



## The idea of material science virtual laboratory

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Received 23.06.2010; published in revised form 01.09.2010

### Education and research trends

#### ABSTRACT

**Purpose:** This article was written to describe the Material Science Virtual Laboratory. Presented laboratory is an open scientific, investigative, simulating and didactic medium helpful in the realisation of the scientific and didactic tasks in the field of material Science. This laboratory is implemented in the Institute of Engineering Materials and Biomaterials of Silesian University of Technology in Gliwice, Poland.

**Design/methodology/approach:** The laboratory is an aggregate of testers and training simulators, placed in the virtual reality and created in various languages and the programming techniques, which represents the properties, functionality and manual principles of real equipment installed and accessible in the real laboratories of scientific universities.

**Findings:** Application of the equipment, that is practically imperishable, cheap in exploitation and easy in the use encourages students and scientific workers to independent audits and experiments in situations, where the possibilities of their execution in the real investigative laboratory will be limited because of the high material costs, difficult access to real equipment or the possible risk of his damage.

**Practical implications:** The use possibilities of the virtual laboratory are practically unrestricted; it can be a base for any studies, course or training programme.

**Originality/value:** The project of the virtual laboratory corresponds with the global tendency for expand the investigative and academic centres about the possibilities of training and experiments performance with use of the virtual reality. This enriches investigation and education programmes of the new abilities reserved so far exclusively for effecting only on real equipment

**Keywords:**

**Reference to this paper should be given in the following way:**

L.A. Dobrzański, R. Honysz, The idea of material science virtual laboratory, Journal of Achievements in Materials and Manufacturing Engineering 42/1-2 (2010) 196-203.

### 1. Introduction

Materials Science Virtual Laboratory (Figs. 1, 2) is a tool developed in Institute of Engineering Materials and Biomaterials, Silesian University of Technology, Gliwice, Poland. Its primary aim is results visualisation of investigations, simulations and

predictions made by utilisation of materials numerical model. Laboratory's secondary aim is to acquaint students and young scientific staff with investigation methodology in wide range of material science. In virtual workrooms simulations of investigative equipment, such as light and electron microscope, hardness tester or Charpy hammer, is placed. The main concept of virtual laboratory is to replace real machines with their virtual

simulations. Real investigative equipment is often not available for students, expensive in usage and difficult to manipulate. Misplaced manipulation can cause damages or life threat situations. Virtual simulations are cheap and safe in use, because all mistakes can be easily erased by simulation reset without any consequences.

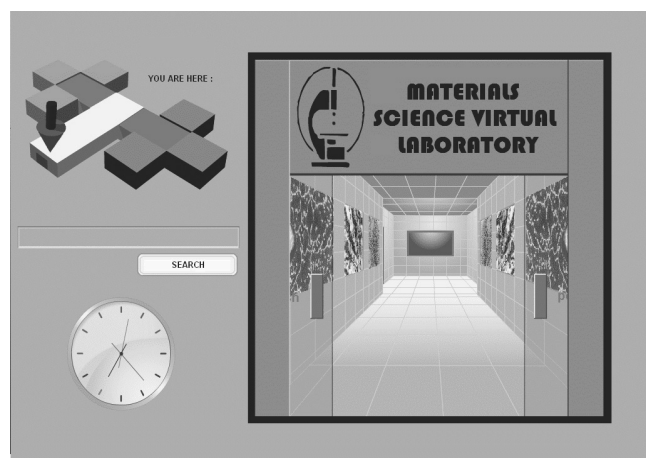
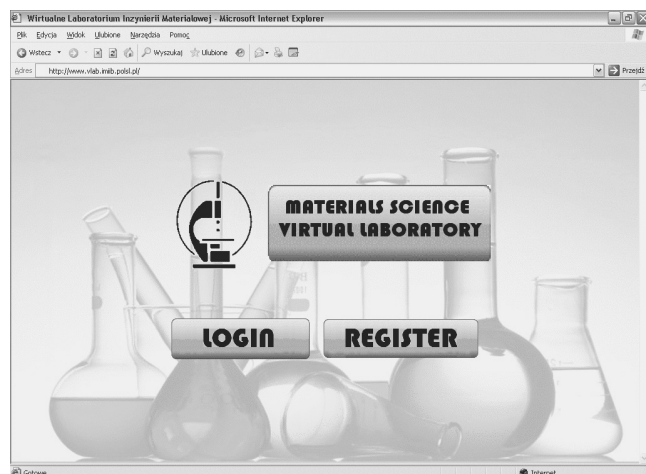


