

Project-based learning under Computerised Education in Heat and Power Technology

Abstract

Introduction

The teaching in Heat and Power Technology world-wide (and in most other technical fields) is usually performed in a classical way in which students listen to some lectures and then solve some textbook problems. Some students also select a project of more applied nature, but these are usually fairly small and do not illustrate the complete course work during a full academic year. Mostly the students do not see the relevance of their studies to real engineering problems until after the end of the studies.

The Division of Heat and Power Technology (HPT) at KTH approach the problem of teaching the last-year undergraduate students the basic knowledge in Heat and Power Technology in a different way. The students and teachers are involved in a "role play" project during one academic year. A company has been founded which intends to construct a power plant for a specific purpose, and delegates the buyer's role to a consultant who in turn intends to have the students at HPT design the complete power plant during one academic year.

This project will be integrated inside the Computerised Educational Program currently developed at the Division (Fig. 1). This project started in 1996 and aims at developing an interactive platform for the teaching of Heat and Power Technology. A CD-ROM is available which offers a number of interactive simulations and multimedia presentations dealing with several fields related to Heat and Power. Inside this CD, the students will find the various reports and presentations made by the students who took the course the previous years (Fig. 2).

Fig. 1: main interface of the Computerised Educational Program developed at the Chair of Heat and Power Technology, KTH.

<http://www.egi.kth.se/compedu/>

Fig. 2: Presentation of the Project of Year 1999/2000 inside the Computerised Educational Program. <http://www.egi.kth.se/compedu/>

Educational Objective

The objective is that the students in an independent and engineering way shall

apply the acquired knowledge in the heat and power curriculum (and earlier courses) towards solving a real engineering problem of doing the basic design of a power plant, while working in a project-team. The students should learn how to, in an independent way as well as part of a team, find important and necessary information in textbooks, and other material outside of the known textbooks.

Course Organisation

The students are the persons performing the project. They select themselves the task-leaders for the various tasks that have to be performed. The task leaders are responsible for delivering certain results at specific dead lines, where a Design Review Team (=DRT) will evaluate the results and inform the project participants, with the expertise the DRT members have, about which direction seems to be the most appropriate.

A co-ordinator will be appointed who is a link between the students, the teachers, the Design Review Team and the Company. The co-ordinator will have to handle different kinds of problems that will occur during the Project.

The technical knowledge the project team will have to acquire in order to solve the various sub-tasks in the project will be presented as lectures at the appropriate time during the whole year. The students will also be able to use the CD-ROM developed at the Chair, which teaches Heat and Power Technology thanks to interactive simulations and multimedia theoretical parts.

An extremely good communication link between the students, teachers and the DRT members should be established. This must be computerised in order to save time and so that all participants will have immediate access to all the necessary information. With this aim in view, an on-line discussion group will be set up and all the reports from the previous projects will be available on the CD-ROM developed at the Chair.

This is not just another calculation from a textbook. It is a real power plant, which the students have to study. As such there is of course not only one possible solution to the project. The students will thus during the year have to take a lot of 'engineering' decisions which certainly will influence the design of the whole plant. For these, the students will have to come with clear suggestions/recommendations before the Design Review Meetings, so that a detailed discussion can take place and a decision can be taken.

The final presentation of the whole project will take place towards the end of the academic year. The project team will afterwards go to the foreseen location and meet a larger group of engineers. During this study trip several other power plants/components manufacturers will be visited.



Computer Supported Education in Turbomachine
Technology
Project No. 011/98

Status Report for the Council for the Renewal of Higher
Education

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STOCKHOLM
1-Jul-03

Status Report

Avdelningen för Kraft- och Värmeteknologi
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**KUNGL
TEKNISKA
HÖGSKOLAN**

