International Flipped Class for Chinese Honors Bachelor Students in the Frame of Multidisciplinary Fields: Reliability and Microelectronics

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Abstract

This paper reports an innovative pedagogic experience performed at South-East University (SEU) with electrical engineering Bachelor honors students (computer science, mechanics, and electronics). The purpose was to develop their motivation and to make them aware of the strategic importance of two aspects of electronic engineering i.e. integrated technologies and reliability assessment of devices and systems. The pedagogical approach was based on a flipped class and learning by project that consisted to involve the students in the two topics. After several lectures on the fundamentals of microelectronics and reliability of electronics components performed by foreign professors, twelve groups of five students were built. Each group had to develop one topic, chosen for its strategic importance. Thus, from a given set of main literature references, the students prepared during three days a twelve pages report and an oral presentation, both in English language. Results were generally very good. Most of the students succeeded in addressing issues that were completely new for them. They clearly built by themselves the skills allowing understanding of all the important aspects of the topics they had to approach. This paper gives details on the organization, the content and the final evaluation.

Keywords: pedagogical innovation, learning by project, flipped classes, microelectronics, reliability, transdisciplinary approach, international teaching

1. Introduction

This paper reports an innovative pedagogic experience performed at South-East University (SEU) of Nanjing (Jiangsu, China) with engineering Bachelor honors students (computer science, mechanics, bio-medical engineering and electronics). The purpose was to develop their motivation and to make them aware of the strategic importance of two aspects of electronics engineering i.e. integrated technologies and reliability assessment of devices and systems. Indeed, while electronics is driving most of human activities sectors, it becomes very important to highlight the major issues of advanced technologies and very high reliability levels of devices and systems. In addition, the evolution of the technologies allows an increasingly spreading of the applications. There are today many fields of application of the electronics in the new concepts of smart connected objects and Internet of Things (IoT). The main well-known application domains are health, transport, communications, security, energy and environment with the microelectronics at the heart of the systems [1]. This means as well an increasingly multidisciplinary

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approach in the pedagogical strategy and an innovative behavior of the future graduate and post-graduate [2]. The evolution of the content of the engineering formations must answer progressively to this new trend of the technics. With the same goal, a transverse discipline that manages crucially the use of a product, is the reliability, discipline that becomes a major objective of all the products that are becoming more and more complex. Reliability is applied at multiple levels of complexity. The simplest case corresponds to a discrete object, for example an elementary transistor. Higher complexity appears in integrated circuits that can contain several billion elementary transistors. The worst situation is related to huge systems, for example data centers that can contain millions of complex integrated circuits, each of which is built of billions of elementary transistors! These two subjects are therefore part of the objectives for students and the challenge is to choose the best pedagogical way to acquire these skill.

The pedagogical approach was based on a flipped class and learning by project that consisted to involve the students in the two topics with a major part of their personal investment. After several lectures on the fundamentals of microelectronics and reliability of electronics components performed by two foreign professors in English language, twelve groups of five students were built. Each group had to develop one topic, chosen for its strategic importance, such as the reliability of the space electronics, the Data Centers, the challenge of very high density packaging, but also the huge development of connecting objects, the ULSI and the large area electronics. Thus, from a given set of main literature references, the students have to prepare during five days a twelve pages report and an oral presentation, both in English language.

After a short presentation of the context, the paper deals with the organization of these international flipped classes, the content of the personal works in the both specialties, an analysis of the main results, and a description of the evaluation of the questionnaire filled by the students.

2. Honors Bachelor

The Honors bachelor students are highly selected students that are supposed to produce an efficient work and to continue in post graduate studies. They are rigorously selected at the entrance and are enrolled in an institute, in this case, the Chien-Shiung Wu College. All the students are selected on the basis of a good capability to work in English language. They are thus expected to attend to lectures and seminars performed by foreign teachers. The students are also able to write documents in English, even if with scientific purpose they have to learn new vocabulary adapted to the domain. There are several promotions spread in four main disciplines: computer science, electrical engineering, mechanics and bio-medical engineering. The managers of the bachelor degree have the possibility to organize specific modules, with the goal to make aware the students in high technologies with a new pedagogical approach. Thus the concept of flipped classes was adopted. Two groups of thirty students were built, the first one having the objective to study the new field of microelectronics, the second the new field of reliability.