Fig. 1. Materials Science Virtual Laboratory a) login and registration page, b) main entrance

Materials Science Virtual Laboratory is placed on e-learning platform. It is available for all students and persons interested in enlarging their skills in investigations methodology. This is the only chance for users without access to real laboratory. In virtual reality it is possible to learn how to proceed with investigation in the real world. Student can make investigations and experiments with simulations as practice before their classes on real equipment.

To access the laboratory a PC class computer with connection to internet is required. Hardware requirements aren't high. Minimum is processor Pentium II 300 MHz, 64 MB RAM memory and 10 Mb/s network card. Software requirements are

operational system with graphic user interface, such as Windows or Linux and internet browser with Adobe Flash plug-in.

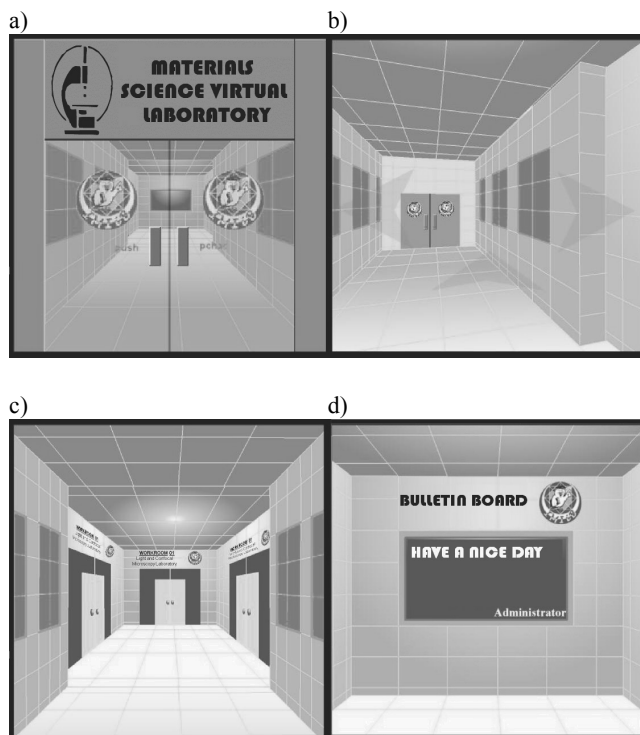


Fig. 2. Materials Science Virtual Laboratory a) entrance, b) main corridor, c) workrooms, d) bulletin board

## 2. Investigation methodology

Users, whose wants to begin the work with virtual devices need to log into the system with their login and password. New users should register with use of special panel. After passing all necessary information's main doors will open and from now on laboratory recourses are available. Virtual walk through corridors takes the user to appropriate workroom. One click on workroom's door is necessary to open them and enter inside. Available is several simulations placed in six workrooms. Inside, one click on the machine will activate the simulation. The investigation methodology on simulations is exactly this same as in corresponding real devices. All effectors, such as buttons or handwheels are placed in simulations in corresponding places as in real machines. The functionality of real machines is simulated as it is without any changes and modification. User through the work with simulations should learn how to manipulate real devices in real world. Additionally, in every workroom interactive didactic materials are placed. There are manuals, training exercises and many others to make the work easy and intelligible.

### 3. Materials science virtual laboratory description

Materials Science Virtual Laboratory consist of four workrooms, in which six virtual devices are placed. Also present are the scientific library and communication system, which is used for passing information's between student, teachers and instructors.

#### 3.1. Light, confocal and electron microscopy virtual laboratory

In light and confocal microscopy workroom (Fig. 3) three devices are present.



