USING EXPERIENTIAL LEARNING MODEL TO IMPROVE THE OUTCOMES FOR MICROELECTRONIC SUBJECT

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ABSTRACT

Universiti Tun Hussein Onn Malaysia has long been committed to improve the teaching and learning (T&L) approach within its undergraduates program. Several T&L approaches such as Problem-Based-Learning (PBL), Project-Oriented Problem-Based-Learning (POPBL) and Experiential Learning have been introduced. Recently, UTHM is actively implementing PBL and POPBL in engineering subjects. However, implementation of PBL or POPBL in all engineering subjects can overload and burden the students. Thus proper planning and implementation of PBL must be done. This paper presents the implementation of Experiential Learning approach in Microelectronic Subject (BKE 4423) for Electrical Engineering students. The methodology is based on an existing educational model which includes four basic stages; active experiences, reflective observations, abstract conceptualization and active experimentation. In this paper, discussion and details are presented on how Experiential Learning model is used to transform existing approach in teaching Microelectronic subject. The implementation of this Experiential Learning approach has improved the learning outcomes for this subject without overloading the students. Therefore, it is proposed that Experiential Learning should be an option and used with PBL in enhancing the teaching method to achieve a better subject learning outcomes.

Keyword – Microelectronic, Problem-Based-Learning (PBL), Project-Oriented Problem-Based-Learning (POPBL) and Experiential Learning

INTRODUCTION

Universiti Tun Hussein Onn Malaysia (UTHM) has long been committed to improve the teaching and learning (T&L) approach within its undergraduates program. Several T&L approach such as Problem-Based Learning (PBL), Project-Oriented Problem-Based Learning (POPBL) and Experiential Learning (EL) have been introduced. The Centre of Teaching and Learning (CTL) in UTHM is actively offering many courses to lecturers to improve their teaching skills.

Faculty of Electrical and Electronic Engineering is offering Microelectronic subject (BKE 4423) to final year students. This subject includes the CMOS integrated circuit design and integrated circuit fabrication in the microfabrication cleanroom of ISO Class 100 and Class 1000. The objectives of this subject are:

• OB1 “To understand the concepts, developments and applications of microelectronic”.
• OB2 “Understand the principle of Complementary Metal Oxide Silicon CMOS circuit design”.
• OB3 “Understand the CMOS processing technology”.
• OB4 “Analyze the design issues and subsystem design”.

In accordance with these objectives, students should be able to:

• OC1 “Explain the concept, development and application of microelectronic”.
• OC2 “Implement the theories in practical and suit themselves in the recent industrial requirements”.
• OC3 “Construct circuit modelling and do simulation on fabrication
This subject is an integration of several microelectronic fields such as integrated circuit fabrication, VLSI design and integrated circuit design. In this paper, experiential learning model is used to improve the outcome OC4 for this subject. This paper also describes how the experiential model is incorporated in the UTHM classroom in order to improve the outcomes for microelectronic students. The methodology is based on the Kolb’s educational model and includes four basic stages; active experiences, reflective observation, abstract conceptualization and active experimentation as shown in Figure 1 [1]. Typically the stages or phases occur non-simultaneously and sequentially, although reflective observations can be made at different times throughout the overall model. Varying time durations are required in order to accomplish each stage. Two aspects can be seen as especially noteworthy: the use of concrete, ‘here and-now’ experience to test ideas; and use of feedback to change practices and theories [2].

As for the first two stages of the model (active experience and reflective observations), before entering the integrated circuit fabrication course, students may have had experience working with various types of fabrication equipments and cleanroom. Thus, these students would be entering the course after having accomplished the first stage and perhaps second stages of the learning model. Although active experience can be done in classroom using simulation and class assignment, it is more suitable to let them experience the cleanroom environment and fabrication equipments since they do not have background in integrated circuit fabrication. Reflective observation of this experience can also be incorporated in the classroom where the students can reflect their experience in the cleanroom and ask questions to the lecturer regarding their experiences [3]. The stage three (abstract conceptualization) can be done by providing various type of physical devices related to the course concept and theories. In this paper, stage four (active experimentation) is done by allowing the students themselves fabricate nMOS transistor in the cleanroom.

