DigiLab: A Virtual Lab for IT Students

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Abstract: - This paper presents a new experience concerning a practical laboratory for Digital Logic Design (DLD) that can be accessed from anywhere via the Internet. Our approach was to design a virtual laboratory, using a multimedia platform, namely DigiLab which can be access from anywhere via the Internet. DigiLab run as an online application where a user needs to have internet connection and user account before access to the application. Virtual laboratory occasionally replaces traditional classrooms due to rapid advances in computer technologies. One of the engineering subjects, Digital Logic course is regarded as an important core requirement in Information Technology (IT) department. The IT student needs to study about logic for hardware purpose in IT. The idea of digital logic virtual lab is to allow students in IT to understand the logic circuit behavior and practice the skills of designing the circuit board with different techniques and instruments. Due to costly traditional laboratory, the DigiLab is designed to fulfill the needs of the knowledge for students.

Key-Words: - Digital Logic Design (DLD), DigiLab, Virtual Laboratory, and Information Technology (IT).

1 Introduction

The development of Information Technology & Communications (ICT), equipments and technologies such as wireless communication, multimedia, computer network and mobile devices have become more powerful and reasonably priced. Web services could be accessed by many kinds of devices from anywhere and anytime. As a consequence in the education field, more students and lecturer have become remote and virtual users as well. The growth of ICT had recently been enhanced due to the significant needs in teaching and learning [1].

Digital Logic Designs (DLD) is one of subtopics in TTTK 1213 Basic electronics and Digital Logic Design subject.DLD contains topics that cover the used of basic gates such as OR gate, AND gate, NOT gate including combinational gates such as NOR gate, NAND gate, EX-OR gate, EX-NAND gate and FLIP-FLOP. Experimenting in labs effectively helps students understand the subject better. Those theories learned in lectures need to be practiced on hand so students would know exactly what they have learned.

Normal experiments usually need students to attend to the lab and finish the tasks given using tools prepared by the lecturers or lab demonstrators. But as today, technologies have played an important part in the learning process. Multimedia material such as videos, animations and graphics can be used to help students understand on how the experiments need to be conducted.

Conventional way of experiments includes preparation of suitable tools before any experiment can be conducted. Problems that usually happen were tools malfunction and sometimes tools were limited in quantity. Preparation of tools make we lose some valuable times. When problems like this occur, it will make the experiment less precise. Moreover, students will lose their focus in doing the experiment and do the lab tasks the way it should be done. Those theories learned in class will not be able to be understood thoroughly. Traditional labs also focus on theories that need to be tested. In traditional lab limited time is placed for students to finish their experiments. This limitation prevents students to explore more on their lab tasks due to the time constraint. Moreover, all lab work needs to be done and completed only in the labs. Therefore we need to develop an application that can overcome those problems.

Virtual labs have been in the past years meaningful and very popular for the tutorial in various fields of subjects making used of virtual lab increasing and help us to gain a lot of information for the DigiLab development process [2].

Virtual Reality (VR) technology will be used to evaluate the feasibility of a design, selection of process equipment and to allow a user to study the factors affecting the quality, time and costs. It is important to note that a virtual reality system is essentially an interactive simulation that can represent a real or abstract system. The simulation is a representative computer based model, which provides appropriate data for visualization or representation of the system. The virtual environment can take many forms and for example, it could be a realistic representation of a physical system [3].

The Internet is becoming popular as it is not limited by political, geographic boundaries or cultural barriers. As the superhighway is becoming a reality, multimedia learning is becoming practical in the Internet environment. Using the Web as a teaching medium is an exciting prospect that makes remote learning easier, allows students to learn at their own pace, and encourages interactive learning. Learners can then schedule their time and progress of learning according to their own styles. Web-based teaching plus a management program can automatically monitor and mark the work of each learner. The lecturer's time can be saved and redirected to identifying and helping learners who are having problems [4].

Virtual laboratory is a computer program that allows student to run cyber-experiments via the web. This allocates the students to perform the experiments remotely at anytime and anywhere. Furthermore, the experimental-oriented problems can be performing without the overheads incurred for maintaining a traditional lab [5].

