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MICROMET: A TOOL FOR PROMOTING EXPERIENTIAL LEARNING IN MATERIALS SCIENCE

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ABSTRACT

MICROMET is a web application aimed to help college students in Materials Science. This application is designed to promote an efficient tool for in-depth study of microstructure-properties interrelationships via a collection of duly classified metallic samples, becoming a complement to the instruction received in the classroom and laboratories.

In convergence with the European Space for Higher Education (EEES: Espacio Europeo de Educación Superior), experiential learning has been used in the University of Barcelona (UB) since 2001. In this case, experiential learning is understood to be active learning in which the student is engaged by developing an activity that is complementary to theory-based teaching. The aim of MICROMET is to provide teaching material that uses the new information technologies to enable the student to consolidate the learning process in a self-teaching way.

The present document gives a brief description of the application's design, as well as the solution of practical cases like those set out for students. Based on these cases, our aim is to appraise the potential of the information contained in the application. Thus, data related to the results of evaluation by the students are presented. These data were obtained during the application of experiential learning over the course of six different academic semesters.

Keywords: *Material sciences, experiential learning, web application, structure of materials, properties of materials.*

INTRODUCTION

In accordance with the directives established in the framework of the European Space for Higher Education, University teaching should stimulate and promote concrete alternatives to the one-way transmission of knowledge. In these new teaching methodologies, the student must become the protagonist, individually, or as an integral part of a group of students, and must be involved within the learning-teaching process.[1] This should not be a passive teaching, where the teacher is the sole protagonist, but an active learning, enabling the students to participate by developing an activity derived from the subject they are studying.[2]

In accordance with these directives, Spanish Organic Law on Universities 6/2001[3] indicates the possibility of using experiential learning, through the new information and communication technologies, in currently existing higher studies in Spain. In this sense, at the University of Barcelona it has been established that, of the 10 hours corresponding to each academic credit, a maximum of 2.5 hours can be dedicated to experiential learning.

There is no doubt that new technologies have promoted and fostered this type of learning/teaching, thus giving them meaning. These types of courses are a supplement to classroom instruction by the instructor, and at the same time a complement for the remaining material taught in the traditional classroom mode.

The promotion of experiential learning has such an impact that the Teaching Innovation which at present is being used by different University groups has been centered on the creation and amelioration of teaching material that makes use of the new technologies, mainly the Internet. In the end, experiential learning presupposes a change in pedagogic strategy which, via these tools, has been seen to be empowered and favored, both by the creation of innovative teaching and by the use that can be made of it. At the same time, students are observed to be attracted and interested in the use of this type of material, due both to its inherent novelty and to the fact of being able to use it from anywhere outside the academic environment. It is precisely on this fact that one can remark that truly this is an experiential and autodidactic type of learning.

At the University of Barcelona, the core subject of Materials Science is taught in the Chemistry Degree and in the Chemical Engineering Degree, and it is also an elective course, complementing the training in lower division courses, obligatory for those students that wish to access postgraduate studies in Materials Engineering, a degree program shared between the University of Barcelona and Barcelona Polytechnic University (UPC: Universidad Politécnica de Cataluña). In the curriculum (Plan de Estudios) for the Degree in Chemistry, the teaching load assigned to the subject of Materials Science is established as 7.5 academic credits, i.e. 1 academic credit is equal to 10 hours, and these are divided into 6 credits based on theory and problems and 1.5 credits based on required laboratory practice. This means that, according to the normative of the University of Barcelona, of the 60 hours of theory and problems, a total of 15 experiential hours can be assigned to the subject of Materials Science.

