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Forming a Virtual Material Lab

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Virtual lab, materials science, animation, computer assisted instruction.

Abstract
Theoretical knowledge taught to students in Faculties of Engineering and Technical Education in chapter lectures needs to be reinforced by applying them in the laboratory or supporting them by simulations. In the formation of a laboratory; restrictions such as appropriate physical environment, time, expensive equipment supply and security are encountered. These restrictions bring out the need to search for appropriate alternatives. It is possible to design experiments independent to space, time and high costs as virtual lab simulations, being an alternative to conventional laboratories. Although the use of virtual laboratories in education does not replace the traditional laboratories, they can be considered as supportive to education. Material laboratory is needed to study science of materials effectively. But most of the universities do not have laboratories or enough materials to be used. Students have difficulties in such cases. Even if there is not any lack of equipment in laboratories, students have a hard time learning the application. Students will have a previous knowledge before going to laboratory by using multimedia techniques (showing pictures, playing videos, sounds etc…). Passing the subjects of science of materials to students by showing pictures and animations will make the education easier, more understandable and permanent, and therefore it will contribute to students' success. The purpose of this study is to improve the quality of Materials Science course using the multimedia features in the face-to-face education. In recent years, multimedia is becoming a whole new way of educational environment. Its role in education is giving more importance to active participation learning rather than passive rote learning. In classes where multimedia methods are used, with the combination of audio-visual aids and animated video games, communication is functioning as entertainment. Therefore, applications being informative as well as fun, offers students an enjoyable learning environment. Within the scope of the study, an education material was created using animations, pictures, graphics and course content. By the help of this material, we can teach the basic subjects and the experiments of the materials science lesson and make them more memorable. And we can support students to get previous research of the subject before going to class at the faculties where they haven't got labs. At the first stage of the study, local and foreign literature was scanned, the information were gathered together and the notes of materials science lesson that students can use have been collected. Later, animations were

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prepared using the programs “Macromedia Flash, Swish and Java” to use in teaching, according to subjects of the lesson. The animations which have been taken from the local or foreign websites were also used for this purpose. A comprehensive educational material including the material science subjects was prepared using the notes, animations, pictures, graphics and documents such as animated .gif. These were brought together using Dreamweaver and Frontpage programs with the HTML code. The shapes and graphics of materials science subjects are difficult and complex to draw on the board. Using the virtual laboratory, no time is wasted by drawing the figures and graphics on the board and topics are presented to students more quickly, more understandably and in a fun learning environment. With this study, students will intensify the virtual laboratory simulations of the experiment and will be more able to adapt in real laboratory environment that has time limitations, and will be able to remake the experiments that they did not understand so it will help them make the experiments more memorable. Even after the completion of training period, this study will serve as an instrument for the students in their personal learning environments. Presentation of the experiments and different material properties enables the students to learn by seeing and understanding. This developed material supports the improvement of education quality both in face to face education and distance education.

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1. Introduction

Traditional teaching-learning environments, crowded classes and the limitation of time and education environment affect the participation of students to the learning process negatively. Usage of computers in education is an effective method to overcome these problems [10]. Computers can provide new materials to students based on one-on-one basis and prepare exercises regarding these materials. Computers can correct the answers the students give to these exercises, they also can help follow up the materials to eliminate inadequacies observed in students and correct the misunderstandings caused by the exercises [12]. Computers, beyond comparison, have more speed, feedback and versatility than other teaching methods [15]. Computers help use educational time in an efficient way. Students spend their limited time by doing efficient activities. The students are rewarded automatically for every learning activity they are engaged in [7]. Transfer of educational contents or activities via computers is called computer assisted instruction. Computer assisted instruction both increases the success and helps improve the high level thinking skills of the students. Thus, students learn by comprehending rather than memorizing [4]. Computer assisted instruction provides easy access to information with internet and education packages, explanatory information, examples and skill practice opportunity [17]. When the teachers giving computer assisted instruction are asked about the advantages of this education model compared to the traditional education, these are the answers: ‘’there is more time to discuss the subject with students, it is possible to analyze the subject more profoundly and complicated subjects are taught more easily’’ [5]. With the development of technology, virtual lab applications in the field of computer assisted instruction are becoming more widespread today.