As it is well known, many applications in engineering are increasingly involving smart connected objects based on microelectronics systems [3]. Two aspects are thus very important: the technics and technologies that are at the core of the systems [4], and the reliability [5] that is one of the main parameters that characterize good products adapted for their mission profiles. These two fields are today a significant component of the background of engineers. They are also at the heart of the future challenge of the technological innovation. That is the reason of the choice of these topics for the students at the level of the third year of the bachelor:

- Microelectronics and Nanotechnologies: engineering sciences at the heart of the smart connected objects and of their applications,

- The reliability challenge for advanced technologies: A critical concern for research, production, economy and modern society.

These two topics are selected by sixty students of the Institute. In order to maintain a high motivation of the students, they build by themselves six groups of five students with the objective to work on one of the proposed topics.

3. Awareness to Microelectronics and to the Reliability

The evolution of the fields of microelectronics and nanotechnologies has presently two main orientations: on the one hand, the ultra large scale integration following the famous Moore’s law [6] with FinFET or FDSOI technologies [7], and on the other hand, the heterogeneous technology approach that inserts the new devices in systems, mainly the smart connected objects based on integrated technologies but also on large area electronics, on thin film technologies, on sensors and actuators that can be linked to the applications. Sensors may concern the physical, chemical, spatial and biological detections, while the actuators can drive mechanical, fluidic, optical, thermal mechanisms that are involved in the monitoring of many security or medical equipment. The evolution of these technologies corresponds to a new law of evolution, named “More than Moore” and includes system in package, systems on chip involving the third dimension and even lab-on-chip. Fig. 1 shows the classical representation of the Moore’s law issue of the IPC report [8].

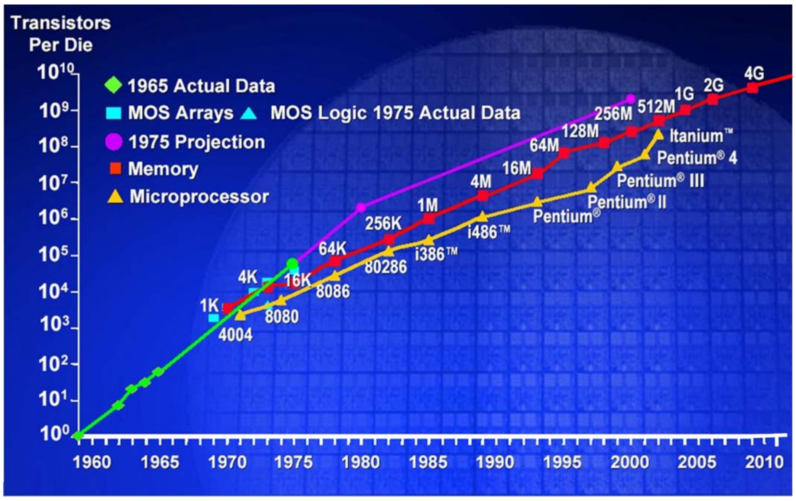

Fig. 1 Moore’s law representation: the exponential increasing of the integration was verified during more than fifty years, even if the slope was a little bit smaller than the predicted one by G. Moore in 1965! (After IPC report [8])

This evolution is also a consequence of the fabulous improvement of the design tools, in the frame of the computer aided design approach. These tools are able to design and simulate very complex circuits with billions of elementary devices (mainly transistors) but also imply the integration of many new functions in heterogeneous technologies. These last are combining electronics functions with either mechanical elements and optical devices, or functionalized surfaces able to detect chemical or biological species. Besides, a multidisciplinary approach is increasingly needed in order to develop in the frame of research and development team’s new products in many domains of applications such as health, transport, communications, security, energy and environment with the microelectronics in the heart of the systems [1]. This combination of these knowledge and multidisciplinary competences is the engine of the innovation. Thus, it is a real challenge to form the young to this new approach.