Fig. 3. Workrooms of Light, confocal and Electron Microscopy Virtual Laboratory

Virtual metallographic light microscope simulation (Fig. 4a) is based on Leica 4A/M. It simulates basic functions such as manipulation of sample table, regulations of magnification, light intensity, image sharpness, and observation techniques. In real device all these functions are accessible through effectors placed on device's housing. In Simulation all functions are called out by clicking on symbols placed on the microscope picture in this same positions as real effectors on real machine. Over thirty different engineer materials are placed in simulation as virtual samples.

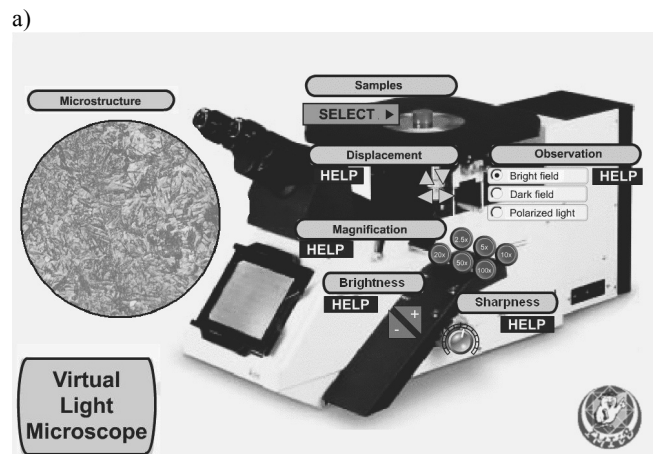


Fig. 4. Simulation of a) metallographic light microscope, b) scanning confocal microscope, c) scanning electron microscope

Simulation of a virtual scanning confocal microscope (Fig. 4b) was based Zeiss LSM500 microscope. It allows the user to learn the basic capabilities of confocal microscope. It is a modern variant of a fluorescent microscope in which the light source is a laser. With this equipment it is possible to analyse the optical cross sections on the surface or inside in samples. Simulation gives control over three channels of data collection, respectively, for red, green and blue laser controlled by symbols on the microscope. The symbol on the housing right side regulates the sample scanning depth. Options included on the keyboard are brightness, contrast, saturation and colour. Additionally help keys explains the importance of appropriate option and how to use it. Observations are initiated from a sample selection menu. The next step is selection of required penetration depth and adjusting parameters of laser beams. Structure Images are presented on the monitor screen. Full size image is available through binocular eyepiece. Blue and green arrows placed on the microscope controlling actual position of the sample inside the chamber and the picture magnification.

Scanning electron microscope is a microscope that for pictures creation uses an electron beam instead of light. Developed a virtual model of scanning electron microscope (Fig. 4c) is designed to simulate the functionality of Opton DSM 940 microscope. It allows to simulate the most commonly used features used during investigations, such as setting an appropriate accelerating voltage, change the magnification, coarse and accurate focus and the ability to switch between two display modes. It is also possible to alter the position of the sample inside the chamber. The virtual sample examination is preceded by an interactive animation showing the chamber opening, inserting the sample on the table and producing the necessary vacuum inside the chamber.

### 3.2. Heat treatment virtual laboratory

The equipment of heat treatment workroom (Fig. 5) consists of a surface induction heater. Hardening of the surface is made by rapid heating of the element surface to temperature above the austenitizing temperature and high-speed in water stream necessary to obtain a martensitic structure in element surface layer.



