Giving enhanced learning experiences through e-learning on Solid State Semiconductor Devices course

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Giving enhanced learning experiences through e-Learning on Solid State Semiconductor Devices course

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Abstract

Advanced level electronics course like solid state semiconductor device is a tough course for the student to understand. The main reason is students are having difficulty to understand the atomic model using mathematics. In fact they are not able to visualize carriers and their behaviors. Therefore, many students are unable to cope with the course and failed in final examinations. In this paper, e-Learning techniques have been introduced through our online portal known as WawasanLearn to overcome the problem. There are three types of e-Learning that have been introduced such as usage of websites, usage of semiconductor applets and virtual lecture series from distinguish lecturer. After implemented for a semester, the failure rate managed to be reduced.

Keywords: Solid State semiconductor devices, e-Learning, WawasanLearn

Introduction:

With today's deluge of information, and the growth of knowledge at a fast rate resulting in the information revolution in which we live now, the world has witnessed a new scientific and technological revolution that has had an impact on various aspects of life [4]. The education sector has taken advantage of this progress by developing new educational means, and establishing integrated educational methodology based on techniques, known as e-learning, which is one of the modern methods in the field of education and training, that assist the learner to obtain knowledge and skills at learner's preferred time and place, through interactive content-based multimedia (graphics, audio, video...), advanced search mechanisms, digital libraries, and Internet portals, whether remotely or in the classroom. [4]

The goal of e-learning is to use all kinds of technology in the delivery of knowledge to the learner at the shortest time, with least effort and greatest interest in order to achieve the learning objectives effectively. The e-learning and distance education act as a key component of the higher education and continuing education. The need for this type of education has increased with the increasing number of potential learners [4]. E-learning comprises all forms of electronically supported learning and teaching. The information and communication systems, whether networked or not, serve as specific media to implement the learning process. The term will still most likely be utilized to reference out-of-classroom and in-classroom educational experiences via technology, even as advances continue in regard to devices and curriculum [1]. eLearning is doubling yearly. classes, e-courses, e-books on how-to and what-to appear by the thousands online weekly. In-person seminars and workshops are limited to location and access. eLearning allows easy access, creation, and
international distribution to a whole new world of experiences -- negative and positive. Avid learners now feel like there is a smorgasbord laid out before them. [2]

eLearning is more cost effective than traditional learning because less time and money is spent traveling. Since elearning can be done in any geographic location and there are no travel expenses, this type of learning is much less costly than doing learning at a traditional institute [3]. Flexibility is a major benefit of e-learning. e-learning has the advantage of taking class anytime anywhere. Education is available when and where it is needed. eLearning can be done at the office, at home, on the road, 24 hours a day, and seven days a week. [3]

Learners like e-learning because it accommodates different types of learning styles. They have the advantage of learning at their own pace. Students can also learn through a variety of activities that apply to many different learning styles. Learners can fit e-learning into their busy schedule. If they hold a job, they can participate in eLearning right at their desk. If the learner needs to do the learning at night, then this option is available while in their pajamas and do the learning if they desire [3]. eLearning encourages students to peruse through information by using hyperlinks and sites on the worldwide Web. Learners are able to find information relevant to their personal situations and interest. eLearning allows selection of learning materials that meet their level of knowledge, interest and what they need to know to perform more effectively in an activity [3]. e-Learning is more focused on the learner and it is more interesting for the learner because it is information that they want to learn. eLearning is flexible and can be customized to meet the individual needs of the learners [3]. eLearning helps develop knowledge of the Internet. This knowledge will help learners throughout their careers. eLearning encourages students to take personal responsibility for their own learning. When learners succeed, it builds self-knowledge and self-confidence. [3]

Distance learning is expanding rapidly in higher education, and this growth is encouraging further investigation of effective design and delivery of individual engineering-based distance learning courses. While distance learning can offer several exciting educational opportunities, any innovative use of technology should be thoughtfully implemented, and teacher/scholars have begun acknowledging the need for more thoughtful inquiry into the use of distance learning technologies [7].