A virtual lab can be defined as a computer environment providing interactive learning in experiments needed to be conducted to gain application experience in education. Virtual lab usage tends to be increasing rapidly in the engineering departments of higher education institutions. Öğüt et. al. (2004), created a source made up of animations to support ''Agricultural Tractors'' course taught in their study, called ''E-Education with Computer Assisted, Web- enabled, Interactive Education CD''. With this source, the subjects are made memorable by supporting the visual learning methods, which are used in order to prevent subjects remain a theory, with animations. Thus, it was aimed that the students can repeat this course in a computer environment, independent to space [16]. In his research called An Integrated Virtual Learning System for the Development of Motor Drive System, Keyhani (2002) conducted the power electronics laboratory experiments, which the engineering students have difficulties in, in a web-based, real-time virtual lab environment. It was observed that the application at the end of the study made it easier for students to comprehend complicated concepts [9]. In their study Akın et. al. (2003) managed to run a machine with a driver by using LabView program and made it possible to analyze every detail of the system. This will help working with a much more comprehensive structure of instruments which otherwise would remain a closed box in a real laboratory. For that reason, a virtual lab built by creating simulations of all electric machinery will not only be a help in terms of cost, but it will also help make the experiments more comprehensible for students [1].

Kantar (2002) conducted a research about the effects of multimedia usage in 8-Grade Science lesson on the success and attitudes of the students. In this study, a Science lesson subject was planned using a systematic teaching method different from traditional teaching planning and multimedia was included in the learning environment. While lessons were taught traditionally with a plain expression and laboratory studies in the control group, lessons were taught in a computer assisted electronic classroom where appropriate software programs could be used in the experimental group. Later, tests were done in both groups. An increase in favor of the experimental group was observed when the averages of both groups were compared [8]. A virtual lab was developed for the virtual creation and configuration of computer networks, which is of great importance in Computer Engineering. All kinds of configurations can be made with such a network structure consisting of computers, keys and routers as if working on a real network on a computer. Besides being beneficial in terms of cost, this structure provides an easier understanding of the whole structure visually. Moreover, as there is no harm of doing wrong configurations, such an application would help students with comprehension and gaining experience [3]. Computer-based tools give the students a chance to start the experiment, follow the procedure, complete the experiment, collect analysis data and evaluate findings. This educational tool decreases the dependence of the students to the teachers and forces the teacher to make the learning process more meaningful. It makes the students decide and there may be right or wrong outcomes of the observation of results. But in the end of the experiment, the students may have made a good observation [6]. Students can bring the learning process out of the campus. They wouldn't be dependent on just school and classes [13]. Being one of the basic science lessons, Material Science is extremely important in training technical personnel [1]. There are some difficulties in teaching material science. It is possible to list these difficulties as follows;

- Most of the students are not familiar with the Material Science terminology
- Most of the subjects in Material Science lessons, should be demonstrated with three-dimentional presentations rather than drawings. For example subjects such as crystal lattice, atomic structure, phase diagram etc. are hard to explain with drawings on boards and it is also hard for the students to envision these subjects.
- The infrastructure required for Material science application classes is impotent. [2] [11]

For the reasons mentioned above and some other similar reasons, the students usually leave classes without fully comprehending the subjects explained in lessons.

This study aims that the 'Material Science' lesson in bachelor degree level schools are taught by using computer assisted animation and web technique and it aims to increase student success rates by using these techniques in the visual introduction of expensive, unavailable equipment and materials and in the application of experiments. In the study, a visual lab education package is created, consisting of two-dimensional animations made by using lecture notes on the basic Material Science subjects, pictures, application programs, graphics, animated GIFs and Adobe Flash program. It is aimed that with this package, the basic subjects and experiments of 'Material Science' class can be taught in bachelor degree level units that don't have a laboratory or in the schools with laboratories this can give the students a chance to make a preliminary research on the subjects before class. Besides, it is anticipated that student success will increase by creating an opportunity to repeat this class outside the campus. An extensive literature review was made for this study.

Lecture notes and animations from the web-sites of different universities from especially U.S.A. and England were analyzed. Some problems such as disarrangement and limited range of subjects were detected in the sources found. This improved study covers the basic subjects of Material Science extensively. William D. Callister's "Fundamentals of Materials Science and Engineering" and "Materials Science and Engineering", Mehmet ERDOĞAN's Material Science and Engineering Materials Volume 1-2, Temel SAVAŞKAN's Material Science and Examination, Eyüp Sabri KAYALI's Mechanical Experiments of Metallic Materials and Emel GENÇKİNLİ's Metallography were made use of. Mateial Science lesson lecture notes and animations from Universities of Tennessee, Ohio State, Budapest, British Columbia, Florida, Texas, Kansas, Pennsylvania, North Carolina State, Notre Dame, Oxford, Cambridge, Monash, National Chung Hsing etc. were obtained through online research. Moreover, lecture notes and animations relevant to the subject obtained from the e-education web-site of Afyon Kocatepe University, Technical Education School [17] and a thesis titled as ''Multimedia Usage in Materials Science Education'' from Süleyman Demirel University Library, were used in this study [2].