Fig. 5. Workroom of heat treatment virtual laboratory

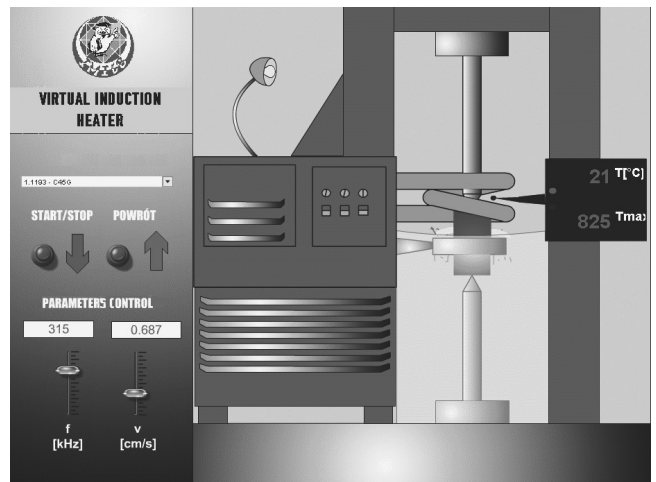


Fig. 6. Simulation of surface heater

Presented simulation of surface heater (Fig. 6) allows controlling the feed speed of the steel samples through the inductor and induction current and frequency. Simulated are the temperature of the surface layer and its structure after the heat treatment process. Due to the construction of heaters, as the highly specialized equipment presented simulation isn't modelled on any particular model available on the market. As a general machine pattern G013 bolt heater was used. Its operation is extremely simple. After material selecting and sample installing user needs to input the appropriate frequency, current and feed speed of the inductor. Hardening process takes place automatically after pressing the start button.

### 3.3. Material investigation virtual laboratory

In the workroom of tensile test examination (Fig. 7a) the universal tensile test machine is installed. In the workroom of materials properties examination (Fig. 7b) are universal hardness tester and a Charpy-type impact hammer.

Static tensile test of metals is a fundamental examination method in researches of materials mechanical properties. Through such tests information about the yield stress, strength stress of different materials are obtained. Shown on (Fig. 8a), virtual simulation is a model of the universal testing machine Zwick ZSN100. Simulation has the necessary functionality to allow implementation of the static strength tests in the elastic and plastic area. After activation and calibration of the virtual machine user needs to mount the sample. Samples are in the tray located on the left side of the machine. After that, the control panel is activated and the parameters of performed investigation should be inputted. After examination start the behaviour of samples in the machine, as well as graphical representations of the results are presented on the screen.

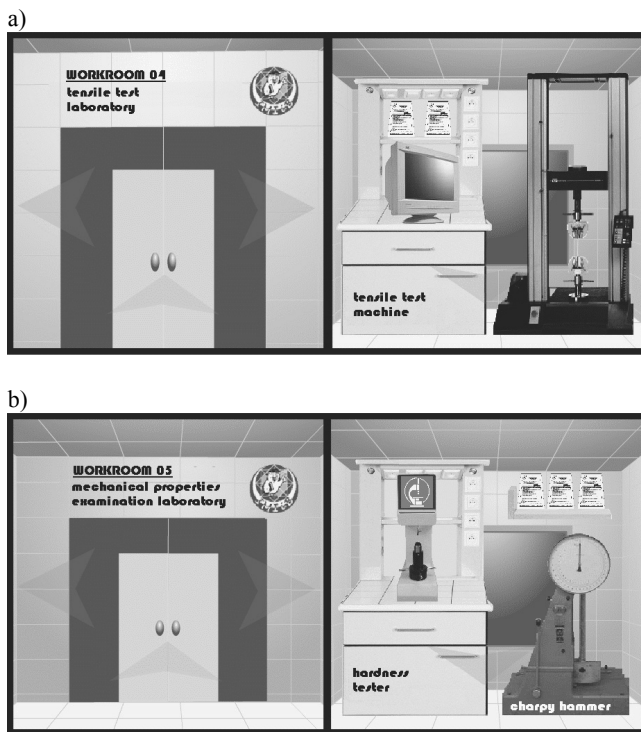


Fig. 7. Workrooms of materials investigation virtual laboratory

Hardness can be determined as a measure of material resistance to permanent deformation resulting from pressing the indenter. Virtual universal hardness tester (Fig. 8c) corresponds with the functionality to Antonik AEDT model. It is possible to test the hardness of flat samples with use of Brinell, Vickers and Rockwell methods. Simulated are a set of indenters and a set of several materials samples. After starting the machine in the first step the user must attach the indenter, and, according to the choice, select the hardness measurement method. Next step is sample attachment. The measurement is automatic and is started at the time when the sample surface contact with the indenter. After completing the test user receives the measurement result, or error message if the test failed.

