DEVELOPMENT OF COMPETITIVE SKILLS IN FUTURE MECHANICAL ENGINEERS

F. Jorge Lino
Faculdade de Engenharia da Universidade do Porto
Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
Email: falves@fe.up.pt

Teresa P. Duarte
Faculdade de Engenharia da Universidade do Porto
Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
Email: tpd@fe.up.pt

ABSTRACT

Nowadays, the Web is a common tool for students searching information about the subjects taught in the different university courses. Although this is a good tool for the first rapid knowledge, a more deep study is usually demanded.

After many years of teaching one course about ceramic and composite materials, the authors, used the Bologna reformulation of the mechanical engineering course to introduce new teaching methodologies based on continuous evaluation.

One of the main innovations is one practical work that comprises the study of a recent ceramic scientific article, using all the actual available tools, elaboration of a scientific report, present the work and participate in a debate.

With this innovative teaching method the enrolment of the students was enhanced with a better knowledge about the ceramics subject and the skills related with the CDIO competences.

INTRODUCTION

Teaching with success is a very demanding task, especially in present time, where the students have a continuous contact with the powerful tools of internet and media. This way, rapid knowledge is obtained at the distance of a simple click, independently of the region of the world where a person is.

Nowadays, when students are admitted in the university, they have already a big control of specific tools, such has typing texts in word processor and doing presentations in power point, and many of them are quick to search for an answer in the World Wide Web. However, when a deeper knowledge about the subjects is demanded, the difficulties start to appear, and essentially when some background about certain scientific principles is demanded, the problems are even bigger [1]. This is the main deficiency that the authors detected on their mechanical engineering students during their classes about ceramic materials.

The Faculty of Engineering of University of Porto (FEUP), Portugal, has the Integrated Master Course in Mechanical Engineering (MIEM). This course has a considerable incidence in materials and technological processes. The introduction of these subjects with the detail that is presently taught is related with the type of mechanical engineers necessities of the surrounding industrial tissue of the region and the country, and in the global employment market.

One of the main concerns of the mechanical engineering professors of FEUP is the transmission of the best general competences CDIO (Conceive-Design-Implement-Operate) [2] and scientific knowledge, but also the development of skills that will be very helpful in the future active professional life.

The course of Materials II [3], of the third year of MIEM, first semester, is divided in two main subjects; the study of ceramic materials and polymers and composites of polymeric matrix. The authors of this work are in charge of teaching the part of ceramic materials that represents more than one third of the course (10 classes of 2h each in 24). The scientific knowledge is transmitted with the help of practical classes, where videos, experimental work and technical visits are used.
In the past, teaching was performed in the classic way with theoretical and practical classes. In the theoretical classes (8 classes of 1 hour for around 130 students at the same time, where it was impossible to have a personalized knowledge about each student), and considering the short number of classes to teach the subject “ceramics”, the emphases was put in clarifying the differences between traditional and technical ceramics. A short introduction to the sintering and explanation of the main differences between solid state and liquid phase sintering, and relating them with the final mechanical properties of the ceramic products is also addressed. After this, students have a short introduction to the manufacturing processes and mechanical properties, with special emphasis on toughness and current research that has been conducting to improve these properties, in order to be able to increase the penetration of ceramics in the materials world parts applications (Harmer and co-authors wrote an excellent paper challenging for these opportunities [4]).

In the practical classes (2h for 25-30 students) students have the opportunity to make simple experiments, namely press powders, determine densities and respective level of porosity and finally evaluate the effect of sintering on the mechanical resistance of the samples.

The final grade was composed by 20% for the reports of practical classes and the remaining 80% for the final exam.

Since 2006 the classes were changed to just practical ones (with 4 works for ceramics and 3 for polymers) with the goal of giving the student a more responsible and pro active attitude, which is characterized by spending much more time at home/university studying the main topics taught in classes. Although the contents of the course remained the same, at the beginning of some classes each subject is briefly presented during 15-20 minutes maximum. After that, students have to answer the questions of the practical works using class facilities and complementary work done at home/university (the course has 6 ECTS – European Credit Transfer and Accumulation System [5], where 1 ECTS corresponds to 27h work).

After 2008, 2 reports (for each part; ceramics and polymers) are the only responsible for the final grade obtained. This means that a more deep knowledge has to be obtained about the students by the discussions on all practical classes and continuous contact with the teacher.