The virtual labs created, will significantly decrease costs, increase the quality of education and will easily be updated. Real lab environments are, without a doubt, essential in gaining experience and supporting knowledge. However, when the reasons and benefits of the utilization of these virtual labs are taken into consideration, it is anticipated that they will support education.

2. Virtual Lab

2.1. Virtual Lab Education Package Main Page Interface

Developed virtual lab software main page interface is displayed in Figure 1. When the Subjects button is clicked, a total of 23 subjects including basic subjects of Material Science under the title of 5 laboratories are listed.

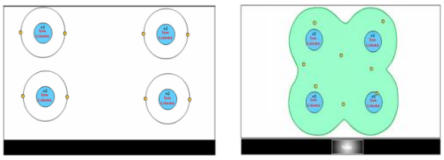
Figure 1: Virtual lab education package main page interface [14]

Foreign web-sites utilized are included in the Links section while virtual labs with national and international web sites including Material Science subjects are being formed. Sources used in the preparation of the study are included under the Sources section.

2.2. Developed Virtual Lab Model Applications

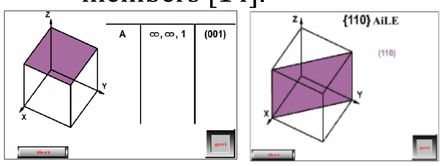
Some examples of animations developed in this study regarding Material Science basic subjects are given in this section. The images and graphics in this study were drawn with the help of programs such as Autocad, Photoshop etc. by using computers. Some images and animations were obtained from different sources and updated before using. Images and graphics were tried to be designed as colorful as possible. Software such as Macromedia Flash, Swish and Java were particularly utilized during the preparation of the animations. Different animations and movies about materials science basic subjects were analyzed on local and foreign web-sites. Features such as taking up less space in the computer memory, watching in full-screen mode, stopping, rewinding and forwarding etc. were improved to enable better control of the existing features. Lecture notes, graphics, images, animated GIFs and two-dimensional animations were combined with Dreamweaver program using html codes and the virtual lab education package was created.

Figure 2: Magnesium covalent bound animation [14].



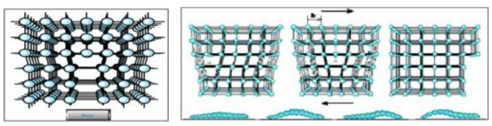
In the animation displayed in Figure 2, magnesium covalent bound formation is displayed. As there are not enough number of electrons on the valance shell, four Mg atoms share two electrons each to become stable.

Figure 3: a) Six different planes in cubic crystal lattice **b)** {110} Plane family and its members [14].



In figure 3.a, six different planes are designed and these planes come one after another by pushing the buttons. Besides, when these planes are displayed on the screen, the length of the line segments separated by these planes (x, y, and z) and miller indices can be seen in the tables on the right side. Thus, numerous planes can be reflected visually. There is an equivalent planes family in symmetrical crystals. Especially in highly symmetrical cubic systems, there are many equivalent planes. In the animation in Figure 3.b, {110} plane family and its members are displayed separately on the same center line as an example to the plane families, by clicking on the forward button.

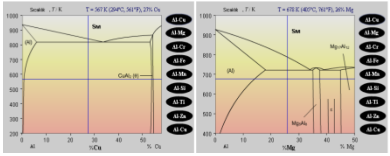
Figure 4: Schematic display of linear errors [14]



Edge dislocation is shaped like the edge of a lacking plane between atomic planes in crystal lattice. It can also be formed by removing one or two lines of atomic layers from a perfect crystal. Different positions of the animation showing edge dislocation is displayed in Figure 4. Besides, the similarity between the movement of a creature (worm) and the movement of the atoms in the material due to the edge dislocation is shown.

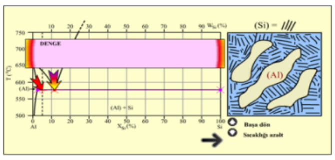
In binary alloy systems which can dissolve each other to a limited scale, in a constant temperature, liquid phase turns into two separate solid phases. This transformation is called eutectoid reaction.

