the exam!). Similar with laboratory exercises and study visits. These very often pass by the students as a nice but not very exciting experience in which the students often copy material from colleagues to get it over with as soon as possible. All these various teaching environments are of course essential and good, and enhance the teaching to a large extent, but the learning aspects are usually much less improved. An important aspect is that the “learning by repetition” can not be achieved as the students often only see some highly interesting material once.

Since the personal computer entered into the university environment in the early 1980’s, teachers with futuristic views have tried to use this technology as part of their teaching/learning material. Other teachers have totally avoided this new media. The limited experience available related to the use of computers in teaching technical subjects at a university level has shown that the students have probably not learned more than in the classical way. As a matter of fact, the experience of using computers in the classroom has often been fairly frustrating for the teacher as they spend a lot of time in preparing the material, which the students thereafter do not use and, moreover, do not at all appreciate the significance of. The fact that most classrooms are not equipped for teaching with the aid of computers is certainly another contributing factor to the many failures in “electronic learning”.

The classical textbook on basic engineering subjects should be considered from a similar perspective as the classroom: it looks almost the same as it did in the beginning of the 20th century. Of course, many more textbooks exist today, covering the scientific and technical progress (but are all much better?) and the most recent books present a limited number of computer simulations in electronic form. The textbook is of course an essential material in the learning process, but it is today possible to enhance this learning with animations, simulations, movies, virtual laboratory exercises, case studies, etc. in a way which greatly surpasses what any printed textbook can offer. Perhaps the time has come when electronic material should be the basis for the learning process, and the printed textbook the appended material?

The main objective of the model presented is to, for the first time in turbomachine related teaching, establish a comprehensive combined learning and teaching tool which from the start has been established as fully electronic, such that it covers all the necessary aspects which are perceived to belong to learning in a modern environment. The secondary objective is to present a tool which can be used as an international platform for a global learning space, in which teachers from different universities work together with the goal to in a common way enhance learning for students anywhere in the world: a tool to be used any time and any place.

GENERAL LAYOUT OF THE PLATFORM

Several computerized simulations have been developed for classroom use over the last 20 years in the field of gas turbine technology. Among the most recent ones can be mentioned Benson et al. (1995, 1997, 1998), Bölcs (1990), Mattingly (1999). An excellent calculation program which can be recommended also for teaching purposes is developed by Kurzke (1998). A first preliminary attempt of a universal educational platform was presented by Léotard et al. (1995, 1997, 1998). Many computer programs for research have derivatives that the researcher has transformed into teaching material. Each one of these attempts is generally good and brings home a specific message to the students. Because of the large cost involved in developing electronic course material, individual efforts have however often been concentrated on isolated spin-off simulations from research topics, and entered into the “classical” teaching material as an attachment. In most cases the students have not been as enthusiastic about the added teaching value as the researcher, and their learning has not been enhanced the way the teacher might have imagined. As far as the present authors are aware the here presented platform is however the first electronic attempt to more completely cover the material a student would use during the learning process of heat and power technology.

This platform collects the theory for courses in the form of overhead pages (which can be used both for lectures and self-studies), interactive simulations, virtual laboratory exercises, virtual study visits, and selected case studies. Additional information is provided by a toolbar, and classical “lecture notes” are as well included (to be read on the screen or printed). Of course, access to vast stores of information by itself does not guarantee broad educational benefits, as pointed out by Boyle (1997). As a matter of fact, the role of computer software is to create an effective environment for learning. Therefore particular attention has been paid to structure the information aiming at more coherence and to enhance interactivity. Firstly, the complete material is organized as a “bookcase” (Fig. 1): a shelf gathers the information about a general subject, which is divided into books, which are divided into chapters (Fig. 1 and 2). Secondly, according to Laurillard’s (1993) advice, all the 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. The main text is limited to keywords or short sentences, but a lot of supplementary information is available as “pop-up” by clicking on underlined blue words (Fig. 3). The student who attended the lecture will benefit from this synthetic presentation but, of course, the one who did not may sometimes have trouble in understanding the points. Therefore such students will enjoy an automatic mode to follow vocal explanations by a guide. This feature is both practical (easy to use, speedily illuminating) and attractive to learners for its efficiency and its motivating ‘human touch’.