Wawasan Open University’s learning Management systems (LMS), also known as WawasanLearn, is a platform to support e-Learning, it plays an important role in enhancing the learning of students as well as sustaining their interest in studies. The main elements of WawasanLearn are supplementary course materials which contain power points slides of each unit of the course, useful links to other websites, free online quizzes, links to short videos at Youtube, Edutube etc, Course overview, Assignments and Specimen Exam Paper. It is based on moodle course management system which is a virtual learning environment. It is a Free web application that educators can use to create effective online learning sites.
The abstract nature of engineering makes this subject difficult to teach in any educational environment, and more so at a distance. Teaching engineering at a distance by its inherent nature introduces additional challenges. Engineering education typically requires students to have physical knowledge that only on-line activities and hands-on experiences can provide (Da Silveira, Da Silva & Térsio, 1999) [8]. Learning scientific courses where visualization of key concepts through computer simulation is possible gives new dimensions for learners. Normally we read in a scanning method when browsing the Net. Now, with studying, reading will require more deliberate and careful. This increases material understanding, comprehension, critical evaluation and practical application. In this paper, e-Learning techniques have been introduced through our online portal WawasanLearn to overcome the problem of Solid State Semiconductor Devices course which is one of the difficult courses for students because they can’t visualize atomic models through mathematical derivations.

A. E-Learning techniques

E-Learning techniques are introduced through WawasanLearn which is Wawasan Open University’s Learning Management System (LMS). It provides online support and resources for students and tutors. LMS remains available: 24 hours a day; 7 days a week. Each course is represented on a 3-pane format. It is divided into 3 sections with 1 section dedicated for tutors. The announcements and forums are also there to make discussion and necessary announcement. All the sections are concisely organized using folders to store various files. During the 1st first presentation of Solid State Semiconductor course the supplementary course material components were not populated with e-learning tools so students were unable to cope with the course and failed in final examinations. Due to poor performance of students the course-coordinator realized the problem of students and introduced new e-learning techniques through WawasanLearn. These techniques are as follows:

I. Usage of semiconductor applets

(a) The unit 1 of solid state semiconductor devices course deals with the Modelling of Atomic Structure of a Material and Electrons. Generally, It is difficult to explain 3D structures of semiconductor crystals through study guides which are possible by the applets of semiconductors. This applet is to demonstrate the 3D structures of semiconductors [5]. The structure can be rotated by mouse. To choose another crystal, you can use the element table in the dialog or choose from the pull down list. Fig. 1 shows the 3D view of GaAs unit cell.
(b) Hexagonal closed packed crystal structures:

Fig. 2 shows the Hexagonal closed packed crystal structures. This applet used to help visualize some of the hexagonal crystal structures [5]. The underlying Bravais lattice is hcp (Hexagonal Closed Packed) structure. It visualizes several compounds of type RX and RX₂ in 3-D view.
The applet presents the lattice parameter, the Miller indices for various lattice planes, and the ability to calculate unit cell volume and the distance between lattice planes. You may type in an arbitrary Miller index in the applet and let the applet show the lattice plane. The applet gives you the ability to move the origin of the abc crystal axes and make the axes origin coincide with the Atom whose coordinate is 000.

Note that the hexagonal crystals use four Miller index numbers for a given lattice plane where the third index is the negative of the sum of the first two indices. That is, IF \( hkl \) Miller indices are found from the intercepts of the lattice plane with the abc axes, THEN the lattice plane is denoted as \( hkml \) where \( m=-(h+k) \).

(c) Fermi Level, Fermi Function and Electron Occupancy of Localized Energy States

Electrons, at thermal equilibrium with its environment (such as the solid materials in which the electrons exist), are governed by the Fermi statistics for their energy distribution. The so-called Fermi function, \( f(E) \), gives the probability with which a quantum state at energy \( E \) is occupied by an electron. The most important property is the Fermi energy, \( E_F \), which enters \( f(E) \) as a key parameter.

According to the Fermi statistics, a quantum state can have a maximum of one electron. Fig. 3 shows the Electron occupancy of Localized energy states. This applet shows \( f(E) \) and the distinct energy states ('localized' because the electron sitting on the state can NOT readily move to the neighboring state) as a function of Energy, the vertical scale, and the Temperature as a variable parameter [5].

