Using New Tools for Education –
A Case of an International Cooperation for a Rapid Prototyping Course.

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Abstract: This paper presents a personal view about the utilization of new tools for education. In particular, the observations and results presented here are based on the experience of the authors who cooperated to teach in a course on rapid prototyping, and their knowledge about educational systems in different countries. As a main result it is illustrated how the new tools for teaching, especially the internet, offer us a new paradigm for education. Maybe the most important point is the design of an individualized education system to address the fact that the time needed to learn the contents of each course depends directly on the students and their capacities.

Key-Words: eLearning, education, rapid prototyping, manufacturing, automatic control, digital systems.

1 Introduction

The traditional education is changing in part due to the utilization of computers and because in many cases it allows students to learn faster and with more illustrative examples. But really provoking a deeper change in education is the internet and the possibility to flexibly control real systems by computer. We may even be confronted with a new situation where we design courses that do not need a teacher at all. That means, we have the challenge to design courses that allow the students to work on their own. So all the difficulties experienced when studying a course by internet must be anticipated and supported. This way, a person with adequate training can study the contents of the course rarely experiencing severe problems. Then, the students have the opportunity to study a subject at their own pleasure and pace. The advice from a teacher will only be necessary when the student is confronted with an unanticipated problem or when he wants to extend beyond the subject.

The observations and results presented here are based on the course Rapid Prototyping - Applications in Manufacturing, Automatic Control and Digital Systems. It is designed to be offered for engineering students of a masters program, based on the experience and knowledge of the lecturers, the authors of this paper.

Each lecturer gained his specialized experience in research and education not only in his home country, Mexico or Germany, but also in France, UK and USA. Based on this broad experience, the course regarding its structure, its contents and its teaching methods has been developed.

The course is offered in cooperation between the Department of Project Engineering (DIP), University of Guadalajara, and the Institute for Electrical Information Technology (IEI), Technical University of Clausthal. It takes place in March and April 2002 for the first time at the DIP.

The Technical University of Clausthal and the University of Guadalajara are collaborating in a variety of programs and projects. This particular cooperation between the IEI and the DIP is supported by the ALFA program. The presented course is one of several joint activities in education and research.

The course’s contents will be presented as well as the new approaches for teaching. Experiences, the
efforts undertaken to maintain or enhance the course’s quality and further aspects especially regarding the international collaboration are discussed.

As a special aspect, three levels of practical experiences for the students during the lecture are discussed. The first level consists of system simulation. The second level consists of the utilization of real prototypes connected to a PC. And the third level is the utilization of the internet to operate a physical system located at the IEI in Clausthal.

It is illustrated how the new tools for teaching are offering us a new paradigm for education. Without doubt, the most important point is the individualized education system where the student studies the contents whenever he wants and at his own pace.

First, a historic overview from traditional to the newest educational tools is given. Then, the course itself is presented and how some of the modern tools have been used. Results and experiences are discussed with focus on the new possibilities offered by the new tools for teaching.

2 Tools for education
The methods and tools for education have evolved in different ways.

They go for example from the "teacher-assistant" relation where somebody transfers his knowledge to another person who begins as an assistant. Then, little by little, the assistant begins to acquire all the teacher’s knowledge including his hypothesis and theories.

The education of large groups requires students to work in a different way. The blackboard has become an essential element for education. The laboratory has also become essential in some areas of the science to help probe and understand principles, laws, or theories.

As some experiments may be difficult to carry out or expensive, sometimes the experiment is recorded on video tape. This way students can see it any time.

In some areas, the experiments are destructive or expensive, and many times they affect the ecology. Simulation has been a good solution in order to avoid these problems. But simulation goes even further as in many cases it replaces the entire laboratory.

Nevertheless, nothing can replace experiments with physical systems, the real world. Therefore, it has been necessary to develop representative prototypes. Most of them have been developed as independent systems while they often interact with a computer today.

As electronic communication evolved it has become possible to take courses where the lecturer is in a different location, in another city or even in another country, than the classroom. Experiments are presented by video or take place in a laboratory without direct advice of the lecturer.