The simulations are the next appealing aspect of the platform. They enable the learners to familiarize themselves with the topic and highlight the key parameters as well as their influence (Fig. 4). Moreover, in each of these simulations, a “guide” gives advice to the students of how to use the simulation in the most effective way. This guide “simulates” the teacher during the student's home studies, but is not intended to ever replace the interaction with the teacher during normal lectures. Yet, the simulations are flexible enough to let any teacher illustrate their main interest. These simulations constitute a second way to learn, based on discovery and experience and then, as such, are another major asset of the platform.

Besides, deeming the inviable ergonomics of a book, the programming tries to enhance the freedom of the user. The bookcase enables to flip through the whole material as the topic of each chapter is automatically displayed on the “white board” (Fig. 1). The contents of each chapter are also available. The user can take notes, bookmark pages as he or she bookmarks web pages and go back to any previous page. Teachers can pre-select pages for their own individual lectures (Fig 5). As such it is possible to use other media to present the basic background (blackboard, overhead projector…) and directly jump back and forth with the pre-selected material from the platform. A browser gives a complete view of all the detailed “pages” and enables to reach any one in a very easy way (Fig. 6). These various tools are designed to meet the different needs of teachers and students. Even a teacher who does not want to use the existing theoretical section is still able to navigate easily and employ the more advanced learning tools available.
Fig. 2: Typical page from the chapter "Introduction to Turbomachines".

Fig. 3: The underlined blue words, "pop-up", provide further information.

Fig. 4: Simulation of “Combined Cycle Power Production and District Heating”. The guide is seen in the bottom right corner.

Fig. 5: Teachers can pick up the elements they want for their lecture by pre-selecting their pages.

Fig. 6: The browser is one of the several navigation tools in the platform, it enables to reach any page.

Fig. 7: Snapshot of the historical content
As courses do not make up the whole material by themselves, the authors want to broaden the education to the history of the related fields as well as to specific knowledge of technical choices for the design of today’s machines. These are part of other significant utilities presented in the form of a “toolbar” at the bottom of the screen (Fig. 7). The historical section gives the main tendencies, in a fairly detailed way, of the turbomachinery development (Fig. 7), as well as an indication to scientists and engineers who have made significant contributions to the field. A gallery gives a significant amount of sketches and photos of different gas turbines, steam turbines and boilers, together with detailed facts related to the scale of the machine, pressure ratio, temperature, number of stages etc. (Figs. 8, 9). This kind of information is of interest to anyone who tries to learn differences between machines, or just want to get a general overview of existing components.

A glossary is introduced to solve comprehension issues related to terminology. It proposes a list of keywords to find the exact definition of most terms used inside the platform (Fig 10), a list of all symbols employed, a list of the units employed throughout the program. Finally, the students who do not have English as mother tongue will enjoy a multi-language dictionary translating specific engineering terms into German, French, Italian and Swedish (Fig. 11). A search engine allows the user to click on many terms and be directed to the page where the subject is treated more in detail.

In any classical textbook the exercises available play a significant role in the student’s learning process. Books often state a problem and then possibly the final answer, and leave the student completely in the dark about how to solve the problem. In the present platform the approach is to specify the problem in a similar way as in a classical textbook, but then to allow the students to “buy hints” from a “guide” about how to solve it. A score of 1–10 points (depending on the complexity of the problem) is obtained in the case the student solves the complete problem, without any help, by clicking on the correct multi-choice answer. Along the way 1–10 “hints” can be bought. For each help bought, the student’s final score for this exercise is reduced by 1 (or more) point(s).