In parallel, the increasing complexity generates new problematic that is linked to the mission profiles of the products, the ageing, the security of the systems that are all gathered in the reliability domain. It is more and more important to evaluate the meantime to failure of each product (MTBF), and more especially the Failure in Time parameter (FIT) that must be very low even in a reliable complex system. This parameter is strongly function of the environment that can be harsh in many applications. This behavior corresponds to the presence or the variation of the parameters such as, temperature, humidity, electromagnetic radiation, particle bombardment, electrical stress (high voltage or high current), mechanical vibrations, mechanical stress, chemical or aggressive ambiances, etc. Fig. 2(1) shows the classical variation of the failure rate in function of the time. The analysis of the reliability consists to understand the three main stages of the evolution, the early infant failure rate, the normal failure and the end of life failure. However, for so complexintegrated electronic devices, the question of obtaining very high yield production levels has imposed strategies of Total Quality Management in the devices processing, with a drastic reduction of latent defects and infant failures at the first stage of the devices life time. Furthermore, as electronics systems are now driving almost all sectors of human activities, their reliability is now one of the main factors conditioning their life safety. Thus, the classical "bath" shaped failure rate curve is being targeted in an almost constant "zero" failure rate, up to the end of life time, as shown Fig. 2(2). The solutions to reach such results are difficult to derive and need to develop particular skills for engineers.

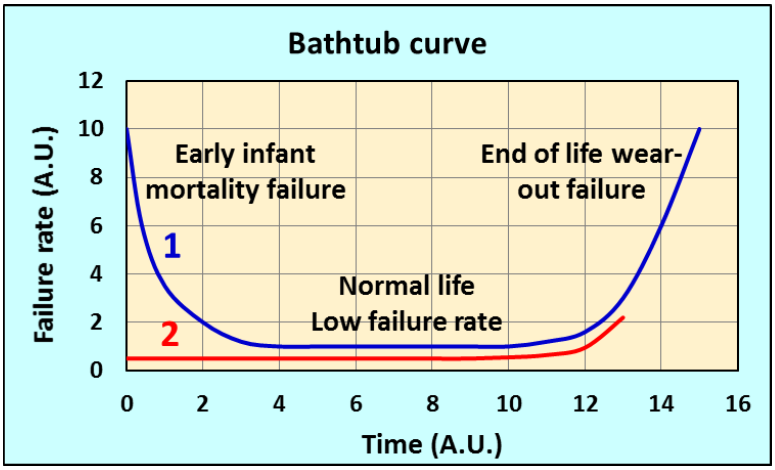

Fig. 2 Failure analysis: 1) Classical bathtub failure rate evolution (blue); 2) Almost constant zero failure rate. The second curve is the targeted behaviour of the innovative circuits and systems (red)

These two topics are selected by sixty students of the Institute. In order to maintain a high motivation of the student, they build by themselves six groups of five students with the objective to work on one proposed topic.

4. Organization of the Flipped Classes

The modules are organized on two weeks. The students are shared into two classes of thirty students, divided into six groups of five students each. The face-to-face duration between students and teachers is about twelve hours. The personal work of each student is approximately five times higher. It includes bibliography research, analysis of the given documents, compilation of the research by the group, repartition of the work, organization of a report, redaction of the manuscript, preparation of the oral presentation involving classical tools such as powerpoint diaporama. More or less, the presentation is half an hour that means a very precise duration and a clear sharing of the intervention by the five speakers.

The students did not yet have solid experience in both areas. As a result, the beginning of both modules was devoted to several lectures that explain to students the context of the disciplines and their main principles. From this approach, the s tudents are selecting their subject after the second conference.