Report
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<p>Abstract</p> <p>The recent astonishing progress in computerized sciences have given birth to multimedia, an electronic revolution sometimes compared to the Industrial Revolution of the 19th century. The application of multimedia to education is one of the pre-eminent challenges of the future for academic and industrial institutions. It will certainly dramatically increase both teaching and learning capabilities.</p> <p>Heat and Power Technology traditionally belongs to a scientific field of high technology. Education in this is however today principally performed in a traditional way, via lectures, calculation exercises and laboratory experiments. The use of multimedia technology opens up possibilities, which did not previously exist, to perform systematic parameter studies and calculations in undergraduate education, so that the students are able to get a taste of the physical variables that govern the phenomena lectured.</p> <p>The Division of Heat and Power Technology at the Royal Institute of Technology has started to develop a “Multimedia Educational Package” within the sector “Turbomachinery”, in collaboration with colleagues at other universities worldwide. This tool, available on CD-ROM and partially on Internet, mainly focuses on Thermodynamic Cycles, Turbomachines, Measuring Techniques, Combustion and Aeroelasticity. Interactivity is the key concept of such a program. Various topics of the educational platform has been also integrated in the Graduate Curriculum at the Division of Heat and Power Technology.</p> <p>The e-learning platform CompEduHPT has been subject of a large-scale pedagogical evaluation that together with the implementation of the Project-Based Learning course have contributed to enhance the learning process within the students of Turbomachine Technology and have been successfully implemented in the undergraduate curriculum. Both the e-learning platform and the Project-Based Learning have reached 7 publications in international conferences, 4 demonstrations, 2 European Academic Software Award and 1 Award as Best Paper by the International Gas Turbine Institute that have attracted the interest of the international community.</p>			

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INTRODUCTION

Since the early-90s, there has been an important revolution in information technology. The Internet has become a worldwide network which growth is now unquestionable. It is more than just a fashion accessory as it reveals a need for these new communication means. In this respect, multimedia, which can be defined as an interactive combination of media, mainly text, picture, graph, sound and video, appears nowadays as a major tool in information distribution.

The 20th century has been rich in terms of innovation processes in information technology. However, there is one place that has been strongly affected by information technology: the classroom. Peculiarly, teaching methods have hardly changed over the last hundred years.

In this context, the Division of Heat and Power Technology at the Royal Institute of Technology started to develop a "Multimedia Educational Package", CompEduHPT, within the sector "Heat and Power Technology" since 1996. This tool, available on CD-ROM and partially on Internet, mainly focuses on Heat and Power Cycles, Turbomachines, Measuring Techniques, Combustion and Aeroelasticity. This package would complement the existing traditional education in such a way that the undergraduate students will obtain a background that corresponds to the best that is given at various academic institutions worldwide. Various topics of the e-learning platform have been also integrated in the graduate curriculum at the Division of Heat and Power Technology.

PROJECT OBJECTIVES

Multimedia Education must fulfill two main objectives: it must improve the pedagogical quality of teaching when used by teachers in a classroom and it must increase learning speed and quality when used by the student at home. It is possible to imagine that in the future students will learn the course basics at home, and then come to the classroom in order to discuss the misleading points with the teacher, as well as further advanced topics on the taught material.

In any case, multimedia educational software cannot be a substitute for a teacher; contacts between students and their professors are of paramount importance, and computers are not supposed to replace this basic need. It must not be confused with long-distance training. Multimedia complements traditional education and makes it easier to communicate between professors and students. Moreover, it should be mentioned that a key aspect of this project is to make the software package user-friendly and attractive to the students. This undoubtedly will increase their motivation.

The goal of the Computerized Educational Program in Heat and Power Technology (CompEduHPT) is to improve education -the teaching and learning aspects- by means of the new information technologies. The objective is not only to cumulate different sorts of information to have an unusual but complete coverage of the material, but overall to focus on the quality of the submitted information. This has been done by

developing a well structured educational tool that illustrates basic phenomena related with heat and power technology that help the students to acquire a physical insight to some of the problems encountered in the field, and thus acquire the critical thinking that is necessary to evaluate various parts of a proposed design.

Four specific objectives have been established to accomplish the main goals:

- Include the overall information -classically taught in the classroom- in a global project that the students have to achieve running the CD-ROM. Such kind of Project-Based Learning (PBL) can be for instance the design of a heat and power plant.
- The platform has to be a problem-oriented program. The program is intended to be an educational program, which means that we always have concern on improving the learning of students, whose interest should be higher with such a modern tool.
- The program must be helpful to teach and learn heat and power thechnology. Thus, the software package has to be implemented in a complete interactive way into the curriculum, such that the computerized part will go hand-by-hand with the rest of the curriculum. Consequently the program will fit the Undergraduate Curriculum given in the Chair of Heat and Power Technology Division.
- Assess up to which extent the transfer of knowledge has been changed with such a program. This is done through an evaluation process established at the Chair of Heat and Power Technology.