Since the electronics field is too large, covering all its aspects in terms of courses, exercises, experiments, projects, needs a tremendous effort [6]. On the other hand, remote laboratories could reduce the operating costs and allow better use of instrument [7].

In Digital Logic Design [8] course that concerns the study of logic circuits and electronic instrument, the laboratory activity is fundamental to get the skills in understanding circuit behavior by using various kinds of instruments and techniques. In traditional laboratory, a hardware laboratory is using logic boards or programmable Field Programmable Gate Array (FPGA) boards. In these setting, students physically used wire sample design from a problem set. Our initial effort was engaged in the realization of a virtual lab to analyze circuit's studies in Digital Logic Design class. This paper will present the DigiLab system architecture design which has been developed for IT students at the Faculty of Information Science and Technology (FTSM), Universiti Kebangsaan Malaysia (UKM) [9].

2 Research Background

In conventional laboratory, all the equipment is prepared by the demonstrator or lab assistant. Every single experiment carried out by the student is based on equipment and the theory given. The main problem that often overwhelmed laboratory is lack of equipment and limited time in doing experiment. Besides that, sometime lost or damaged equipment make problems in the experiment in order to perform good result.

Usually experiment only focuses to the way to prove the concept of theoretical. Therefore, during the lab, time is limited only to state testing. Laboratory experiment also involves a lot of demonstration. This problem can be overcome through the development of digital lab design laboratory called as a DigiLab. This application can help students to investigate explosion theory with more wide. Throughout this application student only perform experiments through the computer on virtual circuit that are provided.

This system is conducted using on-line applications. Students must have permission to enter into DigiLab application. All circuit display and component will broadcast through web browser. Experimental setup would be made by lecturer or demonstrator in charge. Both entities also need a special routing to access into the application. Each experiment shall be enclosed with theories and important rule to make current reference to experiment carried out.

2.1 Related Work

Table 1 shows the comparison between our proposals which is DigiLab with four other applications namely Hamburg Design System (HADES) [10], Circuit Building Application (CBA) [11], Mobile Virtual Lab (MVL) [12] and Digital Logic Builder (DLB) [13].

HADES is a pure-Java framework for object-oriented component-based simulation. It consists;

- a graphics editor to create and interact with simulation setups, e.g. digital circuit schematics,
- an intuitive design and library browser,
- ibraries of JavaBeans compatible simulation models.

Currently, they provide about 200 simulation components, most of them for digital circuit simulation, from basic gates to RT level components from basic interactive I/O to system level components like processors and LC-displays. HADES was developed by Computer Science department, Hamburg University, German. This application is design for digital logic subject and the application is using Java. However the disadvantage of this application is user manual is very complex. They also not provided student record and easier for student laying the experiment they have done.

Meanwhile, CBA was designed by final year student from Engineering Faculty, John Hopkins University, America. This application can only be accessed on-line. The lab experiment is too basic and no information or on-line help button in this application. The major difficulty is the student cannot take out the component in the board when it is not in the right place. Student will be confused on how to use this application.

Mobile Virtual Laboratory (MVL) application represents a complex software unit with many options and modes of behavior. MVL also support the process of teaching and learning of digital design [14]. MVL performs simple laboratory exercises using mobile phones devices and also brings the user closer to implementing a full-scale mobile virtual laboratory. MVL is using Java 2 Micro Edition (J2ME) platform [15], which is designed for development of applications for small devices of limited capabilities, like mobile phones, smart phones and PDAs [16]. But then these mobile applications have several weaknesses such as small display, have low resolutions, input limitations, limitations in accessing the Internet and also lack of standardization and compatibility.

Digital Logic Builder (DLB) is an interactive multimedia simulation which allows students to drag logic gates onto a grid and specify inputs into a circuit. DLB was originally conceived and developed for use of BSc in Information Technology students as part of the UK National Learning Network programme. The programme is delivered online through Moodle, an open source virtual learning environment (VLE). Nevertheless, this virtual lab was relatively limited in scope.

From the comparison we have, DigiLab expand on on-line basis and this application allows exercise to be downloaded as well. The theory and formulas for experiment also appear in the system. Interactive interface and user friendly interface is also considered.