Figure 5: Binary equilibrium diagram [14]



In the animation shown in Figure 5, binary equilibrium diagrams of Al-Cu, Al-Mg, Al-Cr, Al-Fe, Al-Mn, Ai-Si, Al-Ti, Al-Zn alloys are demonstrated. As shown in the figures, these nine different alloys are loaded to the buttons located in the same window. Whenever these buttons are clicked, the binary equilibrium diagram of the alloy, whose name is on the button, is displayed. By moving the mouse over the equilibrium diagrams, depending on the location of the mouse cursor, temperature (°K, °C, °F) and the percentage rates of the alloys can be seen on the upper-right side of the screen. These rates can sensitively change with even the slightest movement of the mouse. Thus, values regarding these nine alloys can be measured without any need for calculation.

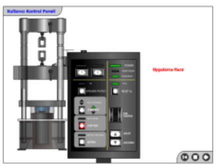
Figure 6: Al-Si alloy equilibrium diagram [14].



In the animation in Figure 6, Al-Si alloy equilibrium diagram is shown. In this equilibrium diagram temperature range is considered as 750-500 °C by clicking on the lower temperature, return arrows located on the lower-right side of the window, micro structures within this temperature range can be seen on the microstructure window on the right.

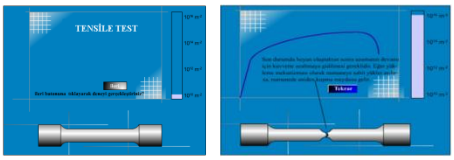
Tensile tests are widely conducted in order to determine the basic design information of the material strength and to be able to classify materials according to their properties.

Figure 7: Tensile test device [14].



Animation in Figure 7 explains the structure of tensile test device and user control panel and how the tensile test is conducted in general terms. First of all, the tensile test device is prepared for application in this animation. Test sample is placed on the holder part of the device and then the control panel is proceeded to. Firstly, the protection button on the control panel is pressed. This button makes sure that the test value is loaded to the sample, the sample is ready for test and that the sample doesn’t get damaged. The light on the button indicates whether the product protection program is active or not. After that, sample positioning is done with the help of up and down arrows located on the right-bottom corner. The light indicator next to the start button shows us whether the mobile mechanism is going up or down. The test is ended by pressing the stop button, when the sample breakdown takes place. Finally return button is pressed and the device is returned to the starting position again. Besides, it is possible to see what the buttons on the panel are used for with their explanations by moving the mouse over the control panel in the animation.

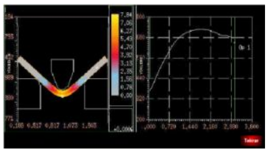
Figure 8: Tensile test sample deformation animation [14].



The animation in Figure 8 is created in order to see the deformation on the tensile test sample in details and simultaneously explain the deformation and tension-strain graphics. When the ‘’next’’ button is pressed, a specific deformation occurs in the sample and this deformation curve is formed in the tension- strain graphic. This curve represents the elastic behavior. Elongation is directly proportioned to strength. When the ‘’next’’ button is hit again, the sample elongates some more and it is indicated in the graphic that the yield point is exceeded and plastic deformation started. In the fourth phase, the instability condition occurs and constriction appears in any part of the sample. This incident is called waisting. The strength is needed to be decreased for the continuation of elongation after the waisting. If constant load is hung on the sample as loading mechanism, sudden breakdown occurs.

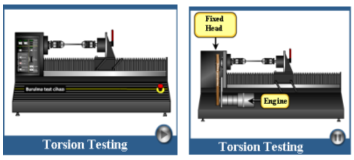
Bending is defined as the deformation occurring after force is applied to a circular or rectangular sectioned sample placed independently on two supports. In the bending tests, rectangular or circular section bars and beams supported from both ends are used (Figure 9).

Figure 9: Bending test animation [14].



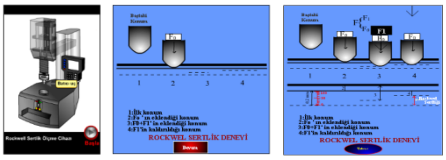
Here, load is applied slowly on a rectangular section sample placed between two supports based on the center of gravity. The deformation occurring in the sample proceeds gradually and the intensity of the deformation is indicated with blue, red and yellow respectively. Also, tension- strain graphic moves along with the deformation in the sample simultaneously.

Figure 10: Torsion test animation [14].