Attending to these needs, the Teaching Innovation Group on Structure, Properties and Processing of Materials (e-PPM: Grupo de Innovación Docente en Estructura, Propiedades y Procesado de Materiales), formed by professors of the Department of Materials Science and Metallurgical Engineering of the Faculty of Chemistry of the University of Barcelona, and accredited as such by the University itself, has designed an autodidactic web application, MICROMET, which enables students to use the new technologies to consolidate part of the concepts acquired during theoretical classroom teaching of the subject of Materials Science. This main objective is shared with other previous works that use the internet, via virtual lectures as proposed by McMahon[4], or using virtual modeling to create dynamic three-dimensional visualization as suggested by Ng[5]. Messler and DeFazio[6] described an interactive module to facilitate the teaching and learning of alloy solidification during welding taking into account non-equilibrium conditions. As described by Meier[7], artificial micrographs may be generated and used as practice in exercises involving measuring grain size etc. Sun and Economy[8] discuss distance learning examining diverse students' backgrounds in a materials selection online course. This is a particularly interesting case because they have a significant number of off-campus students who are working engineers. Davies *et al.*[9] emphasize the use of a flexible learning studio (FLS) with tutorial exercises based on commercial software available to the students. Goodhew[10] makes an interesting discussion about the differences between animations and simulations available from web sites, and between passive and interactive software. He suggests a project protocol for developing interactive software that agrees in substantial detail with the process followed by the MICROMET project.

THE MICROMET APPLICATION

The teaching programs of the Materials Science course, as well as the most important textbooks recommended, divide the content of the subject matter into three large blocks of knowledge: fundamentals, properties, and descriptions of materials. However, the Science and Engineering of Materials could be described as application of the knowledge that links the structure and the properties of materials, for the performance and application of such materials in industrial and technological fields.

With this premise, the MICROMET web application (which can currently be consulted at *http://www2.ub.edu/cmem/materials/html/index.htm*; user: invitado; password: invitado) was designed as a teaching tool which, taking advantage of the new information technologies, lets the student observe the relationship that exists between the microstructure and the properties of the metals and their alloys. The main objective is to make clear to the students how important is the effect that small variations in the composition and/or the history (thermal treatments, machining, etc.) of a metal cause in its microstructure. It is, therefore, a data base where one finds described (in a file for each of the most important metals and their alloys): its composition, nomenclature, classification, thermal treatments carried out, microstructure, and its most interesting properties from the point of view of technology. Thus, it is designed as a tool and resource to engage students of an introductory course with a science-driven approach. The Ashby tutorial database[11] is a powerful tool, widely used in Materials Selection instruction in a design-driven approach that makes it unsuited for a Chemistry degree, but not for a future Materials Engineering degree.

As the MICROMET is currently designed, it is susceptible to being modified and updated with files of other metallic alloys that are considered to be of interest. Furthermore, the teaching innovation group has the expressed desire to make the application available not only in Catalan, the standard transaction language of the University of Barcelona, but also in Spanish and in English, and to make it accessible to others in addition to the members of this University.

As a teaching tool, the application makes available only a small sample of reference metals and alloys in the area of knowledge. In previous study plans, these materials were studied in traditional classroom teaching laboratories such as Metallography, and in the current study plan, via the MICROMET application, the latter are incorporated as experiential content.

In the data base, and as set out in Table 1, the metals have been classified into six large groups according to the most important major metal or alloy. For each metal or alloy studied, there is an initial description of an entire series of characteristic descriptors: the name of the material, a brief description of it, its classification according to different international systems, and its percentage compos-ition. Additionally, it includes one or more micrographs at different magnifications, obtained by optical- or electron- microscope (SEM), with the corresponding description of these and their metallographic preparation, thus enabling the student to visualize the microscopic structure of the material: grain size, grain boundaries, phases present, twinning, crystal growth type, etc. To facilitate assimilation of the information described, other types of graphic information are included, such as phase diagrams or time-temperature-transformation (TTT) diagrams.

Table 1. Metals and alloys included in the web application MICROMET.