	HADES	**CBA**	**MVL**	**DLB**	**DigiLab**
On-line application	No	Yes	Yes	Yes	Yes
Data	No	No	No	No	Yes
Download application	Yes	No	No	Yes	Yes
Interactive interface	Yes	No	Yes	Yes	Yes
Theory and formula	No	No	No	No	Yes

Table 1: Comparison between other virtual labs

3 System Overview

DigiLab is a web-based application. Students need to have user account that will give them access to the application. Virtual circuit, gates and truth table are displayed on web browser. For experimental methods, students need to enter the gate binary values on the given text area. The program calculated the value entered and the output has been displayed.

In this section, we will briefly describe the architecture of the DigiLab surroundings and the characteristic.

3.1 System Architecture

DigiLab is a channel that allows the exchange of information among the instruments through combination of a multiple users, internet, server and database as pictured in Figure 1. The users of the system can be students or lecturer.

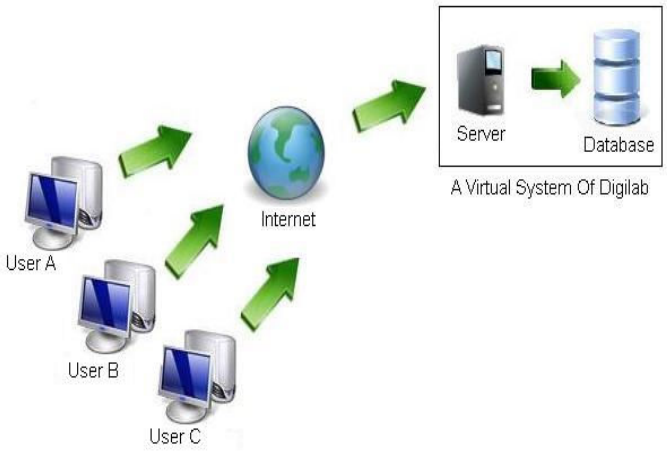

Figure 1: DigiLab System Architecture

As shown in Figure 1, the Internet work as correlation between user and server. Therefore, user must have Internet connection in order to use web browser. By using URL for this application, Internet detected system server to make a connection between user and database.

3.2 System characteristic

The main features of DigiLab are summarized as follows:

- Capable to run as a standalone application or through a Web browser.
- Animated environment with textual tutorial links, demonstration shows and interactive modules.

The objective of the project is prescribed as below:

- Experiment can be accessed by students anywhere but password is required to access.
- Get experiment information in advance.
- To build simple and friendly virtual circuit for the student.
- Application may be added well to enhance in the future.

This application is developed to provide knowledge to student in multimedia environment more comfortable and workable. All this effort will make student familiar, easier, comfortable and available for many student involvements.

This research presents a new experience concerning a practical laboratory for digital logic design from anywhere, anytime via the Internet. The system is running on web server Microsoft Internet Explorer 7 or Mozilla Firefox 2.0. We are using Java Virtual Machine, Structured Query Language (SQL) [17] and Java Applet throughout the study.

4 Methodology

Development of this web application was based on System Development Life Cycle (SDLC) methodology which is a Waterfall method. Websites was develop by using Hyper Text Markup Language (HTML) which play a part to integrate this website with the Structured Query Language database.