The development of computers has a great impact on the education in many aspects [1]. It allows an interactive ambiance including simulations or videos about real life applications.

Nowadays, the internet is changing the way to teach and to make experiments [2]. One change is that any person around the world may have access to self contained courses if no restrictions are imposed. A second change is that physical systems can be operated using the internet with the experiments and the contents being integrated in the courses.

3 The rapid prototyping course
The newly designed course Rapid Prototyping - Applications in Manufacturing, Automatic Control and Digital Systems, incorporates a variety of novel educational aspects. Thereby, each area of application is presented by a lecturer having extended experience in his part.

New methods for teaching are applied, on one hand to present the contents as good as possible, on the other hand to develop a future oriented concept for the course. This is particularly important as it is held by lecturers coming from different countries, and the course shall be offered in the future even if circumstances do not allow every lecturer to be present.

General information about the course can be found on the web site of the IEI. This includes the course’s content, a download section for information, some literature and links to further modules. See: http://www.iei.tu-clausthal.de/~promise/rp_index.shtml

In this course, three ways to present “practice” are included. This is motivated by the context but also provides the opportunity to evaluate the impact using these new technologies. One is the simulation of models as has been done before in several theoretical courses. The second is the use of physical prototypes
in the classroom. And the third concerns the utilization of the internet in order to operate a physical system located at the IEI in Germany (remember that the course takes place at DIP in Mexico).

To prepare the course and to awaken the students’ interest in this elective course, four presentations have been made. In "Studying in Germany", the German lecturer presented general concepts of the educational system in Germany, as well as specific aspects of his home institution. Another presentation "Real-time Systems Control using the Internet", also given by the German lecturer, has been directly related to his area of research. The remaining two presentations have been about manufacturing by Mexican lecturers with one of them dealing with a particular process of rapid prototyping and the other one a computer aided manufacturing system for electro discharge milling.

3.1 Structure of the course

The course is designed to cover three areas: Manufacturing systems, automatic control systems and digital systems with a total time of sixty hours. The time is split into four sections, one for each topic and the fourth for a project. Once the lectures have concluded, each student chooses an area of specialization in which he will carry out the project.

The final evaluation is divided into three parts. The first one is about the general concepts of the course, the second one is about the area of specialty, and the last one is the project.

This time, all lecturers have been present to give their lectures. The Internet has been used for some theoretical lectures and experiments.

3.1.1 Rapid Prototyping on Manufacturing (RPM)

This part of the course was designed to give a complete state of the art of the rapid prototyping technology in manufacturing processes. Some historical elements were reviewed and how this technology has evolved. Then, the role of RPM in time-compression engineering was studied, and the interaction between 3D CAD modelling and rapid prototyping systems. This part finished looking the main stages involved in the generation of data for a rapid prototyping process.

A classification of the different physical rapid prototyping processes was studied. The characteristics of each method was discussed focusing on the most interesting applications of each of them. Also, the technical features of commercially available rapid prototyping equipment was discussed, as well as that of the 3D printers.

Applications in the areas of engineering, medicine and arts were presented. This allowed us to show how the principles of rapid prototyping can be applied in different areas with very interesting results. At the end it was reviewed how to optimize the process of rapid prototyping.

Finally, a case study was presented. From the design of the part in a CAD modeller to the generation, validation and repair of the data to be input in a rapid prototyping machine.

The final project for this part of the course was to propose and to document a design and manufacturing process of a product according to the concurrent engineering approach. This project must justify the rapid prototyping technique and the selection of materials to build the prototype.

3.1.2 Rapid Control Prototyping (RCP)

In this part it is presented how the principles of RCP can be used to design a controller for a particular application. The entire design process is included, beginning from the problem definition until the final prototype controller. The last one is in fact an algorithm to manipulate the system under consideration in such a way that the defined optimization goals can be fulfilled.

![Fig. 1: A mobile example plant.](image)
and an educational two tank system (see Fig. 2). As well, general aspects are discussed like the differences working with or without the tools, manufacturers and criteria on how to choose an appropriate system.