Classification	Name	Description
	Steels	
Steels	Steel	Carbon steel, 0.35%C, normalized.
Steels	Steel	Hypoeutectoid alloy steel quenched and tempered.
Steels	Steel	Hypoeutectoid alloy steel annealed.
Steels	Steel	Hypereutectoid steel.
Steels	Steel	Eutectoid steel normalized
Steels	Steel	Carbon steel , 0.35% C, quenched and tempered.
Steels	Steel	Carbon steel, 0.35 %C, quenched.
Steels	Steel	Carbon steel, 0.35 % C, cold rolled.
Steels	Steel	Stainless steel. Austenitic 18/8
Steels	Steel	Carbon steel, 0.08% C.
	Cast irons	
Cast irons	Gray cast iron	Compacted gray cast iron
Cast irons	Gray cast iron	Spheroidal gray cast iron
Cast irons	Gray cast iron	Laminar gray cast iron
Cast irons	White cast iron	White cast iron
	Coppers	
Coppers	Brass	Brass cold worked and annealed at 750°C
Coppers	Copper-oxygen	Copper extruded
Coppers	Aluminum bronze	Hypoeutectoid aluminum bronze annealed
Coppers	Aluminum bronze	Eutectoid aluminum bronze quenched
Coppers	Brass	Brass cold worked and annealed at 600°C
	Nickels	
Nickels	Monel	Nikel Alloy
Nickels	Inconel 600	Nikel Alloy
Nickels	Nimonic 75	Nikel Alloy
	Aluminums	
Aluminums	Aluminum-copper	Quenching and annealing 70 hour at 260ºC
Aluminums	Aluminum-copper	Aluminum alloy sand casting
Aluminums	Aluminum-copper	Aluminum
	Titaniums	
Titaniums	Titanium-aluminum-vanadium	Forged at 950ºC, cooled 6 hours at 600ºC and normalized
Titaniums	Titanium-aluminum-vanadium	Titanium alloy forged at 1050 ºC, annealed 2 hours at 1050ºC and quenched

Finally, and for each metal or alloy, according to its composition, shape, and thermal treatments, its main mechanical properties are detailed (limit of proportionality, tensile strength UTS, hardness and impact resistance), as well as physical properties (density, electrical resistance, magnetic properties, coefficient of thermal expansion, specific heat and thermal conductivity), chemical properties (corrosion resistance) and technological properties (machinability, conformability, weldability and recyclability).

To provide incentive for the use of the web application as an experiential teaching tool, the student of Materials Science is, throughout the course, offered a series of questions of different degrees of difficulty. By surfing and performing different searches in the data base, the student can answer the questions. Shown below, by way of example, are two types of questions that are offered to students to solve by searching the data base.

<u>Practice Case 1</u>

Copper of a purity of 99.96% can contain up *to 400 ppm of oxygen. Where and in what form is oxygen found in the microstructure?*

The student can carry out searches for types of metal (Figure 1), or keywords. Selecting a particular material such as biphasic copper-oxygen (Figure 2) opens a screen (Figure 3) with the data on composition and classification of the material, as well as links to the microstructure, where the preparation and the chemical etching to resolve the microstructure are described (Figure 4); to the phase diagrams and/or thermal treatment diagrams (Figure 5); and a sets of tables with the most relevant mechanical, physical, and technological properties.

Practice case 2

Compare the microstructure and the mechanical properties of a hypoeutectoid steel with a normalizing treatment and subsequently with a tempering.

In this case, the student can select different files corresponding to a hypoeutectoid steel, with a carbon content of 0.35% and with different thermal treatments, and thus be able to compare the microstructure in each case as well as the mechanical properties (Figure 6).

Additionally, the student will find some keywords defined and a glossary of terms with the most usual words in different languages and their definitions. This is accessible at any time.

EVALUATION AND STUDENTS' RESPONSE

Prior to its application in the Materials Science courses for undergraduate students of Chemistry and Chemical Engineering, the application was evaluated by PhD students, and this has made it possible to detect and correct errors. The students access the application via the virtual campus, and 3500 consultations have been registered since 01/12/2004.