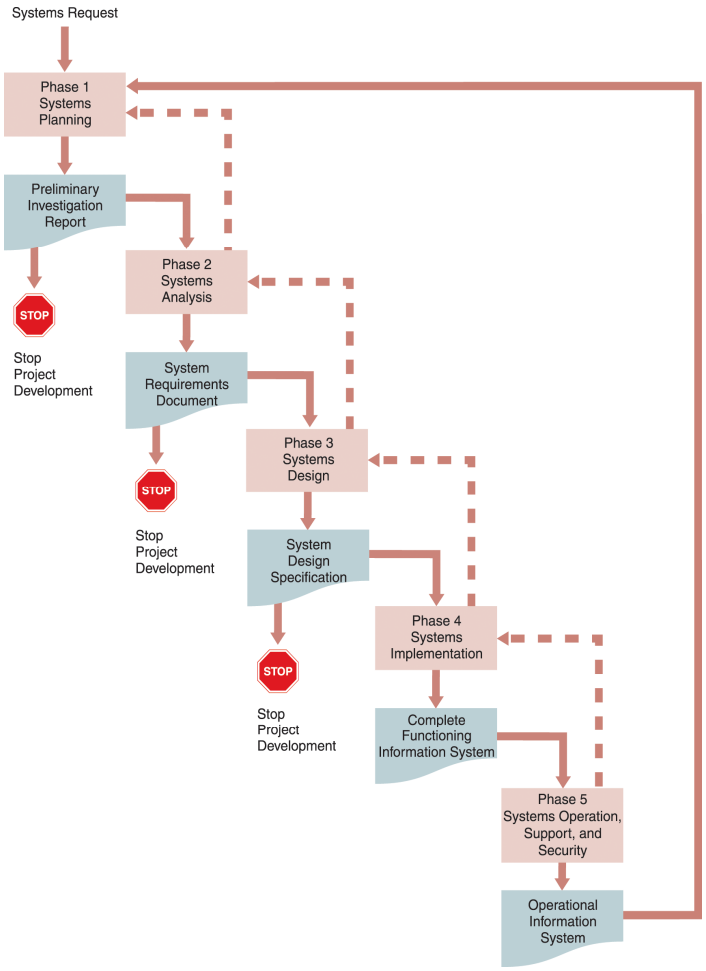

Figure 2: Waterfall Model

Figure 2 shows each phase in the Waterfall Model which is Systems Planning, Systems Analysis, Systems Design, Systems Implementation and Systems Operation, Support and Security. The relationship of each phase to the others can be roughly described as a waterfall, where the output from a specific stage serves as the initial input for the following stage. During each phase, additional information is gathered or developed, combined with the

inputs, and used to produce the stage deliverables. Once a phase of development is completed, the development proceeds to the next phase and there is no turning back.

The waterfall model describes a development method that is linear, sequential and it has distinct goals for each phase of development. The advantage of waterfall development is that it allows for departmentalization and managerial control. A schedule can be set with deadlines for each stage of development and a product can proceed through the development process like a car in a carwash, and theoretically, be delivered on time.

We choose the waterfall methodology because is easy to explain to the user how each phase in the development going which is the activities are well-defined. Besides, it helps to plan and schedule the application that has been developed. Furthermore, verification at each phase ensures early detection of errors or misunderstanding in the application.

5 Design of the System

Functional specification states explain in detailed about activity that need carried out by the system to fulfill the need of the application. These include module and sub module in the requisite system. Figure 3 shows a briefly details on system functional specification to the developing system.

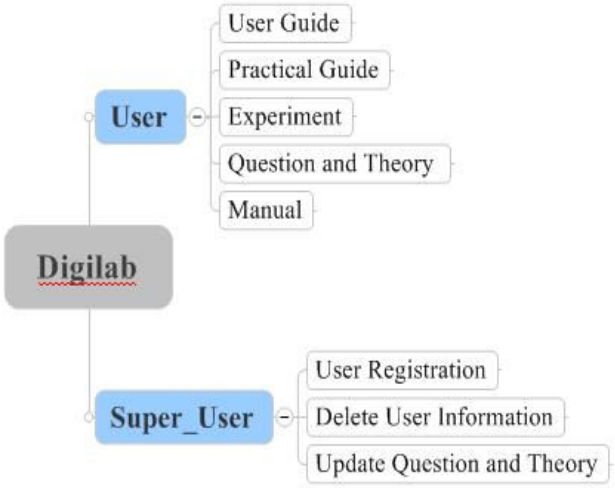

Figure 3: Functional Specification of DigiLab

5.1 User

Sub modules for User are User Guide, Practical Guide, Experiment also Question and Theory. The function of this sub models are as below:

- **User guide**: This user guide aims to provide an overview of DigiLab's for user.
- **Practical guide**: The guide includes practical information. The goal of the Practical Guide is to provide user with the tools they need.
- **Experiment**: A list of labs that contain experiments that you can do. It also contains a method of investigating particular types of experiment questions or solving particular types of problems.
- **Question and Theory**: A theory of question supply where a conceptual theory of question answering is explained.
- **Manual:** Information that will help users to understand and use this virtual lab or Digilab.