As the main goal for several students during their studies seem to be “pass the exam”, a self-assessment quiz has been added (Fig. 12). This allows the student to check the personal progress and easily to go back to the material which has perhaps not been assimilated as well as it should. The questions are of a multiple-choice character with up to 7 possible answers to reduce the chance of getting a good score by random guessing to less than 15%. Five questions are presented in each quiz session, selected from 5 different categories, and both the questions and the answers are presented randomly, giving a large number (≈5*7) of variations even if exactly the same 5 questions would be used more than once. With a growing number of questions in each chapter, it will be possible to use these same questions also as exam questions. As a supplement to the quiz a database, which keeps track on what the student has looked at and achieved, is present (Fig. 13). It gives the student the total score achieved throughout the learning process. This database can also, if wished, be used by the teacher as a mean to follow-up on the progress of an individual student. Each quiz-question has a certain score to it (as with the classical exercises discussed above), and an electronic scoreboard is available in which the students can continuously compare their score against each other.

The individual teacher has a possibility to establish own quiz-questions with the “quiz-creator”. The so established questions will override, or complement, the original questions in the platform. In such a way, by means of this tool and the “page selector” (Fig. 5), the students will primarily follow the teacher’s material and only use the platform as a secondary learning source.

The use of the World Wide Web has recently been introduced into the platform. Before the first lecture, the students must answer a prerequisite test in the form of ten multiple-choice questions on the program web page. This preliminary examination aims at targeting the right level of teaching. In the future, these tests will be part of the CD-ROM and access to a chapter will require good results to the corresponding test. Besides, an electronic group has been established to facilitate communication between and among teachers and students at the same or different universities. The teacher can provide additional material to the whole group or set important dates. The student who has problems somewhere can ask for help from the other persons, and not get into disarray. It also has a social purpose since the person who answers becomes an adviser. If necessary students can ask a teacher but in the developers’ vision, they must first look by themselves. A “Frequently Asked Questions” database will be available for all the students: everyone will be able to profit from the experience of the others. Private companies have the possibility to introduce company proprietary material. These will not be part of the global platform and will need specific user names and passwords.

**SPECIFIC TECHNICAL CONTENT OF THE PLATFORM PRESENTLY**

The platform is in no way intended to leave the impression of being complete at the present time, although there is already a significant amount of material included. It is instead thought of as a start for joint educational collaboration in the field of heat and power technology, with the aim that teachers world-wide will add material which they consider to be good and unique. In such a way the content will be extended over the next few years. Presently the main emphasis has been put on the following courses (or “book-shelves”):

- Heat and power cycles
- Turbomachinery
- Combustion
- Measuring techniques
- Aeroelasticity

with the upper shelf (Fig. 1) giving supporting material of various kind, among these specifically the “Projects-of-the-year”. These latter rely on the concept of “Project Based Learning”: the students have to, as a team, complete a one-academic-year long project. They learn by themselves, while being supervised by a “Design Review Team” consisting of professors and engineers, the traditional matters through the project difficulties (Svensdotter and Fransson, 2000). The intent is that students from different universities in the future will work together on such projects as multi-national teams.

The **project of the year shelf** collects the reports of previous “project of the year” studies, which keep track of the progress and the motivation for choices at each milestone. The 98/99 KTH students had to design a power plant (Svensdotter and Fransson, 2000), and the 99/00 students will thus find inside the platform the technical specifications, the process overview, the feasibility study, the layout and general design, the component design and finally the commissioning of this plant. It is believed that the students will benefit from the experience of their predecessors when they will work on their own “Project of the Year”.

The content of the **heat and power cycle shelf** gives the students a basic repetition of thermodynamic cycles, and concentrates thereafter on various steam and gas turbine cycles, covering the basic Rankine
Fig. 8: Example of overall information contained in the "Gallery"

Fig. 9: Detailed information indicates the key parameters

Fig. 10: The glossary defined keywords, relying heavily on illustration and referring to books and articles

Fig. 11: Glossary: multi-language dictionary

Fig. 12: Quiz for self-assessment, the correct answer is encircled in red and the score is stored in the database

Fig. 13: The database collects the results to the quiz and classical exercises for both the students and the teacher. These results are compared by the platform-developers to the time spent in order to improve the material
Fig. 14: Simulation of a real "turbofan with afterburner and duct burner".