In the animation shown in Figure 10, the parts of the torsion test device and the making of the test are explained. First, the sample is placed on the testing device. Then the engine is powered-up by pressing the start button on the control panel. The sample is forced to torsion because of the belt and pulley mechanism and after a certain amount of torsion according to the sample being brittle or ductile, breakdown occurs in the sample.

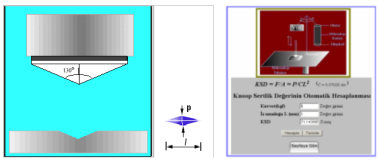
Figure 11: Rockwell hardness test animation [14].



In the animation displayed for the Rockwell hardness test, firstly the preload loading is done with a F0=10kg load. By this means, the stinging pin settles on the sample and keeps it in place. In the second step, the dial of the measuring scale is adjusted to zero and the bigger load is applied. This bigger load is the total load applied and the depth measurement depends on the depth caused by the increase between the smaller load and the bigger one. After the bigger load is applied and removed, the value on the dial with the small load still applied is read according to the standard process.

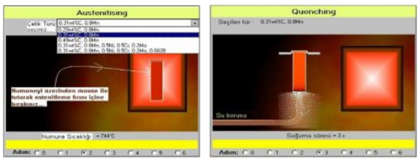
In the upper part of the program seen in Figure 12, an example of a micro hardness test is displayed schematically. Here, force is applied to a rectangular section sample with a square-based- pyramid pin and the diagonal line length of the emerging indentation is measured.

Figure 12: a) Micro hardness test animation. **b)** Micro hardness calculation program [14].



As a result, the required formula for calculating the micro hardness value based on the trace obtained is shown in Figure 19.b. Moreover, micro hardness value formula has been turned into a practical program in order to avoid miscalculations and to save time. In this program the knoop hardness value appears automatically in the bottom cell after the strength to be applied on the sample and diagonal line length of the indentation are entered.

Figure 13: Jominy test animation [14].



In this simulation (Figure 13), the effect of steel composition to the hardenability is shown with Jominy test. You can choose a sample and place in the austenitization oven. Later you can place the sample in the Jominy device and do quenching. After the quenching and reboring the surface of the Jominy sample, hardness is measured periodically starting from the edge. Obtained data can be recorded and jominy curves of each of the steels can be drawn.

3. Conclusion

Utilization of the education package formed under the scope of this study both in traditional and distance education environments for the Material Science classes taught in some higher education units, is considered to be contributing to increasing the quality of education. When used in the traditional education environment, the subjects of the lessons they couldn't attend to or they want to review are made available to the students in any environment with computer. Thus, it is considered that this situation will contribute to increasing the success and the quality of the students. Research on education shows that the students are able to remember 30% of the things they read, 40-50% of the things they heard, 60-70% of the thing they saw and 90% of the things they both saw and heard. In the animations prepared, the students will be given the opportunity to see and understand the properties and tests of different materials. By giving visuality prominence and adapting the individual participation of the student to teaching process, a teaching environment will be created oriented at long-term memory rather than short-term. The subjects will be more fun by being supported with colorful graphics, pictures and animations. Thus, a teaching environment will be created that will make the students feel as if they were playing a game.

The virtual labs will enable spending the time for education effectively. As the students will have to answer the questions generated by the computer and think about the subject before the next step, they will be constantly active. The experiments that are expensive and dangerous to be conducted in real labs will be done easily with the help of simulation method and this will save time and money. By interacting with the computers, students will be able to ask questions, learn their answers and repeat the subjects whenever they want. They won't have to compete with other students who learn faster than themselves and thus a teaching process at their own pace will be provided to each student. The teachers won't have to slow down others in order to wait for the students who learn at a slower pace or they won't have to keep up with the fast-learners leaving the others behind. Rather than sitting in class and learning passively, the students will have a chance to effectively by active participation and computer interaction. The students will have the opportunity to carry the education process out of the schools and they won't be depending solely on school and class for a better learning.

This education material can be multiplied and given to students. So, the students can study wherever or whenever they want to, independent from time and place, without any need for a different computer software or hardware. Moreover, this material can be used by the teachers in class for projection.

Notes:

1- This study was carried out in Süleyman Demirel University, Technical Education Faculty, Department of Mechanical Education and Science Institute under the supervision of Abdullah ÖZSOY and it was derived from Okan ORAL's Master Thesis study titled "Forming A Virtual Material Lab".
2- This study was presented as an oral presentation at international conference which name is FL 2012 -IV. International Future-Learning Conference on Innovations in Learning for the Future 2012: e-Learning Nov 14-16, 2012 Istanbul, TURKEY.

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