5.2 Super User

The function of super user is to create entity specialize use to lecturer and demonstrator. Super user function is as a caretaker in this application system. The job of super user is update consumer registration, update base data, tidy currently question and theory laboratory. The sub modules of this section are: deletes user information, update question, and theory. The task of this sub models are as below:

- **User registration**: Laboratory access registration purpose and is maintained in a secure computer database. A registration of submission number will be given.
- **Delete user information**: This guides covering information about the user. Any deleted information for consumer, must be notified about the changes.
- **Update question and theory**: Revise the most up-to-date question for the student. The practice and hypothesis of DigiLab were identical during time of lab.

User and application can interact via the interfaces. From the interfaces, the system will perform what is desired by the user. It connects the system with the database, server and the application. Interface designs are important to determine system usability. Developing user friendly interfaces will make the application easier for user to use. This application is divided by two into sub-modules i.e. users and super users. Figure 4 illustrates the interaction between user and the application.

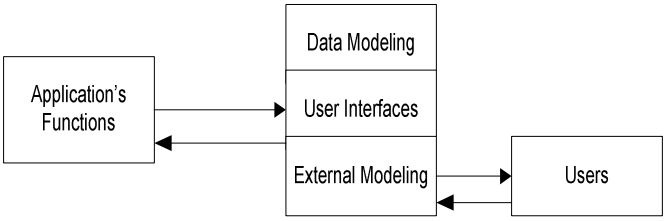

Figure 4: Interactions between Application's Function and Users

6 System Implementation

System Implementation of the virtual laboratory applications is developed using Java and Structured Query Language. The interface is designed with HyperText Markup Language as the programming language with enclosed animation and also attractive graphic display. The target is to provide facility to student to study and understand digital logic design basic concept through virtual experiments without going to the lab and with the convenience of learning at their own pace. In the application development, the hardware and software requirements of the DigiLab are determined. Both are very important to determine application development suitability so that the application can be developed perfectly to achieve the objective which has been prescribed.

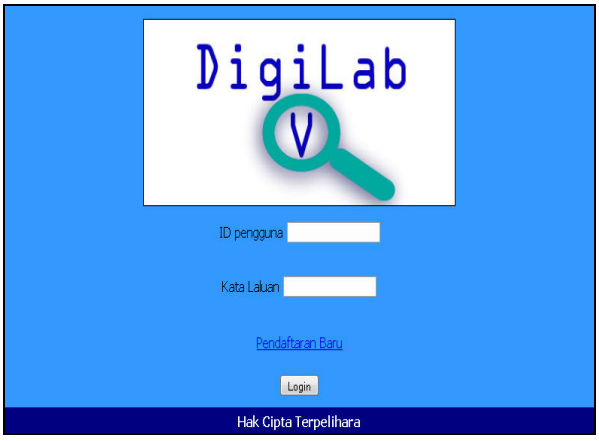

Figure 5: DigiLab User Interface

For experiment on this virtual circuit, student must connect each logic gate arranged based on the requirement or specification. The circuit components will be prepared on the tool where the students only need to drag and drop all the stated components on the circuit. Result of work from the circuits' extension will be broadcast through display bit 0 and 1 on the truth table.
For display theory and experiment that need carried out, button theory and question will be prepared and will display on the toolbar. In order to display theory and question, new window will be appeared. Figure 5 shows the main interface of the application and Figure 6 shows the module user guide of DigiLab.

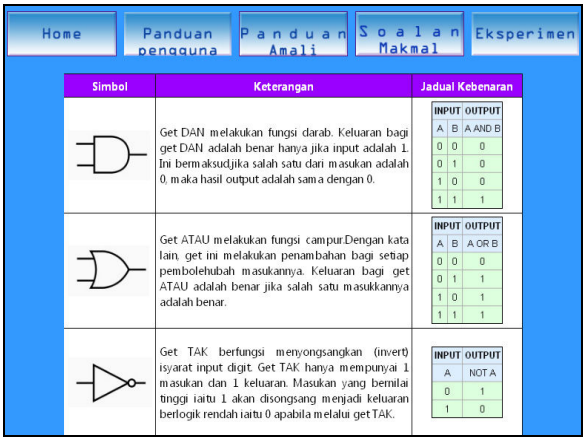

Figure 6: Module User Guide for DigiLab

Module Lab contains several of question and tasks for logic design labs. The screen will be appeared as shown by Figure 7 and Figure 8.