Fig. 15: One of the simulations related to the velocity triangles.

Fig. 16: Virtual laboratory exercise on "Laminar Flames Length".

Fig. 17: Virtual laboratory exercise on "Schlieren Visualization".

Fig. 18: Animation explaining compressor surge.

Fig. 19: Simulation on the force phase angle of the unsteady flow on a vibrating blade.
and Brayton cycles. Passing by aspects like regenerating, intercooling, reheat as well as the combined gas and steam cycle (Fig. 4), the steam injected gas turbine and more advanced cycles like the Humid Air Turbine, Kalina cycle and Air Bottoming Cycle, as well as some propulsion cycles, are described to the students, illustrated with information from some existing power plants, together with a significant number of interactive simulations. In some chapters a spoken text is introduced into the program, again with the idea to enhance the student's learning capabilities during the off-campus studies. As part of the propulsion cycles, simulations related to the ramjet as well as the turbofan, turboprop, and turbojet (all with/without afterburner) cycles can be employed (Fig. 14). On this shelf, as well as on the others, the detailed material is not yet complete, but it is still believed to be of such quality that it will be a significant positive added value to courses in the field at most universities.

On the turbomachinery shelf the user is introduced to the components of a gas and steam turbine, the definitions of the fundamental equations, the two-dimensional velocity triangles, design parameters and cascade flow. Several simulations (see Fig. 15) and animations are available inside this shelf. As there is not yet any discussion related to the three-dimensional flow in this part of the platform, this shelf can be considered to represent an introductory one-semester turbomachinery course.

The combustion shelf is presently very basic and covers only an introduction to general combustion as well as a “virtual laboratory exercise” dealing with laminar flame lengths (Fig. 16). These “virtual laboratory exercises” are intended as a pre-laboratory experience for the students to prepare themselves for a more effective “real” hands-on laboratory exercise, and serve also as an extremely useful tool for the students when they prepare themselves for the exam.

On the measuring techniques shelf a few experimental techniques of relevance to turbomachinery are introduced. First of all the students are given background material to how to perform an experiment, and thereafter material related to pressure, velocity, mass flow and temperature measurements are presented, along with some basic visualization techniques. Both theoretical aspects as well as some “virtual laboratory exercises” (see Fig. 17 for an example) are present. For this shelf complete lecture notes (both in English and French) in a written form exist so that the user can study these on the monitor, or print them out for more “classical” reading.

The aerelasticity in turbomachines shelf is today the last information available. It covers presently a very detailed introduction to the field as well as detailed terminology and nomenclature. There are several animations and simulations present, each covering some essential features for a physical understanding of the phenomena (for examples, see Figs. 18, 19). As for the measuring techniques shelf, written lecture notes are included.

With the content on these five shelves it is believed that the curriculum at most universities who teach the subject of Heat and Power Technology or Air-breathing Propulsion will find something useful inside the platform. Of course, it will not be possible (and is not the intention) for one university to completely fill such a broad field. It is instead hoped that the present content can give a flavor of what is possible with today’s electronic means, and that a joint collaboration in the future will allow for an increase of material, as well as for an improvement of the existing parts, with the objective to increase the users’ learning speed and understanding depth.

TEACHERS’ CONCERN: “WHY SHOULD THIS ELECTRONIC LEARNING TOOL SUCCEED AS MANY OTHERS HAVE FAILED?”

Any kind of change from the traditional educational way is, rightly, treated with a large degree of skepticism; many attempts have been made aiming for significant improvements, with a few successes and many failures. Thus many concerns of various importance have been expressed during the development of the proposed teaching and learning platform. A few of these will be mentioned in this section, together with some ideas of why the present platform can be considered to be more adapted to “electronic learning” than previous attempts in similar directions, and why an “electronic learning” platform can enhance the learning process.