The simulation of Charpy type hammer (Fig 8b) is based on Amsler RKP450. In dependency investigated material sample type and force range can be set. Range setting can be achieved by change of the mass, or by change of the pendulum elevation angle. Mouse or appropriate effectors manipulate the pendulum. In sample tray several samples of different engineer materials with several shape notches are prepared. User should catch the pendulum and block it in the top position. A sample from the tray should be placed on the machine table. One click by mouse button on the hook releases the hammer, which strikes the sample. The work spent on fracture of the sample can be read from arrow pointer, which enlarged appears on the hammer's right side.

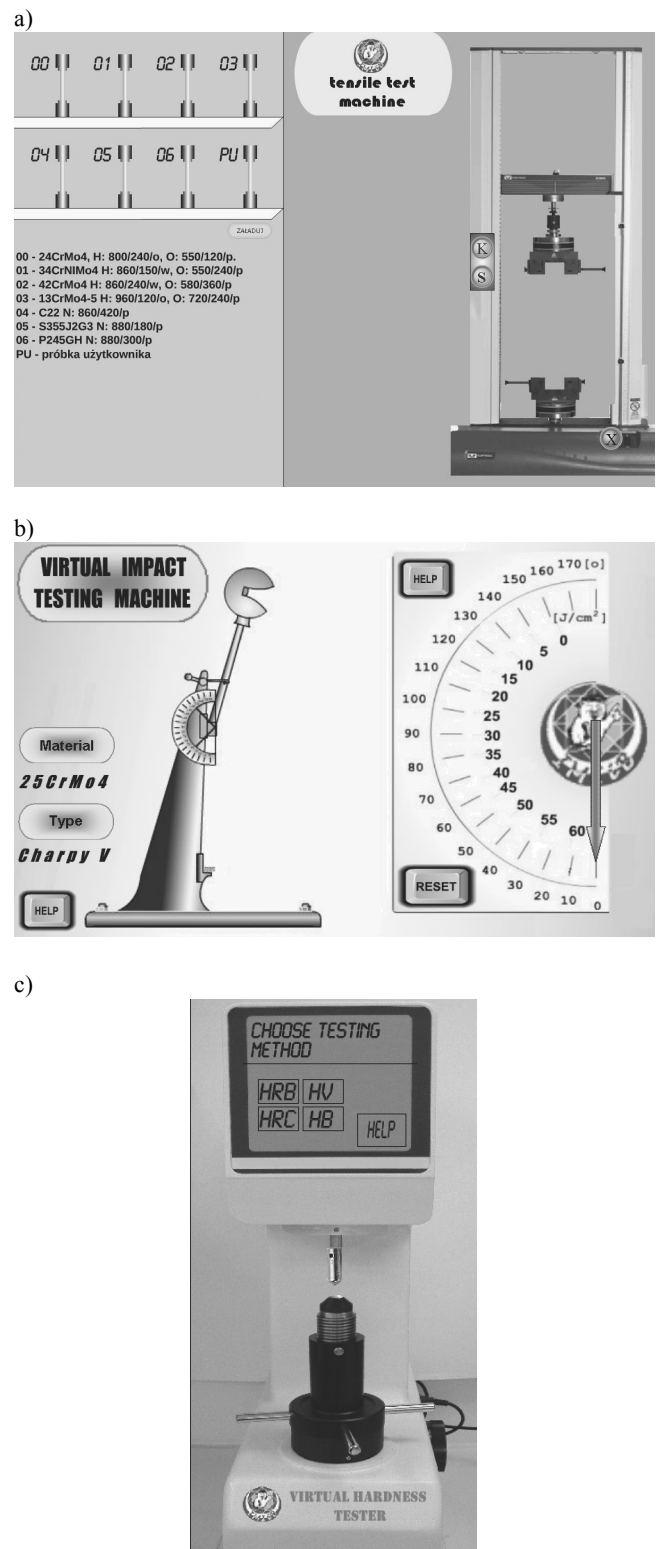


Fig. 8. Simulation of a) universal strength machine, b) Charpy type hammer, c) universal hardness tester