**COURSE STRUCTURE**

The Subject BKE 4423 offers six chapters for one semester. In this paper, EL is implemented only for chapter 6 since this chapter is very difficult to understand using traditional learning approach. This course provides the understanding of transistor manufacturing and skills in integrated circuit fabrication process.
In order to enhance the students learning, several cleanroom technologies are studied. The text book used is ULSI Technology by Chang Sze [4]. The cleanroom classes are studied since different processing technology requires different class of cleanroom cleanliness. Students need to design mask for integrated circuit fabrication using computer aided design (CAD) software such as TurboCAD and AutoCAD. Since in UTHM cleanroom only uses four masks in IC processing, the students are divided into four groups to do the design. The students will be explained the photolithography process and how this process can transfer the mask patterns onto the wafer. During experimentation, the development of oxide silicon in the oxidation process is explained by lecturer. The process of diffusion, etching and metallization will be demonstrated by lecturer before the students experience themselves all these processes. When the students have successfully fabricate the nMOS transistor, the will test the transistor using I-V and C-V characterization tools and conclude their result in their final report.

**EXPERIMENTATION TOOLS**

Most of the students already know microchip and integrated circuit, but none of them experience the integrated circuit manufacturing and processes. Students need to know the environment of integrated circuit manufacturing before learning the manufacturing processes. In this course, students have the experience working in cleanroom environment as shown in Figure 2.

![Cleanroom environment](image)

**Figure 2:** Cleanroom environment

The mask design aid is using transparency film designed using AutoCAD drawing tools. Students have to understand the processing steps before designing the mask. There are four...
masking processes for diffusion, gate oxidation, contact etching and metallization. The sample for mask design is shown in Figure 3.

![Diffusion mask](image1.png)

**Figure 3:** Diffusion mask

The photolithography tools comprise of photoresist coating and UV exposed as shown in Figure 4. These tools will enable the students to use their mask and transfer their designated pattern onto the silicon wafer as shown in Figure 5.

![Photolithography tools](image2.png)

(a) Photoresist coating; (b) UV exposed

**Figure 4:** Photolithography tools; (a) Photoresist coating; (b) UV exposed

The oxidation and diffusion process are using furnaces. This furnaces need to be handle carefully since without proper handling the wafer may crack due to very high temperature. In the oxidation process, hot oxygen gas flowing through the silicon wafer will develop oxide layer. The diffusion process is using phosphorus as the dopant. At high temperature, the dopant will be drive-in the wafer and established a MOSFET structure.

![Silicon wafer](image3.png)

**Figure 5:** Silicon wafer
The etching process is using wet bench module as shown in Figure 6. Using this module, students can do the etching process to remove the unwanted oxide silicon on the silicon wafer and dry the wafer using sin-dryer. Students will observe the difference of the silicon wafer before the etching process and after the etching process.

![Figure 6: Wet etch bench module](image)

The PVD (physical-vapor deposition) furnace is used to evaporate the aluminum foil and stick on top of the silicon wafer in metallization process as shown in Figure 7. This process is done in vacuum and using high temperature. Students themselves will operate this furnace to make them experience the process of metallization. During this process, students need to understand that the pressure inside the furnace must be correct. If the pressure is incorrect, the process might fail.

![Figure 7: PVD furnace](image)

After completing these processes, the nMOS transistor is successfully fabricated. The students need to relate the result from the experimentation with theoretical to ensure their device is working. In order to check the characteristic of the nMOS transistor, the I-V (current versus voltage) and C-V (capacitance versus voltage) must be measured using probe station as shown in Figure 8. If the output of the device is similar with the theory, then the device is working correctly.
Using the experiment tools in the cleanroom, students involved actively in the final stage (active experimentation). Students have better understanding in each of the integrated circuit fabrication process such as the effect of heat and gas flow in oxide growth, the effect of geometric scale in transistor performance and also how to optimize the process parameters. Result from stage four, students have successfully fabricated the nMOS transistor and hence fulfill the outcome OC4.

SUMMARY AND CONCLUSION
Universiti Tun Hussein Onn Malaysia (UTHM) has long been committed to improve the teaching and learning (T&L) approach for the undergraduates program. The implementation of only one approach such as PBL or POPBL will burden the students since this will overload the students learning time. In this paper, implementation of Experiential Learning (EL) inline with the PBL and POPBL is very efficient since EL can be implemented in limited period of time. Having the students experience the cleanroom environment and the Integrated Circuit (IC) fabrication equipments (stage one), will give an idea to the students how the IC is manufactured. Reflective Observation (stage two) during classes can be done by asking question to the students or the students can ask the lecturer regarding their experience. Relating the fabrication equipments and the cleanroom environment to the concepts of theoretically would give the students better understanding (stage three). Finally, by doing active experimentation in the cleanroom (stage four) would give the students the overall picture of what is IC fabrication all about. The outcome from this approach, students are successfully fabricated their own integrated circuit device.

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REFERENCES