In terms of the degree of satisfaction of the students, the application has a section available for comments and suggestions; parallel to this, the instructors have provided an anonymous questionnaire for the students of each course. First the students were asked if they considered

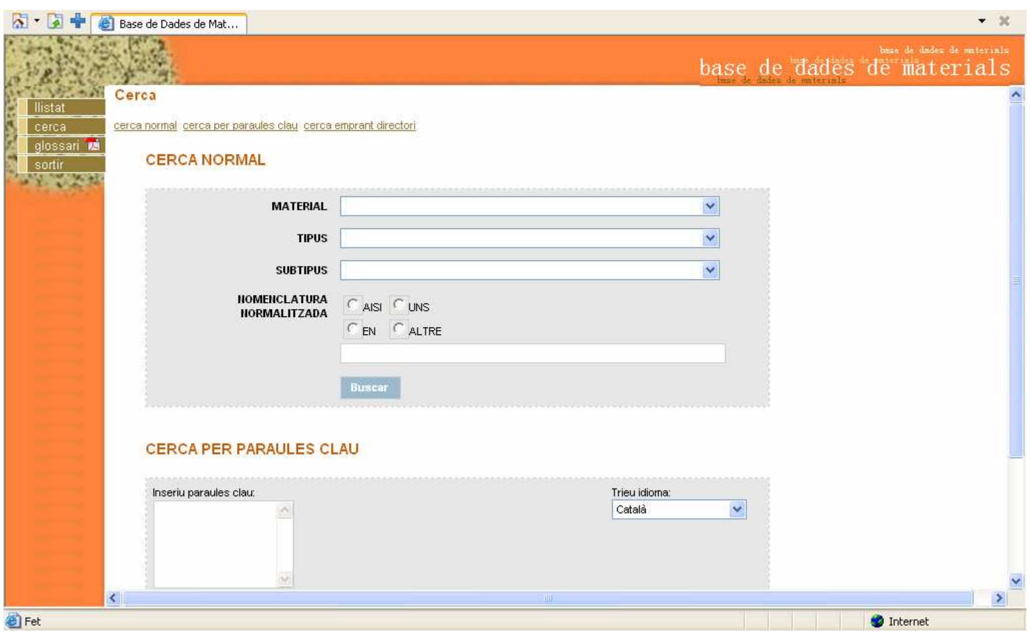


Figure 1. This search screen helps the student to perform a search by type/subtype of material e.g. cast irons, aluminum alloys etc, by clicking and unfolding the different items. Also a search by keywords with choice of language is possible.

Figure 2. A complete list of the materials included in the database, as well as a short description of each one is also available.

Figure 3. Several data describing the material, name, classification, are shown in this screen.

the tool MICROMET interesting and 86% of undergraduate students answered positively. They also were asked about the targeted audience, if they considered that MICROMET could be of interest for undergraduate and postgraduate students, and also for off-campus students. These questions were answered differently by PhD students than by under-graduate students. In general the postgraduate students consider the application more interesting for undergraduate students than for postgraduates or off-campus students. Finally