Tried it before and it did not work:

Many attempts towards using computers in education have been performed over the last 10-20 years. Almost all have failed as the students have not been as enthusiastic as the researcher/teacher was. The main reason for this lack of enthusiasm from the students can, the present authors believe, probably be attributed to the fact that the students are very goal-oriented in their studies. However, often this goal (=pass the exam) is not the same as the teacher’s goal (=learn the subject as well as possible). In almost all attempts the present authors have seen related to computerized education the emphasis has been put on a specific simulation/calculation the students should perform. The basic connection to the underlying theory and, more specifically, to the exam, has been missing. The present platform is established to connect all the essential ingredients into a linked package so that the students see the connection between all the different parts of the curriculum and the knowledge to be obtained (i. e. how to pass the exam).

Not invented here:

This is a teacher, not a student, syndrome. The present authors believe that the basic reason why there are so many different textbooks in certain areas with only small differences is related to the fact that each teacher has his own individual way of presenting a specific material. A teacher might be happy with certain chapters in a specific book, but not with others. Individually written lecture notes are thus perceived as something essential, to a large degree as students cannot be expected (=refuse?) to collect material from several textbooks. Over the years small changes in the lecture material make the teacher to take the decision to go ahead and write a full textbook.

The remedy to this problem in the present platform is to realize that the main importance of the platform is not the way the theory is presented by the individual teacher. It is instead related to the physical understanding by interactive simulations, animations, movies, etc., as well as to the completeness of the lecture material, as prepared by many different teachers, in one volume. Each individual teacher can thus use their own theory for any specific chapter in the way he or she would like (as blackboard, overhead slides, lecture notes, etc.), and they may or may not choose to include this material in the platform or to distribute it to the students. Of course, if a teacher thinks that nothing inside the existing platform is of any interest whatsoever, the authors can only conclude that this teacher must have an excellent material available, and would hope that it can be made available to a larger audience immediately.
I want to use my own material:
No problem of course. Any teacher should use the own material as long as it is better than what is offered. The cost for developing a complete learning material will however prevent most teachers from developing anything better than what can be done in the form of a consortium. The "page-" and "quiz-creators" can be used to include own material in different ways. Easy jumps between any part of the platform to the teacher’s own PowerPoint (or other) files give an increased flexibility for the teacher to improve the lecture material.

"Many students do not speak English well enough" and "teachers want to preserve their own language".

The most important aspects of the platform are the simulations, the animations, and especially the pedagogical and other "added-value" links. It is believed that these in the long-term perspective will be of enough value to teachers and students to compensate for the lack of material in the students’ own language. Furthermore, although the material in the program is in English it is of course normal that the teacher during the lectures speaks the language that would be spoken without the existence of the proposed platform, and also that the teachers under certain circumstances may offer some material in the platform in another language than English (as an example, the lectures notes of several “books” on “The Measuring Techniques” are both in English and French). With the growing number of foreign exchange students at many universities worldwide it may actually be beneficial for many students to have some reference material also in English.

I like to browse the book:
This is a very important factor, and it can of course not be done on computer in the same relaxed way as with a traditional book. The platform tries to be flexible on this issue: first of all the navigation inside the platform is easy and user-friendly, and secondly all the material is offered also as a printed version, if anyone would select to use the material in such a way. Furthermore, printing utilities such that the user can print anything from the platform have been included.

I can bring the book everywhere
This is of course another important aspect. However, the present authors consider it highly likely that there, within a few years, will be “reading computers” of low weight and long battery life. The weight of a computer and the length of a “study-session” will thus probably not be of any concern in a few years, especially not as the students do not have to carry with them several kilos of books anymore.

