Experiential Learning Approach for Digital Electronics Laboratory using expEYES Junior

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***Abstract*—History reveals that an appropriate integration of traditional and pedagogical methods can help in creating an experiential learning environment. This environment created in the classroom and/or laboratories helps in effective Teaching-Learning process. However creating this kind of learning environment only in the college is not enough, as students remain isolated from this environment beyond college campus. Hence, an alternative method should be adopted so that the students can work in the same environment even beyond college campus. This paper proposes an environment favorable for experiential learning at an affordable price to carry out Digital Electronics (DE) experiments, using open source hardware (expEYES Junior-expEriments for Young Engineers and Scientists) and software (Python) at affordable price. To validate the adaptability of proposed methodology for DE laboratory, the pilot project implementation in department of electrical and electronics is documented with results. Also the comparison of possible ABET (a-k) attainment with traditional methodology is presented.**

I. INTRODUCTION

Experiential learning for all time has been and perhaps will be an important component in the educational process. In the 25th Century B. C. Confucius was lecturing his own faculty colleagues that they should, Show the students the way but never take them to the place. Throughout the centuries all the crafts, trades, and professions have used the experience for achieving competence. Learning by doing is essential to the educational process. ”Experience is the best teacher” and ”practice makes perfect” have always been regarded as fundamental axioms. Even so, the opportunities in experiential learning activity have never been fully exploited in university education [1]. There are various ways of introducing experiential learning in engineering curricula, namely, laboratory, course projects, case studies and other active learning methods. With the help of laboratory sessions, experiential learning can be introduced from the early semester of engineering. Hence the laboratory has always been regarded as a necessary component of the educational process.

There is considerable amount of work being done to bring in experiential learning for students using different learning plat-forms like teckbot used at Oregon State University Corvallis [2], FIDO controller at Massachusetts Institute of technology [3], Pearl DE laboratory where students interact with remote experiment, change parameters and in some cases modify and design experiments[4], ADLab where DE laboratory is taught using FPGA[5] and also strategies like teaching Boolean logic using Pac-Man game[6]. However

there is no work done in introducing a low cost platform for students to enhance their learning skills by doing things beyond laboratory hours. This paper is an attempt made by the authors to bring in experiential learning into DE laboratory taking advantage of open source platform expEYES Junior.

Organization of the paper is as follows: Section II describes the motivation for the proposed methodology. Section III covers details of Modern Engineering tools used to create experiential learning environment. Section IV presents the particulars of proposed methodology with some examples. Section V deals with ABET (a-k) outcome attainment of proposed and conventional methodology. Section VI concludes the work presented.

II. MOTIVATION

At present the experiments in DE laboratory are broadly categorized into Demonstration, Exercise and Structured enquiry experiments [7]. Demonstration experiments give an idea about the basics of the laboratory course. Students are expected to do Exercise experiments with the aid of knowledge gained by demonstration experiments. In the last category of experiments students are motivated to design a digital application for the given problem statement. Hence, to complete the assigned work, students have to apply the concepts learnt in classroom as well as knowledge gained in demonstration and exercise experiments. The designed circuit should be realized using hardware. Assessment is based on the circuit design and hardware results of the circuits. Limitations of the current methodology are as mentioned below:

- Does not address students of all learning styles.
- Use of costly equipments/instruments like Cathode Ray Oscilloscope, function generator, DC power supply.
- This poses limitation in students’ ability to carry out experiments beyond college campus.
- Difficult to monitor the individual participation of student in team work.
- Slow learners are overlooked because of limited laboratory duration.
- Students are encouraged to test only hardware circuits in the laboratory.

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- Does not encourage learning of software skills demanded by industries.

These limitations can be addressed by proper design of teaching methods and creating experiential learning environment.

A transfer to an experiential based education explicitly acknowledging different learning styles has been forwarded as a more effective alternative to traditional pedagogy [8][9][10]. Students are categorized by different learning styles, preferentially focusing on different types of information and tending to operate on perceived information in different ways. To reduce attrition and improve skill development in engineering, instruction should be designed to meet the needs of students whose learning styles are neglected by traditional engineering pedagogy [11]. Survey was conducted for 25% of the class strength to identify the different learning styles of the students. The different learning styles considered are active, reactive, sensitive, intuitive, visual, verbal, sequential and global. Index of Learning Styles Questionnaire by Barbara A. Soloman and Richard M. Felder from North Carolina State University is made use of to conduct the survey. The result of the survey conducted to identify different learning styles of students is given in Fig.1. The scores for different learning styles are recorded on a scale of 10.