METHODOLOGY

Course Goals

It is expected that by the end of the semester students have acquired basic and advanced knowledge in the field of ceramic materials, polymers and composites of polymeric matrix, namely:
- Knowledge of the different ceramic materials; polymers and composites of polymeric matrix used in different branches of engineering, their main applications and properties;
- Comprehension about the mechanical properties of these materials;
- Capacities to perform different type of experimental work, collect data, interpret and relate them with the different treated subjects. Perform small projects involving the taught materials; namely materials and manufacturing processes selection;
- Capacities to collect scientific data using different sources (books, scientific papers, databases, internet, technical visits and public oral discussions);
- Capacity to perform group practical works and presentation and discussion of the achieved results.

The ceramic part of the course should contribute to the following CDIO (Conceive-Design-Implement-Operate) skills number [2]:
- 1.2 (nuclear knowledge in engineering);
- 1.3 (advanced knowledge of engineering);
- 2.1 (thinking and resolution of engineering problems);
- 2.2 (experimentation and knowledge discovering);
- 2.4 (personal skills and attitudes);
- 3.1 (group work);
- 3.2 (communication);
- 4.4 (project).

Presently the new evaluation system of engineering courses is based on EUR-ACE skills [6] that for this course are:
- 3.1 (Knowledge and understanding - An in-depth knowledge and understanding of the principles of their branch of engineering);
- 3.2 (Engineering analysis – The ability to solve problems that are unfamiliar, incompletely defined, and have competing specifications);
- 3.3 (Engineering design – An ability to use their engineering judgment to work with complexity, technical uncertainty and incomplete information);
- 3.4 (Investigations – The ability to identify, locate and obtain required data);
- 3.6 (Transferable skills – Work and communicate effectively in national and international contexts).

In this paper emphasis is given to the Practical Work number 1 “Analysis and discussion of a scientific paper”, which corresponds to 50% of the final grade of ceramics part of the course. The following sections describe the objectives of this
experimental work and all the tasks and evaluation procedure.

Specifications of the Work

Objective. Analysis, interpretation of a supplied scientific paper about ceramic materials and complementary search about the topic treated on the paper. Elaboration of a report, a poster (A4) and a presentation and public debate about the performed work.

The report should contain the necessary information for the reader take a decision. Consider that you are an employee in a company and that your boss asks you to study a subject and supply him a report containing all the necessary information to take a decision about adopting or modifying a technology/process in the company.

Recommendations: The reports should be quickly understood by the reader, for this they should be:
- Well presented (the subjects being well organized enhancing what is more important);
- Well written and does not contain orthographic errors;
- Present the subjects obeying a schematic that was defined at the beginning. For that, after the cover sheet, include the index that shows the organization of the report;
- Frequent use of graphics, tables, figures or others that makes the presentation appealing, easy to read and comprehensible of the work performed;
- At the end indicate the main conclusions;
- Identify the bibliographic references, by names and dates, or numbers, on the text, figures, tables and graphics;
- The presentation of samples or parts/components of the studied materials, during the oral presentation, as well as personal initiatives to visit companies or interviews to specialists, related with the proposed topic will be graded positively;
- Use of SI Units.

Evaluation. All the groups should deliver the report on the deadline and supply on the 1st day of the oral presentations and debate one CD containing the following elements (not obeying the deadline to deliver all the work elements will be negatively classified):
- Presentation of the work;
- Poster;
- Report;
- Elements collected during visits or others.

All the reports presented by the students that contain copied parts of other reports will be graded with a “0”.

The single use of internet sites as references will be classified very negatively. All the groups have to present in Annex at least the two best scientific papers (copies) found about the studied topic (Warning: these papers should be used as references on the report). Do not forget that there are in the FEUP library, DataBases, such as Compendex and the knowledge library: http://www.b-on.pt, where numerous papers can be found.

Reports structure. The basic structure of the reports (to be adapted for each particular paper) should be the following:

Cover sheet: Authors of the report (complete names), local, period of the work and date delivered, subject and course, title of the work, number of the group and class, reference to supervisors and main collaborators.

Contents: Include page numbers and all the titles indicated along the work.

Summary and Objectives: Should be clearly indicated the objectives and working methods employed.