It is difficult to concentrate as long on a computer as in a book
This is a very valid concern, which the present authors fully agree with. It is thus of high importance that any electronic learning tool will have a significant amount of diversification incorporated to avoid loss of concentration. Still, it is likely that a "learning session" will be shorter with electronic learning than in the case a classical textbook is used. Furthermore, one of the main reasons for the electronic learning is to reduce the learning time which then of course justify the shorter "learning sessions". In the present program the number of pages per chapter is limited to 10-15, with a significant amount of diversity inside each page.

Will this platform replace the teacher:
This is absolutely not the intent! However, it is hoped that through the fact that many persons are involved in the effort the material included will make it possible for an interaction teacher ↔ student on a higher intellectual level than what sometimes can be possible in the classical teaching environment. This may very well put a larger burden on teachers as more students may have more of the complicated questions that traditionally only a few exceptional students have come up with. But this must be regarded as a positive problem by any teacher!

All students everywhere shall not be presented with the same material
This is again a very valid argument which has to be addressed by individual teachers. The presented platform can serve as a base for a faster and more thorough learning of a significant amount of material, but it is also intended to arise the students’ intellectual curiosity. The student ↔ teacher interaction at a higher physical understanding level, as well as the fact that the material in the platform will be presented by several person (while still in a similar framework), will thus be the main catalyst for the students “out-of-the-box-futuristic” thinking.

Will this platform replace the book:
Again, this is absolutely not the intent! However, it could very well be imagined that a material as presented in the platform in the future will reduce the number of similar undergraduate (and beginning graduate) textbooks on an identical subject. There will also in the foreseeable future still be a large need for high-level textbooks on special scientific topics. But today’s emphasize on “printed book with accompanying electronic simulations” will probably be changed towards “electronic simulations with accompanying printed material”?-

How can the student take more serious notes than just text:
As in the classical learning environment, any student or teacher can make notes on paper and keep or submit these to the teachers. In the present platform, there is a possibility to write in plain text as comments but there is not yet a way to make personalized comments in electronic graphical form inside the “notes”-package. However, when more computers will have received touch-screens for writing such an option can without problem be introduced.

It is not possible to assess the students knowledge with computerized multiple-choice exams:
This is a concern for many teachers, as they consider multiple-choice questions to be much too simplistic. It is true that a computerized exam with multiple choice questions can not replace an oral exam, with the student/teacher interaction. However, the present authors maintain that most written exam questions can be replaced by electronic multiple-choice questions, without the fear that the student can pass the exam by just guessing. Guessing can of course never be excluded but with 7 possible answers and a negative score for wrong answers the probability of successfully passing the exam in this way becomes very low. The other fear is of course that the students can pass the exam by solving the problems correctly but without acquiring the fundamental physical understanding of the material which the teacher intended. This concern has to be taken care of by sophisticated multiple-choice questions. Such pedagogical tools are already common in various exam forms.
A teacher would like to use his own exam-questions as the emphasize on the lecture material from various teachers are different:

This is of course no problem. The platform is conceived such that new quizzes can easily be added, and that individual questions can override the ones presently in the platform. It is however believed, and hoped, that most teachers would not have anything against that their students also test the knowledge against questions established by other teachers. This can nothing but improve the student’s understanding. Furthermore, if a certain number of teachers would like to eliminate certain questions from the platform this will of course also be possible. In general new questions from different teachers will however probably be added instead and thus enhance the value of the platform.

Why should the student use this program as they still need a textbook:

The need for a textbook will depend on the teacher and the specific chapters. Presently there are lecture notes of, it is believed, sufficient quality in some chapters, and these can be printed by the students if they so would like. As time goes on it is hoped that different teachers would work together to establish a common text for each individual chapter which many instructors would be comfortable with. Of course, every time a teacher would have a new text, this can be put into the program so that students can have access to it. It is thus without problem possible to have several complete, but somewhat different, textbooks for a specific chapter available inside the platform if this would be necessary! It is however rather probable that most teachers would like to make only minor adjustments to a common text. The advantage would be that the teachers could still use the chapters from the “electronic platform” which they would be comfortable with, and could thus concentrate upon improving certain chapters instead of writing a full textbook. With this system the total cost for the lecture material would, in a fairly short time perspective, be reduced for the student, as all the material needed for basic studies of Heat & Power Technology would be directly available from the platform.