![Fermi Level, Fermi Function and Electron Occupancy of Localized Energy States](image)

Fig.3

Try to move the Fermi level, \( E_F \), using a mouse drag, and watch the electron distribution. Also try to vary the Temperature and watch its effect.
(d) Haynes-Shockley Experiment

In the unit 4 Haynes-Shockley experiments explained. It is a classic experiment that demonstrates diffusion of minority carriers in a semiconductor could result in a current. The applet shown in Fig. 4 visualizes the following processes of excess minority carriers in a semiconductor:

• generation of excess carriers, by a laser beam,
• diffusion, due to the concentration gradient,
• drift, by the applied bias (or electric field), and
• recombination loss.

If you click on the **Stop** button, the process stops. The **Start** button initiates a new process. The **Pause/Resume** button temporarily halts the process so that the data can be recorded or a momentary snapshot of the process can be examined.

![Haynes-Shockley Experiment](image)

The three checkboxes, $N$ vs. $t$, width vs. $t$, and displacement vs. $t$ display the data in the lower part of the applet for the total number of excess minority carriers, width of the concentration profile, and the displacement of the peak from its initial position, respectively, as a function of time for the first 100 microseconds.

Due to the long lifetimes of excess minority carriers in a Ge crystal, as compared to the short lifetimes in the Si or GaAs crystal, example is given for a Ge crystal.

You can change the conduction type, bias value, length of the sample, temperature, lifetime, and mobility (of minority carrier) using the bottom panel and examine their effects on the excess minority carrier processes [5].
(e) **Kronig-Penny Model:**
In the unit 2 of Solid state semiconductor devices course the Kronig-Penny model explained which is a simplified model for an electron in one-dimensional periodic potential. The possible states that the electron can occupy are determined by the Schrödinger equation. Generally the Kronig-Penney model of a solid is difficult to understand by students in distance learning because they are not able to visualize the atomic model through mathematics. The applet in Fig.5 is to realize the Kronig-Penny Model through visualization:

![Kronig-Penny Applet](image)

The potential is controlled by the V and Width sliders. V sets the magnitude and Width is the width in lattice constants. The dispersion E(k) is plotted in red in the right hand plot. The green line in all the plots shows the value of the energy. The top plot shows the wave function at the energy selected. The real part is in red, and the imaginary part is in blue. The magnitude is plotted in orange. The potential is also shown in black. The Bloch Functions plot shows the periodic bloch functions. The color code is identical to the top plot. This visualization increases the interest of students in the topic and they learn the concepts better than before [6].

II. **Usage of websites**

(a) Educypedia is an information resource about Scientific and Educational material: Electronics, Science, Engineering, Encyclopedia and Information Technology. All the links are tested with respect to content, no commercial links. Educypedia is the most complete Encyclopedia in the world with access to the very best Web Resources for Education. The best free resources on the web!! It is used extensively in the presentation of Solid State Semiconductor Devices course.

(b) NPTEL provides the quality of Engineering education course material in the web by providing free online courseware. NPTEL is an acronym for National Programme on Technology Enhanced Learning which is an initiative by
seven Indian Institutes of Technology (IIT Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and Indian Institute of Science (IISc) for creating course contents in engineering and science. These course contents are very useful for teachers and through them improve the quality of students. In addition, the course materials (both web and video) are freely accessible by everyone independent of their geographic location. These courses can be used by professionals for updating their academic background. Open and distance education using NPTEL contents are long term prospects for Open Universities. The contents helps evolve criteria for focused learning and a common set of standards for professional education through participation by everyone concerned under this platform. It is a very useful resource for solid state semiconductor device course.

(c) InTech free access websites for free e-books:
InTech people are highly qualified in the field of science and technology, in 2004 the InTech founders started out with an inspiring mission - to provide barrier-free access to a rich collection of superior scientific literature, and to add to the body of free knowledge available under the Open Access label. It is best source of good books free of cost so teachers and learners can use for engineering courses like solid state semiconductor devices course.


III. Virtual lecture series from distinguish lecturer
(a) NPTEL provides E-learning through online Web and Video courses in Engineering, Science and humanities streams. The mission of NPTEL is to enhance the quality of Engineering education in the country by providing free online courseware. Lecture Series on Solid State Devices by Dr. S. Karmalkar, Department of Electrical Engineering, IIT Madras is useful for understanding of the semiconductor at equilibrium.

(b) TUDelft provides E-learning through online Web and Video courses in Engineering, Science and humanities streams as shown in Fig. 7. TU Delft cooperates with many other educational and research institutions, both in the Netherlands and abroad. The high quality of our research and teaching is renowned. TU Delft has numerous contacts with governments, trade associations, consultancies, industry and small and medium-sized companies.