The program is intended to be used by the teacher and by the student. The teacher should use the established material in an interactive way during the lectures, but the students thereafter should be able to use the material on their home computers to improve their learning capabilities and, speed, of the subjects in Heat and Power Technology. The program is not aimed at solving all the kinds of physical processes or industrial situations the student could be confronted to, but using the multimedia specificities is a mean to help him better understand the global phenomenon of the field.

METHODOLOGY

The advantages of multimedia educational tools as a complement to traditional education are not obvious for everyone. Thus, the content of the program has been organized in such a way that the user is able to navigate freely in the package and understand the relationships between the different parts. Moreover, the contents are organized in a progressive degree of difficulty to help newcomers to understand the basics behind the phenomena and achieve a progressive learning while giving the opportunity to review more complex theories to those students already familiar with the basics.

In 1994, the American Association for Interactive Multimedia published a report that highlighted the following advantages of multimedia education:

- The assimilation rate is 65% higher than with traditional method.
- The training consistency is 50 to 60% better.

- The assimilation speed is 38 to 70% higher.
- The memorization of information is 25 to 50% higher.

Even though the results were related to different activities of the companies, there was a general consensus on the beneficial advantages provided by multimedia training. Thus, multimedia becomes a key element in education for the following reasons:

- It increases the learning speed: A multimedia educational program is available all the time. It can bring support to the teacher in terms of availability. Whereas the teachers have their working hours during which they have to share their time among the classroom's students, the computer is always available depending on its user's willingness.
- The more the student use it, the less it costs.
- The quality is the same for every student and does not depend on the teacher's skills anymore.
- It integrates the basics of any subject, which are very often responsible for the non success of the students.
- It improves the students assimilation because it stimulates all senses of the human body. Multimedia enriches pedagogy by mixing different media. Good multimedia educational software simultaneously stimulates different senses, resulting in better assimilation and memory. Each student reacts differently in these two processes; for instance, some appreciate visual memory, others oral memory. Multimedia is a combination of graphics, sounds, music, voice, videos and animation. These different media are uniformed through the training software with the objective of stimulating at the user's senses.

The multimedia platform for computer supported education in Turbomachine Technology has been structured in an analogous way as a printed book is arranged. There are presently 6 shelves or main subjects within Turbomachine Technology:

- The first shelf "Introduction and project of the year" contains an introduction to the e-learning platform and general overview of energy issues including environmental taxes as well as the purpose, specifications and examples of the Project-Based Learning that is taught in the Division.
- The shelf "heat and power cycles" contains information about heat and power cycles, propulsion cycles and virtual study visits.
- The shelf "turbomachines" presents the different components of steam and gas turbines, fundamental equations, two-dimensional velocity triangles, design parameters, cascade flow, numerical methods and transonic flow in turbomachines.
- The "measuring techniques" shelf contains few measuring techniques associated with turbomachines. It includes pressure, temperature, flow velocity and mass flow measurements as wells as flow visualization techniques.
- The "combustion" shelf presents some combustion basics as well as combustion chemistry, laminar and turbulent flames, solids combustion and pollutants emission, combustion devices, catalytic combustion and thermal radiation from combustion processes.

- In the “aeroelasticity” shelf are included topics such as introduction to aeroelasticity, basics of aeroelastic systems, structural models, classical flow models and experimental techniques.

The purpose of the platform is more extensive than other computer tools developed for learning. It is not limited to have a collection of overhead slides in which the theory is presented but also to fully exploit multimedia features to facilitate and improve the learning process and particularly to support the learning in the project-based learning course. Therefore, additional components such as animations, videos, virtual study visits, quizzes and simulations have been included. Although several multimedia features have been considered it has not been forgotten traditional learning tools such as calculation exercises, lecture notes and case studies, which are presented in CompEduHPT in an interactive way to the student. Moreover, virtual lab exercises have been included to help the student for the real lab exercises facilitating the theory in form of e-pages and also through simulations of the lab exercise.