Each group had to develop one topic, chosen for its s trategic importance, such as the reliability of the space electronics, the Data Centers, the challenge of very high density packaging, but also the huge development of connecting objects, the ULSI and the very large area electronics. Thus, from a given set of main literature references, the students prepared during three days a twelve pages report and an oral presentation, both in English language.

5. Effective Works of the Students

The students had to prepare their presentations. The subjects of the presentation and of the short report cover the most important aspects of the field, i.e., the evolution of the integration, the development of new technologies, the extension of the field of applications, more especially in the evolution of the connecting objects and of internet of things (IoT) on the following topics for the microelectronics field:

- new technologies for the future integration,
- evolution of MEMS,
- large area electronics,
- microelectronics for telecommunications,
- connecting Object for Environment Application
- the substrates for integrated microelectronics and solar cells.

For the reliability, the subjects cover the main types of applications on the devices and on the systems:

- the reliability of the space electronics,
- the harsh environments: Reliability impact on electronics devices,
- the reliability of Data Centers,
- the challenge of the very high density packaging,
- the dielectric degradation and breakdown.
- The radiation effects.

6. Survey Based on a Questionnaire: Main Results

In order to have a good appreciation on the pedagogic efficiency of the approach, the students were asked on the several points of the experience. Ten questions were directly focused on the organization and on the content of both modules :

- adequacy of the topics to the curricula of the bachelor students,
- diversity of the subjects with the curricula (engineering),
- duration of the modules that were concentrated on two weeks only,
- organization (lectures, schedule, presentations),
- quality of the evaluation of the work (marks obtained by the students),
- originality of the pedagogical approach,
- contribution to the awareness of the technological challenges,
- improvement of the general skills and knowledge,
- relevance of an oral presentation,
- impact on English language practice.

The answers were shared in five types: very bad, bad, good, very good and excellent. The results are anonymous in order to avoid any limitation on the student side. In addition, a case was reserved to free comments. Very few students have filled this case. Among the sixty students, fifty eight have answered. Thus, the return percentage is 96.7% that represents a real significant sampling of appreciations. Fig. 3 shows the histograms of the answers for the two modules.

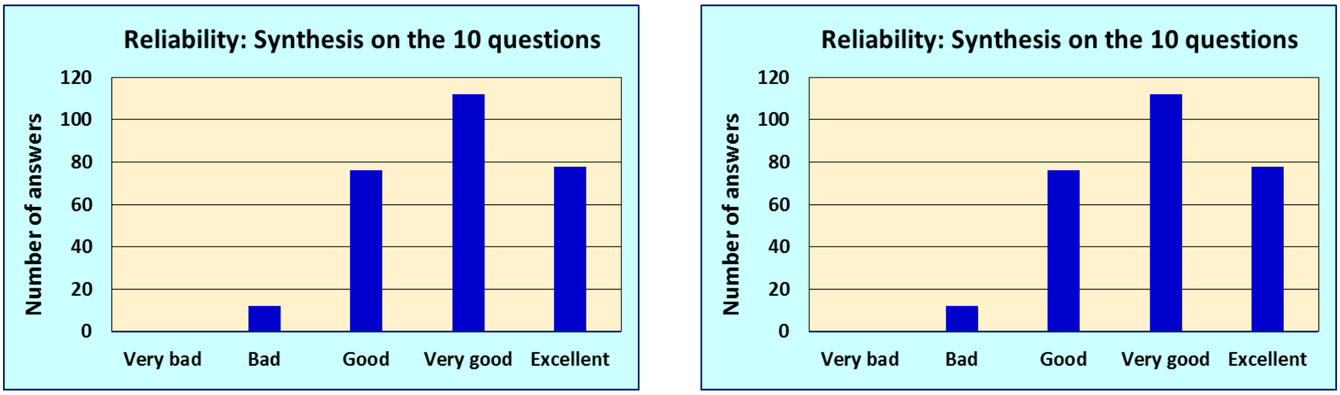

Fig. 3 Cumulated answers of the survey. On the ten questions (300 answers), for both specialities, the students found the approach very good in average. A large majority has considered that the foreign language was not a drawback. Only two students had some bad feeling on the modules (organization and interest)

For both specialties, the students found the approach very good in average; more than 70% have considered the experience very good or excellent. In the free comments, no remark on the amount of personal work they had to do. They well accept the approach mainly due to a good motivation and probably for its novelty, for them. A large majority has considered that the foreign language was not a drawback. Only two students among the fifty-eight had some bad feeling of the modules (organization and interest).