Figure 7: Main Module

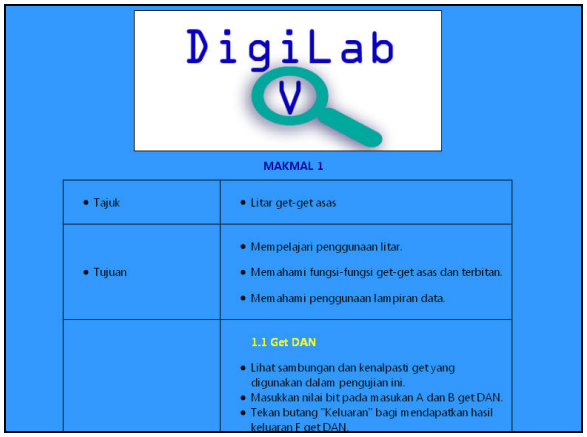

Figure 8: Interface of Lab 1

7 Future work

For our future work we look forward to improve on interface display in order to keep up with the development of technology nowadays. More modules are also needed for more exercise in future. We also plan to add some functions for users to build their own circuit extension as in a real laboratory. Several techniques also need to be developed in order to improve students understanding. Since we proposed the multimedia elements used in the Digilab implementation, so the techniques will exploit videos, animations, tutorial player and also reference links which are the media elements. The future works on the techniques are explained in the following section.

7.1 Videos of lab techniques

Laboratory techniques to be videotaped were selected from several teaching laboratory techniques used in remote laboratories and also classes in UKM. Outlines of the elements of the videos were written and scripts were prepared to guide in the video process.

Recent studies have suggested that students are more engaged when presented with active-learning strategies [18]. The laboratory provides one of the best opportunities for active learning as laboratory classes are designed to teach concepts through experiential learning. Most laboratory sessions are taught onsite; however, with advances in multimedia and online delivery, all or portions of lab sessions can be taught virtually. Virtual lab courses have met with varying success. While Leonard [19] reported that video delivery was equivalent to in-class courses with regard to standard learning outcomes and the video learning approach was more time efficient.

One method of technology-assisted learning is the use of computer simulations to instruct students in the use of lab equipment and procedures. For example, the University of California at San Diego has developed a virtual interactive lab manual [20] for students to experience laboratory exercises through computer simulation before performing them in the lab. Another approach discussed here is the use of videos to enhance preparation for laboratory sessions.

Viewing videos of laboratory techniques increases students self-reported knowledge, experience, and confidence with specific techniques. These videos can be used in a wide variety of laboratory courses, ranging from basic introductory courses to advance specialized courses. Although these videos were not meant to be substitutes for actual lab work, but still this is another alternative for students keep learning and learning. Figure 9 shows the topics that need to videotape which is basic and advanced lab techniques.

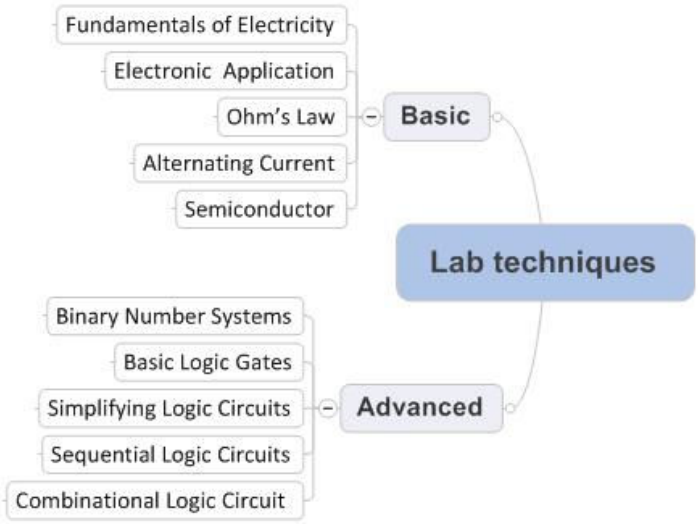

Figure 9: Videos of lab techniques

7.1.1 Basic

For basic lab techniques, there are five topics to be videotaped which are Fundamentals of Electricity, Electronic Application, Ohm's Law, Alternating Current and Semiconductor. Each of the topics has the subtopics to be videotaped. The list below give briefly details about the basic lab techniques.