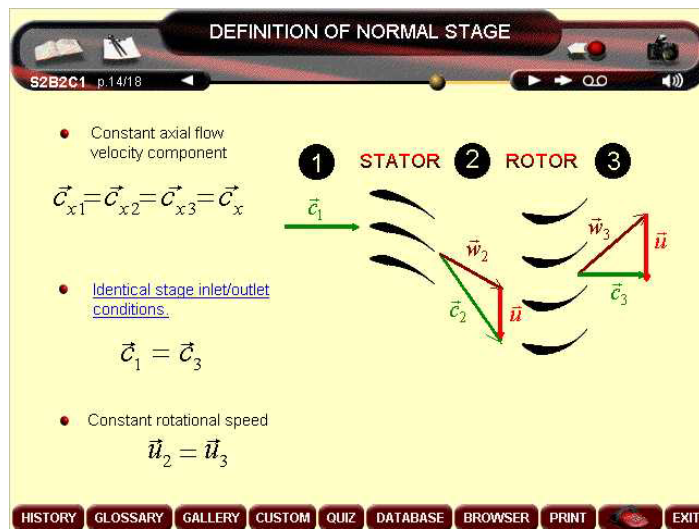


Figure 1: Theory Page

Additionally, other program utilities are available in a toolbar at the bottom of the screen. This toolbar contains a glossary, history about turbomachines and scientists related with the field, gallery of different turbomachines, browser, help, and a local database with the user’s successes and failures plus the possibility to perform a quiz or printout the theory part. A discussion forum is available not only for students at KTH but also for students using CompEduHPT at other universities. Furthermore, the possibility to participate in e-lectures through the use of audiovisual conferences from experts in the different subjects is available for distant or local learners to complement their theoretical review of the material provided by CompEduHPT. These e-lectures are totally interactive if the distant learners have the necessary features such as a fast connection and a web camera/microphone.

All these features together constitute a complete e-learning environment to facilitate the assimilation of the different concept by the students.

PROJECT STATUS

The e-learning package “Computerized Educational Program in Heat and Power Technology (CompEduHPT)” has been implemented in a complete interactive way into the undergraduate curriculum given in the Chair of Heat and Power Technology

Division. Various topics of the educational platform has been also integrated in the graduate curriculum at the Division of Heat and Power Technology.

Furthermore, about 107 chapters on the different subjects within Turbomachine Technology have been implemented in the e-learning platform to support the Project-Based Learning course. This chapters include the theory, animations, videos, quizzes, lecture notes, lab exercises and calculation exercises to enhance the student's learning process and provide a solid theoretical base to develop the project included in the Project-Based Learning course.

Moreover, cooperation with other universities have been established to guarantee the student's access to the best quality material available from different experts in the topics included in Turbomachine Technology. The universities currently cooperating in this project are: Duke University (USA), EPFL-Lausanne (Switzerland), Helsinki University of Technology (Finland), INSA-Lyon (France), Kyiv National University (Ukraina), Laapenraanta University of Technology (Finland), Indian Institute of Technology (India), University of Moratuwa (Sri Lanka) and Gadjah Mada University (Indonesia).

Moreover, a review process of the material included in the platform has been started and experts in the technical subjects as well as in education will perform it to guarantee a good quality material. At this point it is important to mention the involvement of the KTH learning lab as one of the advisors for the project. Moreover, a reference group has been established with members from industry and academy to have an overall perspective of the different needs and try to provide to the students a complete education that can help them in their professional live.

ACHIEVEMENTS

Several goals have been achieved in the last 3 years including implementation of the Project-Based Learning, pedagogical evaluation of the e-learning platform CompEduHPT, publications in international conferences, presentations, reports, Master of Science Thesis and European awards.

Project Based Learning

During the last two years, the project based learning PBL course has been in continuous evolution. A number of improvements in some aspects have been introduced. These were revealed by the yearly review and there will be an improvement in the review process itself in the near future.

There are different models for PBL models as mentioned by researchers in higher education (se for example: Biggs 1999). The model used at our division is based on three main parts. The customer, an external industrial partner, is presenting their

problems. Students are supposed to define the problem, fragment it into small sub-projects and solve the different parts. Students also constitute by themselves into small sub-groups. They also have to appoint a leader for each team and a leader for the whole project. Projects teams refer to two a review teams called DTRM. The DRT or Design Review Team is formed by supervisors (i.e. teachers) and industrial experts. Several meetings are organized and students are requested to present the advancement in the different sub-task as well as a review of the overall advancements done (see Almqvist et al. (2000)).