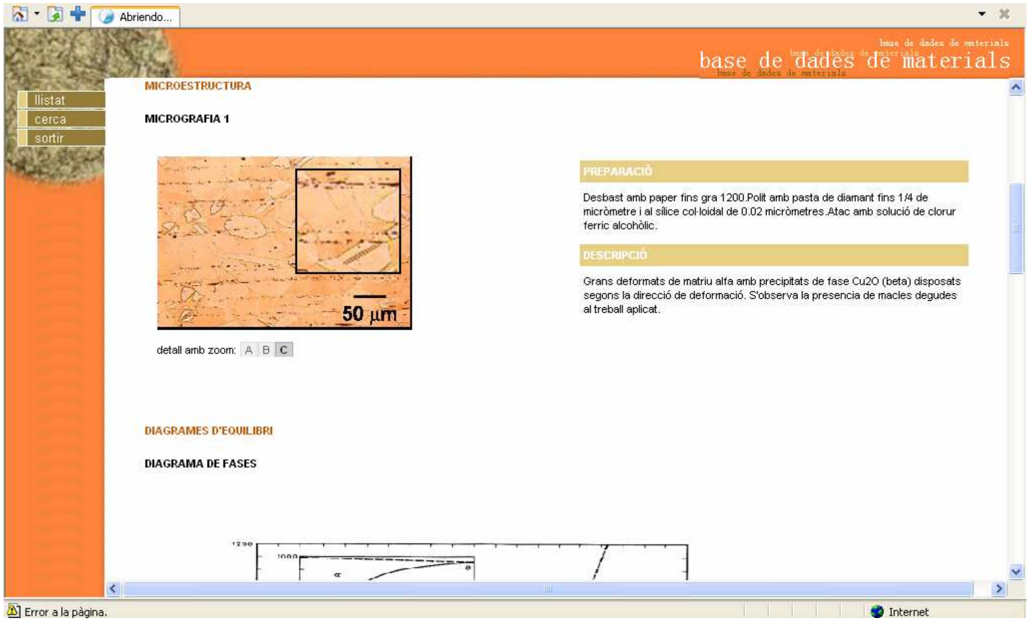


Figure 4. By clicking on *microestructura* the student can observe all the micrographs available for a specific material, as well as the information relative to sample preparation and a short description of the observed microstructure.

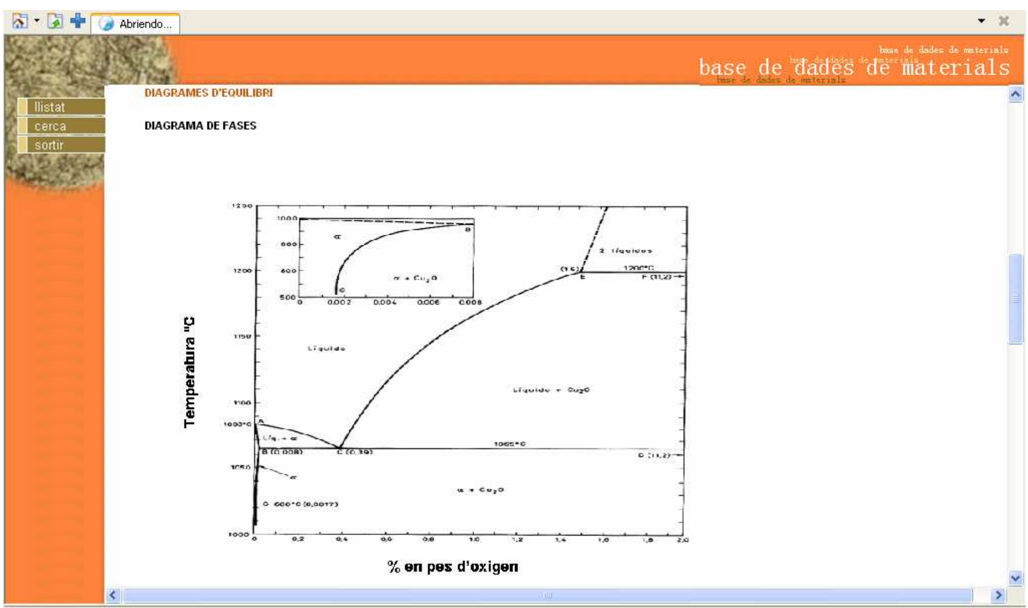
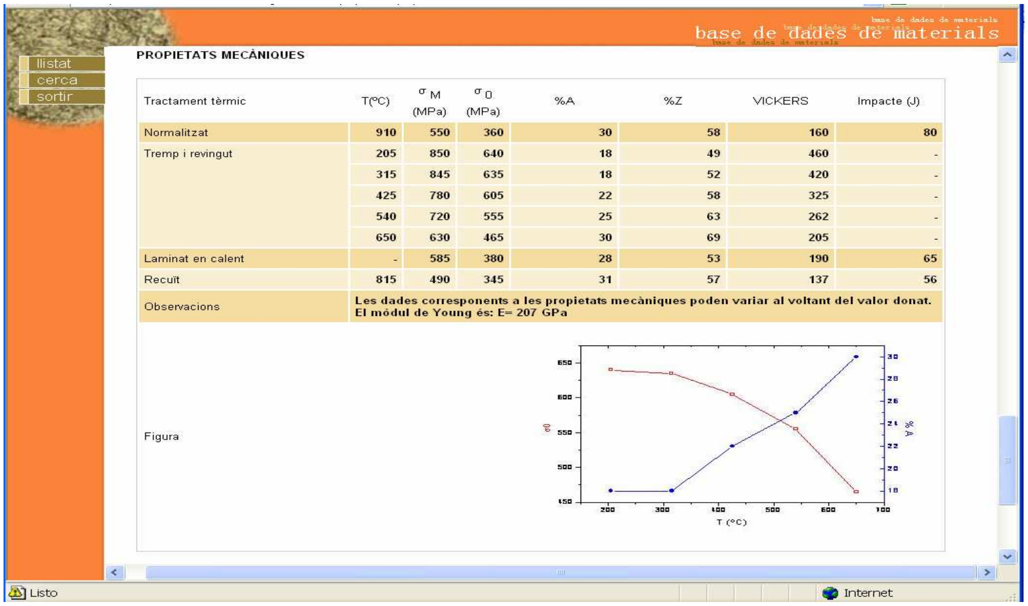