Fundamentals of Electricity

- Current
- Voltage

- Resistance
- Electronic Measurement-meter

Electronic Application
- Power
- DC Circuits
- Inductance
- Capacitance

Ohm's Law
- Electric circuit
- Application of Ohm's Law
- Kirchhoff's Current Law
- Kirchhoff's Voltage Law

Alternating Current
- AC Measurement
- Resistive AC
- Transformers

Semiconductor
- Diode
- Transistor

7.1.2 Advanced

For advanced lab techniques, there are five topics to be videotaped which are Binary Number Systems, Basic Logic Gates, Simplifying Logic Circuits, Sequential Logic Circuits and Combinational Logic Circuit. Each of the topics has the subtopics to be videotaped. The list below give briefly details about the advanced lab techniques.

Binary Number Systems
- Binary Numbers
- Binary and Decimal Conversion
- BCD Code

Basic Logic Gates
- AND gate
- OR gate
- NOT gate
- NAND gate
- NOR gate
- Exclusive OR and NOR gates
- Buffer

Simplifying Logic Circuits
- Veitch Diagrams
- Karnaugh Map

Sequential Logic Circuits
- Flip-Flops
- Counters
- Shift Registers
- Memory
- State Diagram

Combinational Logic Circuit
- Encoders
- Decoders
- Multiplexers
- Half Adder
- Full Adder
- Memory: RAM and ROM

Basically, we use videos in instruction to improve student understanding and to enhance preparation for laboratory sessions. Several videos were produced introducing students to both basic and advanced techniques. Each video were several minutes long and students could view them multiple times prior to class. So, this is an advantage for students to revise back whatever they learn and looking forward for more understanding using the virtual lab. The video collection also serves as a resource for review and standardization.

7.2 Flash Notes

Flash provides a means to create interactive virtual learning environments, where lecturers and students can explore places and things previously limited by the classroom or simply by time constraints. Students can participate in a visually exciting, engaging activity that meshes traditional textbook learning with a hands-on activity. Participation can lead to investigation of subjects previously difficult to visualize or investigate [21].

The multimedia simulations have been chosen because of many reasons, such as;
- may boost curiosity, creativity, and teamwork [22];
- capable to increase learning retention and transfer [23], [24], [25];
- provide more consistent course delivery [26];
- improve attitudes towards learning [27].

The artwork and environment can help create an environment where the student can read and explore. Meanwhile the experience is enriched with the interactivity.

Nowadays, students preferred learning in an interactive way so that they are not bored. Flash notes on digital logic design subject will be prepared in the Digilab to

increase student engagement in learning by virtual lab. Animations capable features are innovations which can enliven the learning experience. Experiencing a concept or idea engages students, and an engaged student is a learning student. Instead of having a lecture day and then a lab day, the student experiences both on the Web.

7.3 Tutorial player

Students will be guided with tutorial player which is voice recording on the information about digital logic design concept. The player will be prepared so that students can capture multiple times on what they were learning. The player is like tutorial for the students which they can play, pause, stop and play it again and again. This tutorial player will greatly transfer the student enthusiasm on gain much more knowledge.

8 Conclusion

This virtual laboratory application or DigiLab is design to create a more effective lab to make the new alternative laboratory in order to cut the cost and save the sustain. Additionally, we realize that the traditional laboratory is still useful. The exposure to boards and wires also provides more interesting and experience to student. DigiLab, however should be considered not as a complete replacement of the actual laboratory experience, but rather as a very good teaching aid to the students worldwide. We believe that our choices in the design make this DigiLab an excellent balance between a software approaches to teaching logic design at the introductory level, especially for IT student.

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