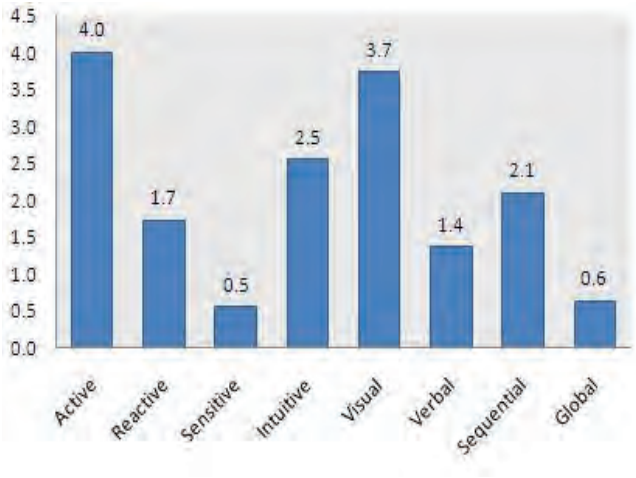


Fig. 1. Statistics of feedback to identify learning styles of student

The graph in Fig.1 shows that, educators have to address students of different learning styles. The graph reveals that majority of the students have active, visual and intuitive learning styles. One of the best ways to ignite students of all learning styles is to bring in the concept of experiential learning. Some of the objectives that can be attained taking aid of experiential learning are [9]:

- Strengthening concepts of engineering fundamentals.
- Promotion of students's ability to use modern engineering tools.
- Encourage students to boost their self confidence.
- Ability to plan and execute.

The proposed method of creating experiential learning environment discussed in section IV makes use of open source software Python and open source hardware expEYES Junior. Advantages of the proposed methodology are as mentioned below:

- Improves level of understanding of the course.
- Increased individual student participation in performing experiments.
- Students get an opportunity to polish their programming skills.
- Students can own hardware at an affordable price, do all possible experiments in sophisticated manner beyond the college campus.
- This hardware and software setup can also be used to carry out project work since the hardware platform is programmable.
- Caters to the needs of students of all learning styles.

III. MODERN ENGINEERING TOOLS

A. *expEYES Junior*

The expEYES Junior (expEriments for Young Engineers & Scientists) is an open hardware platform which uses open source software (Python scripting language). This kit is designed to support a wide range of experiments from school to post graduate level. It also acts as test equipment for Electrical and Electronics engineers and hobbyists. expEYES Junior comes in a compact size of 8.6x5.8x1.6 cm and weighs only 60 gm.

The platform of expEYES Junior, shown in Fig.2, combines the real-time programming capability of microcontrollers with ease and flexibility of Python programming language for data analysis and visualization. The advent of new generation computers and availability of tablets has paved the way to explore experiments with accuracy. The expEYES Junior can be interfaced with tablets having Android operating system 4.0.0 and above. The block diagram of expEYES Junior given in Fig.3 shows how the hardware (external circuit) can be made to communicate with expEYES Junior. The expEYES Junior houses the microcontroller which needs to be programmed by the user with Python programming language. However, the communication between the expEYES Junior and the Python program can be accomplished by importing the library eyesj.py/ejlib.c. The Python program is converted to .hex for-mat to make it compatible with microcontroller. The external connections can be taken out from the microcontroller directly to interface with the hardware. Detailed documentation is available in [12], [13].

B. *Python*

Python is a universal scripting language and is known for the ease with which it can be learnt, even by novices. The code written in Python can be read easily as it can be compartmentalized. Python programming language consists of all data types including strings, lists and dictionaries. Writing a complicated code is avoided in Python as the syntax is clean, with a consistent calling structure for modules and functions. Hence Python programming language is an elegant and clean programming language. Python programming helps the programmar to be an object oriented developer without paying for system programming level syntax like Java or C++. Python possesses the property of interoperability, with interpreters available for all common operating systems. Python uses

small, well fashioned components, called modules. Modules are very easy to design and use, which encourages code libraries [14].