The design process of the controller can be treated independently of the rapid prototyping tools. The tools support the development in such a way that simulation and real-time operation can be realized based on the same software. This way, the laborious and time consuming code and data transfer between simulation and real-time system can be reduced, and errors due to the manual transfer avoided.

The key advantage of the rapid prototyping tool is that the designer can focus on the control design process. However, these tools do not guarantee good and quick results by themselves. For efficient application, the methods for control design have to be regarded as well as a systematic process in the model design that now serves for the simulation and for hardware control. Often, if not working systematically, still multiple models are created and, due to the rapid code production and implementation, these tools invite students to "play". As a consequence, the advantages applying these tools are not used, and neither time is saved nor errors avoided.

In lectures at IEI, simulations have been included for many years. Thereby, the design process is carried out interactively with the attending students if the audience is not too large. This way, the dynamic behavior of systems can be visualized and the effect of parameter variation can be demonstrated.

For even more realistic demonstration, a complete mobile test-stand for use in lectures has been developed. This includes a portable personal computer with an integrated DSP based real-time system card. Attached is a multipurpose connector panel. For about two years, this mobile rapid prototyping system has been used with a variety of systems for education and research purposes.

Especially for the use in lectures, a compact plant has been developed that can be controlled by the portable computer. This plant is a motor driven rotational pendulum for a position control and can be placed on a projector for transparencies. So the pointer and its dynamic behavior can be shown even to a large audience. Additionally connecting the computer to a projector, the entire design process in simulation up to the plant operation in "hardware-in-the-loop" experiments can be demonstrated to the audience.

An exercise covering the contents of a 3-hour lecture takes place in the internet, only. The internet exercise has been designed in such a way that the entire methodology of control design is practiced by the students on hand of the two-tank-system.

The module can be carried out offline in most parts. For this, the necessary files can be downloaded as a zip-file. Only for the remote lab features, the user has to connect to the internet.

The didactical structure of the module is given in a cyclic process of: Information - Problem to solve using this information (- sometimes: Additional aid to solve the problem) - next set of information...

After having realized the theoretical control design, the student can simulate the dynamic plant behavior using his controller. To do this, the student defines his desired form of simulation and parameters in an html form in his browser. These data are sent to an IEI server where the simulation of the two tank system is carried out using the specifications. The results are returned as plots.

In the final step, the simulation results can be verified by experiment with the plant. The parameters that have shown good results in simulation are entered in a Java applet used to control the system. The dynamic behavior can be seen in real-time by online plots and a webcam image. For details about simulations and control of the remote lab see [3].

Except for the general part, the examination of the students specializing in control is carried out over the internet, as well. First, general questions about Rapid Control Prototyping have to be answered. Second, some problems in the exercise about the control
design for the two tank system have to be solved. These problems are marked in the module; their answer does not require special knowledge about control theory. They do include, though, the interpretation of the results obtained in simulation and experiment. All results are handed in by email.

The project of control is also offered and carried out via the internet. Here, the students have to design a web page with contents related to Rapid Control Prototyping. This may be a point of interest in Rapid Control Prototyping or an example application.

The page is to be designed in a similar style as the learning module about the two tank system in a considerably shorter manner.

For orientation, the introductory page is designed to be (optionally) used as a template including documentation. It can be downloaded as a zip file that contains the html template file and some images supporting the design. This way - after a short orientation in the html file - the student can design his own web page focussing on the contents.

3.1.3 Rapid prototyping on digital systems

One characteristic of actual digital systems is their rapid evolution and the short life time of the products. Thus, at least for the development, it is inevitable to rapidly test structures, and to modify or include more functions.

A fundamental aspect of digital systems is the treatment of information. The course has been designed for engineering students not necessarily specialized in digital systems. So the focus is on teaching the fundamentals. This way, the students shall gain the capability to principally understand and use a system designed for the treatment of information, for a new process or a new product.

The fundamentals of rapid prototyping are studied, taking into account where to use these tools and where not to use them. This part is completely oriented to the development of digital systems.