### 3.4. Samples preparation virtual laboratory

In order to implement virtual experiments in workroom of virtual preparations (Fig. 9.) a panel serving for generation of samples (Fig. 10) was developed. This panel is used to generate a material sample of existing or hypothetical, newly proposed material. It is divided into sections. User needs to input all necessary values from the given range of chemical composition, conditions of heat and plastic treatment and elements shape and geometric dimensions. After that, material samples file is generated. These files are placed in machine simulators to investigate the mechanical properties or structures using the available virtual apparatus.



Fig. 9. Samples generation workroom

MATERIALS SCIENCE VIRTUAL LABORATORY		VIRTUAL SAMPLE GENERATOR	
Material selection: Skład chemiczny		<b>Chemical</b>	
Material list: St35		0.41 %C	
Plastic treatment: Walcowanie		0.58 %Mn	
Heat treatment: Ulepszanie ciepłe		0.03 %Si	
Geometry: diameter: 140 mm, section: Okragły		0.13 %P	
Normalisation: Temperature: 740 °C, Time: 480 min, Coolant: Olej		0.005 %S	
Quenching: Temperature: 880 °C, Time: 50 min, Coolant: Woda		1.57 %Cr	
Tempering: Temperature: 540 °C, Time: 20 min, Coolant: Powietrze		0.16 %Ni	
		0.1 %Mo	
		0.001 %W	
		0.16 %V	
		0.003 %Ti	
		0.18 %Cu	
		0.36 %Al	
<b>GENERUJ</b>			

Fig. 10. Virtual samples generation panel

In materials sample trays with samples permanent implemented in simulations, there is an option for loading an external sample into the machine. This sample will be sending

through loading panel to appropriate simulation and then open the machine. After closing the panel, loaded sample will appear in the tray in the prepared place. At the same time in the machine can be pre-loaded only one external sample. Loading of another sample deletes the sample currently contained in the memory simulations.

### 3.5. Library and communication system

The laboratory consists not only of equipment simulations. Teaching aids, exercise instructions, manuals and tutorials are no less important for the processes of active learning. Adequately prepared supporting materials are necessary in the processes of research and teaching. Materials Science Virtual Library is available from each laboratory by the manuals icons included in every workroom (Fig. 11).

Library is divided into three sections. The first one included interactive presentations such as the periodic table of elements and iron-carbon equilibrium diagram, which contains a knowledge compendium about presented topic, allowing quick and easy access at one time. Only a single mouse selection is necessary on the field of the element or structure to display the detailed data along with pictures and examples. There is also a calculator to assist the engineering calculations. The main section of the library contains electronic books on topics related to research and exercises implemented in the laboratory. User can find here studies on light, electron and confocal microscopy, tensile strength, toughness and hardness, as well as information on sample preparation for research purposes.

The possibility of communication is essential in teaching and research. Contact between students, which are carrying out similar tasks and contacts with leading attachment, significantly affects the learning process. In the real laboratory students cooperating with each other and often share their experiences, raising their qualifications. This possibility can't be absent in a virtual laboratory.

## 4. Results and discussion

The frames of this article allowed only for the very cursory presentation of the Material Science Virtual Laboratory project. However, this few examples have shown potential use possibilities of the virtual reality to scientific and educational aims. The interaction with simulations of investigative equipment opens new possibilities in acquiring of knowledge and skills from the field of material engineering. The virtual laboratory is a modern educational and accessible platform for all users. It delivers the knowledge not only to students, but also to teachers and other persons, who want to expand their knowledge with the functioning and operating methods of investigative equipment. The respective elements of the laboratory are the attractive introduction of the studied task and they can be applied directly at the university classes as the program fundamentals of materials science projects, or as supplementary units of the teaching programme. In both cases the education process is richer about new possibilities of traditional and distance learning.