Fig. 4 Results of the survey. General appreciation of the students on the two modules. Only two students among fifty-eight were not satisfied of the modules and of the flipped class approach

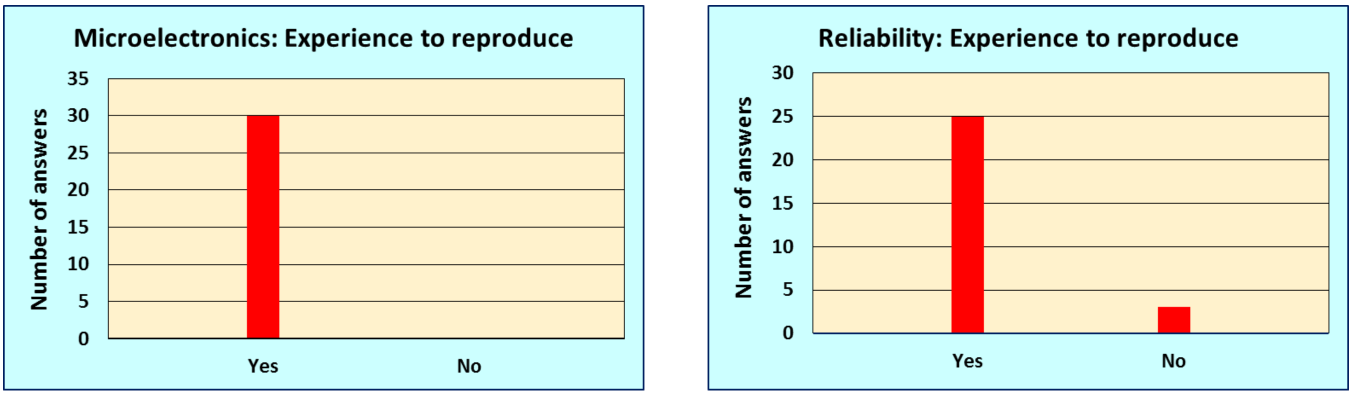

Fig. 5 Result of the survey on the opportunity to reproduce this experience for the next promotion. Only three students among fifty-eight have considered that the modules could be cancelled next year

Fig. 4 shows the general evaluation of the modules. A large majority was very satisfied and more (a majority of excellent!). Its represents more than 80%. This is a proof that the two modules have answered to a need that was very appreciated by the students.

On the basis of these results, a specific question about the reproduction of the same modules for the next promotion was asked. A large majority of the answers was “yes”. Fig. 5 shows the histogram of these answers.

Among fifty eight students, only 3 estimated that the experience is not interesting for the new students. In other words, 94% of the students found that this experience can be reproduced for the future Honors.

7. Conclusions

Results were generally very good. Most of the students succeeded in addressing issues that were completely new for them. They clearly built by themselves the skills allowing understanding of all the important aspects of the topics they had to approach. They were able to highlight the main problems to solve, to improve the current solutions, and to perform a presentation in English.

In conclusion, such a self-made intermediate project by the students has been very beneficial to introduce new teaching sessions related to the new concepts applied to advanced microelectronic technologies and high reliability devices, within the framework of international studies. This approach is included in the updated strategy for higher education oriented towards innovation [9]. The French national network of microelectronics, GIP-CNFM [10-11], has adopted this strategy for many years. More recently, the Chinese government [12] has also followed this evolution.

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