Figure 5. By clicking the link *Diagramas de equilibrio* the student will have the equilibrium phase diagram, with the location of the studied composition.



Tractament tèrmic	T(ºC)	σ M (MPa)	σ 0 (MPa)	%A	%Z	VICKERS	Impacte (J)
Normalitzat	910	550	360	30	58	160	80
Tremp i revingut	205	850	640	18	49	460	-
	315	845	635	18	52	420	-
	425	780	605	22	58	325	-
	540	720	555	25	63	262	-
	650	630	465	30	69	205	-
Laminat en calent	-	585	380	28	53	190	65
Recuït	815	490	345	31	57	137	56
Observacions	Les dades corresponents a les propietats mecàniques poden variar al voltant del valor donat. El mòdul de Young és: E= 207 GPa						

Figure 6. For this hypoeutectoid steel by clicking the link *Propietats mecàniques* the student has a table of mechanical properties and can evaluate their variation as a function of the thermal treatment conditions.

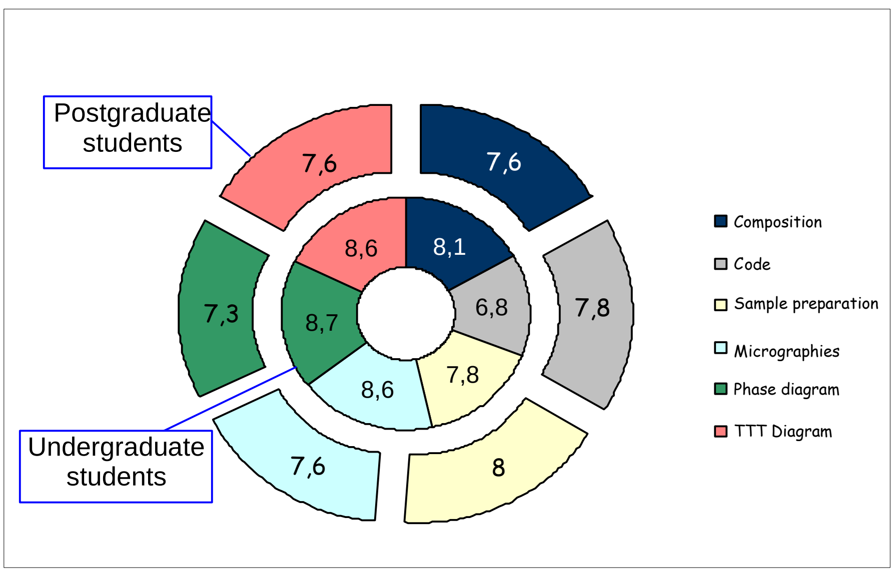


Figure 7. Score (scale 1-10) obtained from the anonymous questionnaires answered by 15 postgraduate students and 123 undergraduate students.

they were asked to score from 0 to 10, which information included in the different parts the application they considered to be more interesting. The summary results of the students' responses are presented in Figure 7.

In general, undergraduate students score higher, and this is probably because they are introducing themselves to a new field of knowledge quite different from the chemistry curriculum.

CONCLUSIONS

The MICROMET web application is a tool for promoting experiential learning for Materials Science at the undergraduate level that relates the microstructure of different metals and alloys with their composition, thermal treatments, and most relevant mechanical, physical and/or chemical properties.

Because this is a case of an open application, it is possible to incorporate new alloys of technological interest.

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