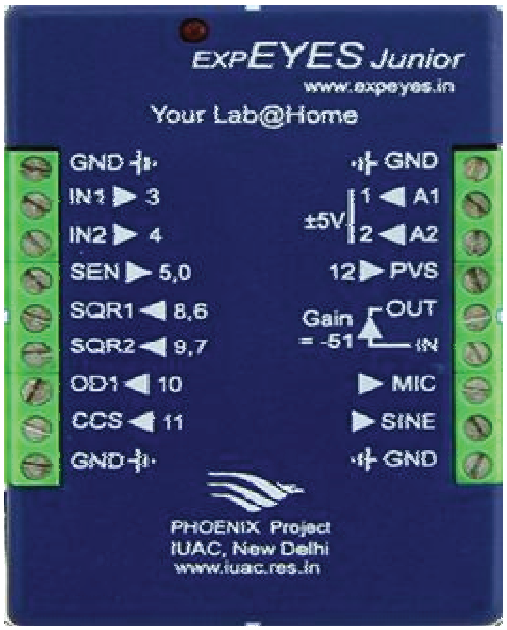


Fig. 2. expEYES Junior module

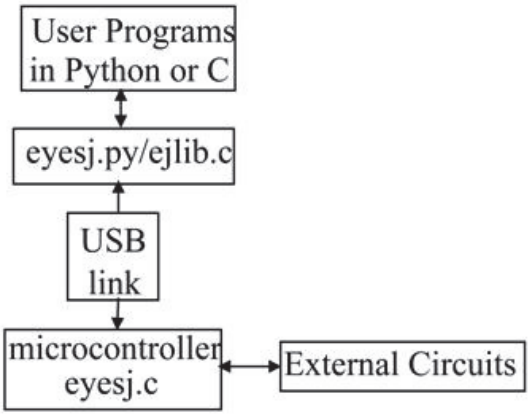


Fig. 3. Block diagram of expEYES Junior

IV. PROPOSED METHODOLOGY

Role of outcome based education (OBE) in shaping students' career is critical [8]. In OBE environment, new and innovative pedagogical methods are always encouraged to make Teaching-Learning process more effective. This section documents the methodology adopted by the authors to implement experiential learning in DE laboratory.

The 3rd semester students of Electrical and Electronics Engineering are expected to work 3 hours per week in DE laboratory. However the slow learners may not be able to complete the experiments in scheduled time. This is identified as weakness and suitable solution is thought of to create a mobile laboratory for students at affordable price using open source platforms. In BVBCET, students are provided with tablets having Android operating system during 1st semester. This is used for interactive learning in courses like mathematics, physics, chemistry etc. The use of these tablets can be extended in DE laboratory also. Through exploration, it was discovered that interfacing the tablet with expEYES Junior and Python could facilitate mobile laboratory for experiential learning.

The categorization of experiments discussed in section II remains the same. However execution starts with modeling of Digital circuits using Python, as a part of pre-experimental work. The results obtained by modeling are validated through experimental verification using expEYES Junior. The same methodology is incorporated for all categories of experiments. Thus Hardware and Software skills of the student can be strengthened.

Experiential learning environment can be created at an affordable price without the use of costly equipments like CRO, function generator and DC power supply. In addition to this, students are made familiar about the significance and application of microcontroller. Consequently satisfying the important prerequisite in embedded system design. Further, students can utilize this platform to experiment and to implement complex control algorithms for various real time applications.

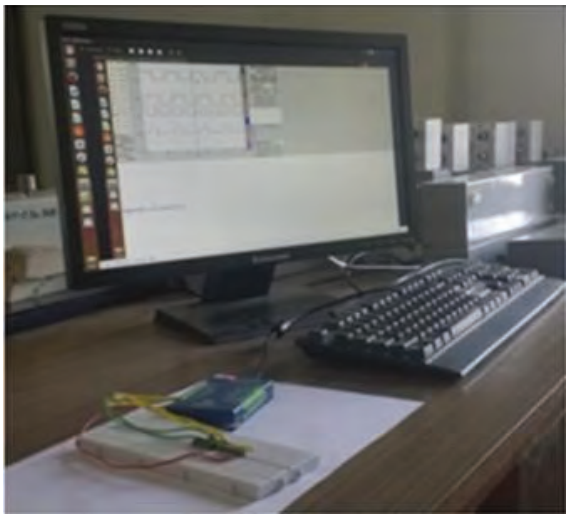


Fig. 4. Proposed Laboratory Set up for DE laboratory

The laboratory set up for proposed methodology and mobile laboratory are captured in Fig.4 and Fig.5 respectively. Fig.4 shows the requirement of expensive equipments is eliminated using expEYES Junior platform and desktop. Fig.5 shows the interfacing of expEYES Junior platform with tablets to set up mobile laboratory.

The list of experiments which the student has to carry out remains unchanged in the proposed methodology. The list of digital circuits tested by authors using proposed methodology is given below:

1) Demonstration experiments
   - Realization of Boolean expressions using logic/universal gates.
2) Exercise experiments
   - Realization of half/full adder and subtractor.
   - Realization of arithmetic circuits using MUX and DEMUX.