There is too much material in the program. The students will be overwhelmed:

The classical approach for most teachers is to guide the student through the material which should be covered during a specific course by indicating which pages should be read in which chapter in which book, which pages are for learning and which are for browsing, etc. This procedure is exactly the same in the present “electronic platform”. The teacher will in an individually prepared accompanying information indicate to the students which parts of the platform are of highest interest for this teacher’s specific course. Furthermore, a teacher can of course select to present the different subjects in separate “platforms” (i. e. in different “bookcases”), although some of the advantages with a common platform for the entire subject of Heat and Power Technology would then be lost.

The students should not get everything served inside one book. They should learn to find material at other places:

This is of course also a very valid comment. The reason why there are so many textbooks with similar basic engineering material is however as the lower classes of undergraduate students generally do not accept to receive materials from different sources (different notations, high costs...). For these students there would be no change in the working habits. For the senior years the only change is that the students have a significant larger amount of material available in the “electronic book” than in a “classical textbook”, but it is in no way perceived that all the material a students would need to solve a real-life problem will be present in the “e-book”. There will thus not be any significant change in the student’s working habit with the appearance of “electronic books”.

All students do not have access to an appropriate computer at home:

As seen from the preliminary evaluation discussed below, this fact was some sort of surprise to the authors since KTH had made some deliberate efforts a few years ago to allow students to acquire home-computers inexpensively. Yet it is believed that, as time goes on, less and less students will be in this situation. Otherwise the student will have to study the material on the campus computers, much the way that most students today not buy all textbooks but instead go to the library to study these.

Difficult to communicate among teachers at different universities:

The initiator of the platform dares to put forward the statement that there unfortunately in a “normal” teaching environment is hardly any exchange between teachers at different universities! Any kind of collaboration would thus be a progress. In the platform the following electronic communication groups are offered:

• Students and teachers discussing technical aspects of the platform
• Students and teachers discussing the solution to specific problems in the platform
• “Frequently-asked-questions”-group which anyone can consult
• Students sending individual comments to the platform developers
• Teachers sending individual comments to the platform developers

In the two last cases the caretaker of the discussion groups will judge if the comment is of such a general interest that it should be added to the “frequently asked questions”-group.

Virtual laboratory exercises and study visits can never replace a “hands-on” experiment:

Of course, this is not the purpose. However, a virtual exercise or study visit will allow the students to better prepare themselves beforehand, and will also allow a detailed repetition of the material afterwards. The learning process of the student will thus be improved.

PRELIMINARY ASSESSMENT

It is not expected that neither teachers nor students will embrace the presented platform fast or fully. It is of course recognized that detailed assessments have to be performed related to both the way the user perceives the technical issues of the platform as well as, more importantly, how the students learning process is improved with the tool.

Various preliminary versions of the platform have been employed in a course in the teaching at KTH for the last three years. During this time both the platform interface and the course material has evolved. It is however still important to note that only about 10-15% of the teaching material in the Division of Heat and Power Technology (which covers about 400 hours in total) is presently imported into the platform. The first year the tool was only used as a teaching tool (i. e. by the teachers) in the third year (of a 4 year curriculum). It was perceived that the students had better assimilated the material related to velocity triangles than previous years. The second year the platform was made available to students in the form of a CDROM as well as on the local network at KTH, but ridiculous technical problems appeared
(there were no CDROM-readers in the PC-rooms at KTH, and the students did not have access to the network on which the program was installed)! Before these problems were solved more than half of the quarter was gone, and the assessment by the students was (rightly) very critical. The “lessons learned” was of course that in order to keep the students’ interest there can be absolutely no flaws in the access to the program! The third year an evaluation related to the ease of use of the software was performed and the students appreciation of the media showed a very high (70% and above) appreciation rate. However, not enough care had been put on the correlation between the exam questions and the material in the program, and as such a complete evaluation of the students knowledge could not be performed.