An introduction to digital systems is included focusing on their functionality and how they can be combined to form a complex system. After that, different tools are presented to design a digital system. Therefore, schematic design, state design, VHDL design and design based on high level languages are discussed. As an exercise, a digital system based on a FPGA is carried out.

Two different kinds of projects are offered for this part of the course. In one, the actual state of specific and programmable CI’s is investigated. The other one is about the implementation of a new function into a FPGA.

To gain practical experience, the students work with simulation tools in the first step. After a successful design they proceed to load it onto an evaluation board to test their results. So, the student works in simulation and with a physical prototype.

4 Results

On the date to hand in the final version, the last part of the course has not been carried out. Thus, some of the overall experiences cannot be reported here.

In the students’ opinion, simulations are very interesting but sometimes they doubt that simulation results represent a real situation.

Therefore, working with real prototypes, students can experience the strengths and the limitations of the simulation tools by comparing simulation results with those obtained by a real system. Nevertheless, in the sequence theory – practice remains in the educational process.

Using internet features, this may be a little different because the physical system can operate at the same time as the theory is developed. Besides, the students can go forward and backward as desired. This way, they can review theoretical concepts when desired which helps to gain a better understanding of the subject to study.

Introducing the internet experiments, some members of the audience found it hard to believe that they were actually seeing the control of a real system and not a recorded film. But the change of parameters and the subsequent reaction of the system seen in online plots and by webcam images helped to convince the critical audience.

5 Conclusions

Courses at a distance have been a reality for many years. However, these courses are expensive, require special equipment and besides, the lecturer must be present in another place.

The new concepts offer an alternative to the classic ones because they may be accessible to every person interested in it. This may be worthwhile from economical and technical aspects. But what seems even more interesting is that each student is able to learn at his own pace as well as at his own schedule.

It is planned to make all contents of the courses available on the internet including the recommended
exercises. A student only needs to hand in required homework and at the end he has to prove that he has acquired the knowledge and the ability to dominate the subject. Besides, as an international cooperation is the base for this new paradigm of education, internet communication tools such as newsgroups or forums can be created so that students could have advice available even outside working hours at his own location. This implies different working strategies from the teachers side because the teaching activity turns to be more individually oriented to meet the needs of each particular student.

For the moment and according to the recent experiences as fair evaluation without personal contact seems difficult.

At present, internet communication is carried out primarily by e-mail. But as the technology advances, communication may also include visual contact by standard. Then, personal contact could be almost the same as if being in the same place.

In the lecture Rapid Prototyping, a variety of modern tools and new features of education are included. The experiences gained in this collaborational effort will be used not only to maintain and improve this course but also to support similar efforts elsewhere. The authors believe that these kinds of concepts may serve to give examples to other educational institutions to develop future oriented education. This way, the challenges of the current globalization can be addressed actively instead of just following routes long before explored by enterprises.

Intelligent concepts may even help to increase educational quality while at the same time dealing with very limited financial resources. But who is to design creative and future oriented solutions if not the members and students of universities?

To set up the remote test-stand, the DIP will be using the same real-time hardware (a micro-controller based embedded system with network capabilities) as is used in the IEI remote lab. This way, both partners hope to work more efficiently due to shared experiences.

Currently, the course takes place entirely in the Spanish language at the DIP, Mexico. Ways to accredit and maybe offer the course at IEI, Germany, will be investigated. Thereby, the different educational systems are considered a minor problem in comparison to the language barriers (Spanish, German) - maybe with the common denominator being English. With strong integration of the internet and with support of local lecturers, this goal is expected to be a realistic option in the future.

Acknowledgements
The authors would like to thank the aid received from Alejandro López Pamplona, working at the IEI in Germany, who helped to a great extend in the preparation and the design of the internet components.

References

Outlook
In order to develop appropriate internet modules for future use, course participants will be offered to support this effort as part of their final thesis projects. This may be the design of lecture modules with the focus being on presenting the contents. Furthermore, it is planned to set up a new remote lab experiment using the mobile test-stand. This way, combined with a lecture module, hardware-in-the-loop experiments could be carried out entirely in the internet instead of the demonstrations in the lecture as is done currently.