State of Art: Comprehension and discussion of the following aspects (adapted at each case):
- Typical chemical composition, type of chemical bonds, structure, etc.;
- Powder manufacturing processes;
- Physical and mechanical properties, or others;
- Processing (manufacturing processes for parts and components);
- Applications (practical examples in different areas);
- Future and new challenges;
- Other elements that seems interesting (for instance, recycling possibilities);

The main objective is to relate these topics with the contents of the course.

Conclusions: Present the main conclusions in a clear synthetic way.

Future work suggested and critics: When justified it should be indicated the difficulties found and the suggestions relatively to performing future work, working methods, topics, etc.

References: The incorrect indication of the references penalizes significantly the work. Each reference or paper should be indicated between brackets along the text, using the last name of the first author and publication date, or alternatively by a number. In the end of the work, each cited author will have the complete specification, including:
- Author(s); title; editor (or journal where the article is included), data, local of edition and pages.

In the case of the reference be done by two or more authors it can be used in the text the
abbreviation et al., but in the end all the authors have to be referred.

Example:
Reference during the text:
(Duarte et al., 2008) or [1]
Reference in the bibliographic references:
or

Presentation and Oral Debate. The oral presentation of the work is defined at the beginning of the semester. The maximum time for the presentation is 8 minutes for each group (exceeding this time has a penalty) followed by a debate (around one hour) with the students that did the same work.

The evaluation of each group element is based on the following:
- Time used during the presentation;
- Presentation structure;
- Knowledge of the subject and capacity of clearly do the presentation.

The questions of other group’s colleagues and the teaching staff are helpful to enhance the debate. The performance of each student will be evaluated by the teachers of the subject/course.

Poster: The poster should be evaluated considering the following elements:
- Subject title;
- Course;
- Year;
- Objectives;
- Introduction;
- Work done;
- Conclusions;
- Future work;
- Photo of the groups elements;
- Local of the work;
- Other elements considered relevant.

Grade. The final grade is obtained by the following evaluation:
Report (11/20):
1. Cover sheet (1/11);
2. Contents (0.5/11);
3. Summary and objectives (0.5/11);
4. State of Art (4/11);
5. Conclusions (1/11);
6. Future, critics and annex (0.5/11);
7. References (1/11);
8. The two best scientific papers and its use on report (2/11)
9. Design of the report (0.5/11);
Poster (3/20)
Oral presentation and debate (6/20):
1. Oral presentation (3/20);

CASE STUDY
In the academic year of 2009/10, the following papers were given to the groups:

As an example we select the paper number 5, by Joerg Adler, “Ceramic Diesel Particulate Filters”, Int. J. Appl. Ceram. Technol., 2 [6] 429-439 (2005). This paper has the following abstract:

“Twenty-five years of diesel particulate filter (DPF) developments have shown that ceramic materials are well-suited candidates to fulfill the harsh requirements of exhaust after treatment. The introduction of DPF in passenger cars in Europe in 2000 was a real breakthrough from both a scientific and a commercial point of view. Different systems and filter materials can be used as DPF; however, at the moment silicon carbide wall flow filters seem to be at advantage. There is a continual demand for cost-effective and reliable materials and systems forced by increasing legal emission standards”.

Students designed posters in accordance with the instruction supplied. Figure 1 show two posters of this subject; poster a) is considered a very good one, while poster b) had a lower grade (is more superficial in terms of objectives, materials and processes, does not contain conclusions and has a poor design).

The analysis of the reports delivered by the students have shown that they can produce a very well structured report, with very high graphical quality (cover sheet, figures and tables, typing font and layout of the pages). This means that in the generality the reports are pleasant to read and the main conclusions and important data are very easily and quickly obtained by any reader.

The weak points detected in the reports are:

1. Many students still have difficulties in indicating the sources of the data, figures and tables used on the report, although very precise instructions were supplied to them;
2. Some did not understand the correct way to indicate the references along the text although they introduce the references in the end in a correct and complete way;
3. There is still a tendency to use as references, just websites. Although this is not bad, because much useful information can be obtained, this is not enough for engineering students;
4. They found more important and detailed information, related with the subjects taught on the course, when they analyse scientific papers, although many of them tend to search more papers just from the authors of the paper under study;
5. The great majority selected the two papers that they considered the most important and included them in the Annex, but they did not use the concepts/ideas contained on the papers in the report. This means that this capacity to extract the most important data (synthesis
capacity) from a subject that is studied and explained in detail is still a lack in students' capacities;