Two reviews have been conducted for this course. The first one conducted in year 2000 revealed that the PBL concept enhanced students' motivation and provided the possibility to learn critical thinking and selection of the information they need for the project. They also learned how to define a problem and solve it. Some difficulties have been expose such as the lack of experience in presentation among students – especially the Swedish-speaking students. The high specialization within sub-groups resulted in lack of understanding of the whole projects, which the students did not appreciate. I addition to that, the intervention of supervisors to specify the deliverables of the project in its early phases has not been well perceived by students. The review resulted in concrete suggestions such as changing the leadership of project-teams and including lectures in presentation techniques and project management.

A more recent review conducted during the academic year 2001/2002 showed that problems related to presentations and leadership issues were resolved. In turn, other minor problems were revealed such as some tension with project sub-groups. In general, students liked the PBL model used and were highly motivated and in particular in the beginning of the course. However, it has been noticed that some students and particularly the project- and task-leaders prefer to tackle the project by themselves and from the beginning. It is worth noting that as the course went on enthusiasm of students deceased due mainly to external conditions that the division cannot affect such as the slowness of industrial partners in providing information and the decrease of their interest in the final result of some sub-tasks. The study suggested some improvements consisting in adding a lecture on group dynamics and also a new assessment scheme with some individual measures. As for the contact with industry it has been suggested to select companies that are really interested in the results of the student project.

Pedagogical Evaluation

The CompEduHPT project evaluation was carried out in different levels and including different aspects. As for the level these include a local reference group and an international group of specialists. The aspects that are part of our review process consist in the correctness of the technical information included, the pedagogical aspects and the programming of the platform.

In the pedagogical aspects we evaluate whether the learning material is presented in a didactical way and also if the material is presented using different means such as text, picture, videos and simulations ensuring both motivation and genuine reinforcement of the theory learned. The last aspect is the programming of the platform, which plays

an important role for the end-users, the students. This aspect was given the greatest interest in the last few months of the project during which it was decided to outsource this part to programming specialists so that the expertise of engineers in Heat and Power Technology could be better focused on the technical/pedagogical issues.

Two reference groups constituted of specialists in the field of Heat and Power Technology, some of whom are experts from industry and others originates from Academia, have been created. One of the groups is in Sweden, and the other consists of international members. The local reference group meets twice yearly and provides the developing team with valuable information both on the technical content and the features that can be added or improved. Members of the international reference group meet once a year during the International Gas Turbine Institute yearly conference. This group contribute to the evaluation process through the discussion of different aspects of the platform and provides us with feedback on the work already completed and also with new ideas and vision for future development.

Providing students with a reliable and enjoyable learning environment is one of the most important goals of the project. Therefore there has several times been reviews by students in order to check the quality of the educational material and how the students can benefit better from it.

A review process has been installed in order to make sure that the learning information included in the educational platform is of highest standard. These reviews are performed by teachers interested in the field, as well as by students following the courses based on the learning material.

One review is based on the student-centred focusing on the point of view of the student. The review form was designed based on the suggested by Oppenheim (1992). This evaluation included two main aspects; the general aspects of the platform, which consist of the time required to learn how to use the platform, the user friendliness of it and the design of icons and buttons. The second aspect is related to the learning material. This part is more developed due to the importance for the pedagogical questions we wanted to investigate. They are summarized as follows:

- The frequency of using the platform
- Length of study sessions
- Structure, optimal length and level of difficulty of the study material
- Structure, optimal length of the hypertexts
- Review of the utilization of the chapter's objectives and summaries.

The results of this study revealed the following:

The platform is very easy to use for most of the students; however, for a number of them it seems that it is slightly hard for them to learn it very quickly. The reason may be that most of them rely on the trial and error way instead of reading the users' manual we provide, or that we should slightly review the design of icons or the layout.

As for the educational material, the study has confirmed that the original design of was good to a certain extent. However, more structured chapters could be developed

more accurately as concrete measures were performed related to the optimal length of the main chapters and the hypertexts. The study also revealed the fact that student use our platform quite frequently and for study period ranging between half an hour and one hour at the time.

Finally the study provided an insight on how students view the importance of different educational tools. A special interest was on simulation, quizzes and also the graphics in general. Students also mentioned the combination of theory and exercises. Some negative aspects such as non-optimal programming aspect were highlighted. These issues which will be taken care of by programming experts in the near future. These measures will hopefully considerably improve the reliability and the quality of the platform.