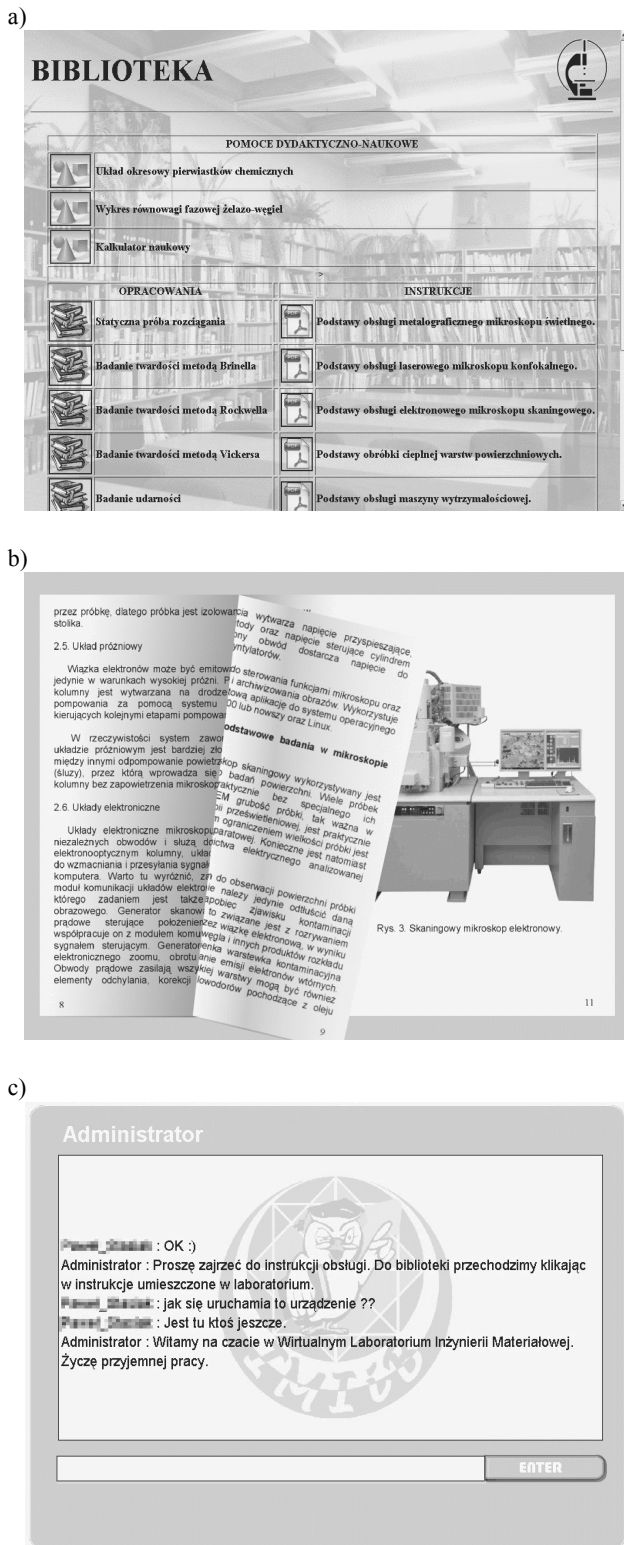


Fig. 11. Library placed in Materials Science Virtual Laboratory  
a) main page, b) e-book, c) chat.

## Acknowledgements

The authors would like to thank the administration of “Batory” foundry for access to their research results, and to Zeiss Polska for the biological samples which were helpful in the building of the virtual confocal microscope.

The paper has been realised in relation to the project POKL.04.01.01-00-003/09-00 entitled “Opening and development of engineering and PhD studies in the field of nanotechnology and materials science” INFONANO, co-founded by the European Union from financial resources of European Social Fund and headed by Prof. L.A. Dobrzański.



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## Additional information

Selected issues related to this paper are planned to be presented at the 16<sup>th</sup> International Scientific Conference on Contemporary Achievements in Mechanics, Manufacturing and Materials Science CAM3S'2010 celebrating 65 years of the tradition of Materials Engineering in Silesia, Poland and the 13<sup>th</sup> International Symposium Materials IMSP'2010, Denizli, Turkey.

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