6. Most of the students focus on some innovative tendencies for the future, but many of them forget to check if the authors have published any other papers after the current one on analysis. This is a very important issue, considering that not all the papers submitted to the groups were from the same year, and many innovations could occur after the paper published date;

7. In the specific case of the paper “Ceramic Diesel Particulate Filters”, it was detected that the relation between the function of the filter and the type of ceramic material that is demanded for this particular application, namely the necessity to resist high temperatures and the porosity level, is very superficial touched. This means that students have some difficulties in relating the challenges for this type of components applications with the main topics that they learn in the course;

8. Students tend to explain adequately how the filter works because they found schematics and inclusive videos on the “net”. All of them talk about the main materials for this type of application, presenting their generalities and main properties, but they do not focus on how these filters are produced and what are the technical problems related with pressure drop along the filter. It is expected that they supply more experimental details; what are the challenges for the manufacturer or for the engineering group? Some of this information can be find on the papers supplied on the Annex of some group reports, for instance, the paper “Performance Evaluations of Aluminum Titanates Diesel Particulate Filters”, from R. S. Ingram-Ogunwumi, Q. Dong, T. A. Murrin, R. Y. Bhargava, J. L. Warkins and A.K. Heibel, in SAE Technical Paper Series, 2007 World Congress, Detroit, Michigan, April 16.19, 2007, is very helpful but not correctly explored;

9. Some students present the microstructures of the filters but they have difficulties in relating this type of microstructure with the process where the material is to be applied. Relating these concepts and inclusive with mechanical properties is still a difficulty.

RESULTS

From the work performed by the students, one can summarize the following points:

1. Students are still not very comfortable with this type of classes, and many of them tend to almost not raise questions to the colleagues, because they feel inhibited and are afraid of what the colleagues can think about them;

2. Some students are very active and participate intensively, but many times they just talk about generalities, when the teaching staff ask more detailed aspects of the work, and specially topics where it is necessary to relate the things that they read with the contents of the course, they have serious difficulties;

3. This is the second year of implementation of this type of work, and we figure out that students are improving and start to be more familiar with this type of classes. This is the only class, during their Integrated Master’s course in Mechanical Engineering, where they are confronted with this type of continuous evaluation.

We asked some students to give their opinion about this practical work, and the main points can summarized as:

1. Difficulties in read and understand technical English, but in the end they considered that they improved a lot;

2. Short period of time to perform the work, considering the requests that they had at the same time for other courses;

3. Difficulties in collecting information about more technical aspects, due to not find the correct papers and also because some of the papers that they considered interesting, based on the available abstracts, were not of free access;

4. They like the challenge for the deep study of the ceramic topics, considered the supplied papers interesting, learned a lot and should have even more time to better study the subject;

5. The work contributed to their synthesis capacity, and a systematic way to study a subject.

Figure 2 shows the percentage of approved students since the academic year of 2005/06 until the present. The graph reveals that the change from the classic grading (done with the classical exam 2005/06) to the present one (started on 2006) improved the motivation for the course, significantly increasing the number of approved students (we are just considering the students that were submitted to all the evaluation procedure).
It should be also referred that the slight decrease in the year of 2009/10 is due to fact that a more rigorous control of classes’ participation and assiduity gave us the capacity to distinguish students.

Figure 3 show the average final grade. This graph also shows an improvement on the average grades in the last four academic years.

CONCLUSIONS
The introduction of continuous evaluation in the course of Materials II of the Integrated Masters in Mechanical Engineering of Faculty of Engineering of University of Porto, changed with success the way that students study the ceramics subject.

It was demonstrated that the evaluation of the students with a practical work that demands a considerable search in the World Wide Web and databases, followed by the elaboration of a report and a public debate is a very demanding work that students enjoy and actively participate. This structure facilitates their learning and enrolment, increasing their knowledge about the ceramic topics covered on the course and contributes to the improvement of their research and synthesis capacities that they constantly will need in the near future.

ACKNOWLEDGMENT
We would like to acknowledge the students of the third year of MIEM (2009/10), Cristiano Coutinho, Pedro Marques, Ana Tavares, José Vilas, Albertino Arteiro and Nuno Santos, for their important feedback about the course.

REFERENCES