(c) Keio University also provides E-learning through online Web and Video courses in Engineering, Science and humanities streams as shown in Fig. 6. Keio University has a proud history as Japan's very first private institution of higher learning, which dates back to the formation of a school for Dutch studies in 1858 in Edo (now Tokyo) by founder Yukichi Fukuzawa. Since the school's inception, the students of Keio have risen to the forefront of innovation in every imaginable academic field, emerging as social and economic leaders.

B. Results before and after introduction of e-Learning Techniques

I. Performance of Students before e-Learning Techniques

Jan'2009 semester was the first presentation of the course. The performance of students in the final examination was not satisfactory with 11.36% of students scored grade As and 36.36% scored grade Bs. The course passing rate for this presentation was 48%. Of the 23 failures in the examination, 16 students were allowed to register for the supplementary examination. The threshold for the re-sit...
was set at 20% in the examination score. The completion rate of 41% was a setback for this presentation due to above said reason.

The distribution of grades achieved by the students is shown below in a bar chart for a better visual impact as in Fig.8. The figure showed a fair distribution of grades from A to D.

II. Performance of Students after e-Learning Techniques

Jan’2010 semester was the 2nd presentation of the course. The performance of students in this presentation was good with 30.76% of students scored grade As and 33.66% scored grade Bs. The course passing rate for this presentation was 73%. Of the 28 failure in the examination, 15 students were absent from the exam. The threshold for the re-sit was set at 20% in the examination score so 20 students are eligible for supplementary exam. The completion rate of 64% was good for this presentation after implementation of e-Learning techniques through WawasanLearn.

The distribution of grades achieved by the students is shown below in a bar chart for a better visual impact as in Fig.9. The figure showed a fair distribution of grades from A to D.
C. Results & Discussion:

The performance of the two semesters is compared after implementation of e-Learning techniques through LMS and the following table shows the difference.

<table>
<thead>
<tr>
<th></th>
<th>Final registration</th>
<th>Total Examinees</th>
<th>Passing rate (%)</th>
<th>Completion rate(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 2009</td>
<td>51</td>
<td>44</td>
<td>48</td>
<td>41</td>
</tr>
<tr>
<td>Jan 2010</td>
<td>119</td>
<td>104</td>
<td>73</td>
<td>64</td>
</tr>
</tbody>
</table>

It was found that there is increase in the overall passing and completion rate.

- From the average participation in the WawasanLearn has proven the batch of the students in the Jan 2009 semester was taking less interest in the difficult topics where mathematical model like Kronig-Penny model, Haynes-Shockley model discussed.
- The presentation of solid state devices topics using semiconductor applets attracted students to learn the topic with more interest which yielded in good performance of students.
- The virtual lecture series from distinguish lecturer has helped them to understand and analyse various aspects of solid state semiconductor topics.

In today’s media-rich world, we’re exposed to all sorts of multimedia which helps inspire ideas for eLearning course, but it also can create customer expectations. This can be a challenge when working with customers because many of them have preconceived ideas of what they want, whether or not it’s appropriate to the course or you have the resources to deliver it. Also because they’re exposed to so much multimedia, they may have a mental model of what they want, but they’re not quite sure how to explain it. In those cases, they get more clarity by seeing things they don’t want versus being able to identify what it is they do want. Of course this can waste a lot of time if they’re waiting for you to design something before they tell you they don’t like it. Provide a list of diverse elearning examples where they can see different approaches to elearning. Have them pick out the ones they like and the ones they don’t like and identify how they distinguished them [9].

D. Conclusion:

We presented the study which has shown the importance of e-Learning techniques. The first presentation of the course has shown that the students were unable to cope with the course and failed in final examinations due to the difficulty to understand the atomic model using mathematics. Students overcome the problem in the second presentation after introducing the e-Learning techniques through WawasanLearn. The three types of e-Learning have been implemented and explained such as usage of websites, usage of semiconductor applets and virtual lecture series from distinguish lecturer. We hope the study will provide lecturers of engineering some idea of the presentation techniques on their own courses.
Acknowledgment

The author wishes to thanks Prof. Gajraj Dhanrajan & Prof. Wong Tat Meng of Wawasan Open University, Penang, Malaysia for encouragement and support.

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