The program has also been used on a much smaller scale at universities in Finland, Switzerland and the USA. All the comments obtained from the colleagues at these universities have been worked into the platform.

The evaluation will continue during the academic year 1999/2000 in a more precise pedagogical, as well as technical, manner.

CONCLUSIONS

An electronic learning and teaching platform for the field of heat and power engineering is presented. It is believed to be the first complete electronic textbook in the field which covers the main essential ingredients in a modern educational environment, such as:

• presentation of the basic theory in an electronic, interactive form together with printed versions of the material in the classical form,
• “pop-up” for further very detailed information,
• interactive simulations with guided messages,
• movies and animations,
• virtual laboratory exercises,
• virtual study visits,
• case studies,
• polyvalent glossary,
• pre-requisite test in the web,
• electronic discussion groups,
• interactive exercises and exam questions.

This type of new electronic learning platform can hopefully serve as a base for a better teaching and learning environment in a global life-long education in the field of transforming chemically bound energy to heat and power in the future.

FUTURE WORK

The latest navigation and customization tools must be evaluated during the academic year 1999/2000. The comments will yield corrections.

Presently the information available in the platform is related to the thermo- and aero-dynamics of gas turbines. It would be highly appreciated to have collaboration in material science and in maintenance of machines in order to improve these aspects.

The platform is currently available to teachers for testing on a common CDROM. In the future, it is intended to make it available directly on Internet.

The core of the platform is more or less independent of the topic. It is scheduled to extract it in order to provide the background programming to the one who wish to develop a course on another topic.

ACKNOWLEDGEMENTS

The platform presented has been developed with funding partly from the Council of Renewable Education in Sweden (B. Jalling), together with the School of Mechanical and Material Engineering at KTH (Prof. M. Hansson), Birka Energi (J. Alsparre) and the Division of Heat and Power Technology. The ideas expressed are the authors alone and do not necessarily correspond to the ones of the sponsoring organizations. A significant number of undergraduate and graduate students at the KTH have been involved in the project. Their work is acknowledged in detail inside the program.

A special thanks goes also to the colleagues with whom the first author has discussed many pro’s and con’s of an electronic platform over the years.

REFERENCES

Benson, T.J.; 1995
“An Interactive Educational Tool for Turbojet Engines”
AIAA 95-3055

Benson, T.J.; Trefny, C.J.; Walker J.F.; 1997
“Interactive Design Tool for Turbine Based Combine Cycle Engines”
AIAA 97-3160

Benson, T.J.; 1998
“Using Computers in Fluids Engineering Education”
NASA TM-1998-208810

Boyle, T.; 1997
“Design for Multimedia Learning”

Bölcs, A.; 1990
Private Communication
EPF-Lausanne, Switzerland
ASME papers 1999

Kurzke, J.; 1998
“Gas Turbine Cycle Design Methodology: a Comparison of Parameter Variation with Numerical Optimization”
ASME Paper 98-GT-343

Laurillard; 1993
“Program Design Checklist for Making the most of the medium”
http://iet.open.ac.uk/h802/2/sup/DesignCheckList.html

Léotard, P.; Roy, S.; Gaulard F.; Fransson, T.H.; 1998
“Computerized Educational Program in Turbomachinery”
ASME Paper 98-GT-415

Mattingly, J.D.; 1999
“New Software to Support System Approach to Conceptual Design of Aircraft Engines”
AIAA 99-2849

Svensdotter, S.; Almkvist, P.; Fransson, T.; 2000
“Introduction of Project Based Learning for Designing a Heat and Power Plant into the Last Year Curriculum”
Accepted for the ASME/IGTI 2000