We believe that the review process is providing us with valuable information on how to develop the platform and that it is very well adapted for projects of this kind. Its comprehensiveness and regular reviews by different partners ensure the availability of feedback on all aspect and innovative ideas leading for a further improvement of CompEduHPT.

Publications and Presentations

Several publications and presentations have been the results of the different developments in computerized education at the Division of Heat and Power Technology. The results of the Project-Based Learning have been presented at American Society of Mechanical Engineers conference ASME TURBO EXPO 2000 in Munich, Germany. The paper presented was

- *“Introduction of Project Based Learning for Designing a Heat and Power Plant into the Last Year Curriculum”* by Svendotter et al.

A paper by Gaulard et al was presented at the FLIP'98 Conference in Stockholm, Sweden entitled: *“Computerized Educational Program in Turbomachinery”*.

Also, the following papers have been presented at American Society of Mechanical Engineers conferences:

- *“Computerized Educational Program in Turbomachinery”*, presented at ASME TURBO EXPO 98, Stockholm, Sweden by Leótard et al.
- *“An International, Electronic and Interactive Teaching and Life-Long Learning Platform for Gas Turbine Technology in the 21st Century”*, presented at the ASME TURBO EXPO 2000, Munich, Germany by Fransson et al. This paper was selected for publication in the Journal of Engineering for Gas Turbines & Power, July 2001.

Also, the following 2 papers by Salomón et al have been accepted for ASME TURBO EXPO 2003, Atlanta, USA:

- *“Gas Turbine Simulations in the Computerized Educational Program CompEduHPT: Educational Aspects”*
- *“Gas Turbine Simulations in the Computerized Educational Program CompEduHPT: Three Case Studies”*

Another paper by Kazachkov et al has been accepted for the for the 2003 AIAA Conference in Reno, USA entitled: “*Interactive Teaching and learning Platform for Numerical Methods in Turbomachinery*”.

Finally, a demonstration of the CD-ROM was given at

- CALISCE 98 in Stockholm,
- Science Festival 1999 in Gothenburg,
- Netlearning conference 2002 in Ronneby
- Nordisk Energiforskning Annual Meeting 2002 in Oslo.

A complete reference list of the papers and presentations is given in Appendix 1.

Master Thesis and Project Reports

Since the computerized educational project started in 1996, 20 Diploma thesis have been carried out at the Division of Heat and Power Technology. A complete list of thesis carried out in Computerized Education since 1996 until December 2002 is included in Appendix 2.

Moreover, about 10 reports have been written since 1996 related to Computer supported education in Heat & Power Technology. A complete list is included in Appendix 3.

Awards

The Computerized Educational Program has been awarded by the European Academic Software Award (EASA) during 1998 and 2000. These two prizes have represented an important step in the development encouraging the improvement of the platform. Moreover, during the competition for the EASA award the e-learning platform has been reviewed by several experts in the areas of heat and power technology, education and information technology. The comments given by them have been used to improve the platform in those aspects that were needed.

The paper “*Computerized Educational program in Turbomachinery*” was awarded as the best educational paper in the conference ASME TURBO EXPO 1998. Moreover, the paper “*An International, Electronic and Interactive Teaching and Life-Long Learning Platform for Gas Turbine Technology in the 21st Century*” was selected for publication in the Journal of Engineering for Gas Turbines & Power, July 2001.

CONCLUSIONS

There has been an important development in computerized education at the Division of Heat and Power Technology since 1996. This together with the Project-Based Learning has served as an important step towards the enhancement of teaching and learning of Turbomachine Technology subjects. The student acceptance of the e-

learning platform CompEduHPT and the PBL project has been important. Several pedagogical evaluations of both the platform and the PBL project have been carried out. These evaluations have shown interesting results and some modifications have been done to improve both platform and project organization.

Moreover, the e-learning platform CompEduHPT has reached a considerable amount of publications and presentations that have attracted the interest of the international community. The different members of the local and international reference group have also contributed with the dissemination of this innovative way of teaching Turbomachine Technology.

FUTURE WORK

There are many new ideas and plans to continue in the field of computerized education. For example, it is planned to develop a remote lab on profile losses to make the lab available for local and distant students. In relation with the educational platform CompEduHPT, there are plans to develop and include more educational material to support completely the PBL course. Also, the students will be able to participate in distant lectures given by expert on different subjects.

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