- Realization of D and JK flip flop.
- Realization of 3 bit synchronous and asynchronous counter.
- Realization of Serial In Serial Out, Serial In Parallel Out, Parallel In Parallel Out and Parallel In Parallel Out shift registers

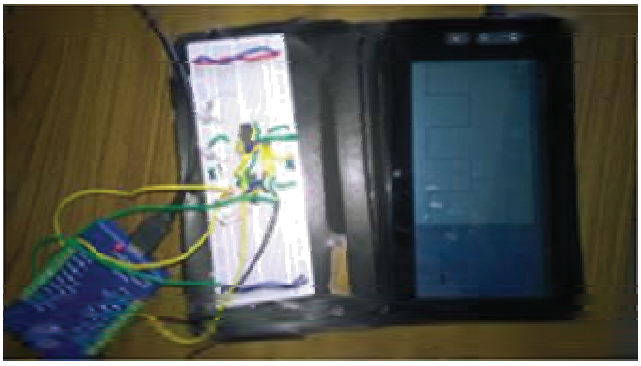


Fig. 5. Interfacing expEYES Junior with Tablet

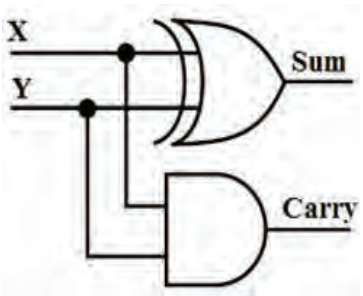
To validate execution of the pilot project, an example of combinational circuit (Half adder) and sequential circuit (3-bit asynchronous counter) is documented. The implementation details of these two circuits are discussed in the following subsections.

A. Half Adder

Half adder is a combinational circuit which logically adds two single bit numbers to give sum and carry as outputs. Fig.6. shows the logic circuit of half adder. Table. I gives the truth table of the half adder. Fig.7. shows the experimental verification of the circuit under consideration.Fig.8. shows modeling of digital circuit using Python programming language. Results captured in Fig.9. validates the truth table given in Table. I. The experimental results of half adder using expEYES is shown in Fig.10

TABLE I TRUTH TABLE OF HALF ADDER

X	Y	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1



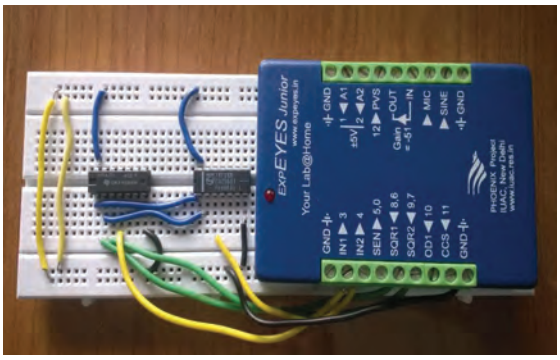


Fig. 7. Hardware requirement for Half adder circuit

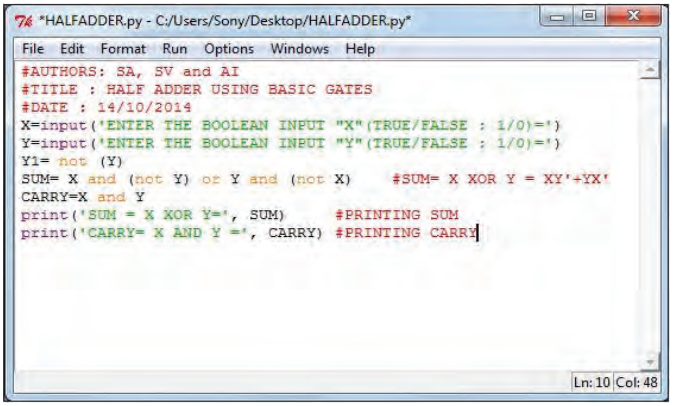


Fig.8. Modeling of half adder circuit using Python scripting language

B. 3 bit Asynchronous counter

A sequential circuit that goes through a prescribed sequence of states upon the application of input pulses is called a counter. A ripple counter shown in Fig.11.consists of a series of JK flip flops. The output of each flip flop is connected to the clock (CLK) input of next higher order flip flop. Fig.12 shows the experimental verification of asynchronous counter.

V. ATTAINMENT

This section deals with the comparison of attainment of outcomes in conventional methodology and possible outcome attainment in the proposed methodology. It is evident from Table. II. that the proposed methodology. helps in attaining i and k over traditional methodology.

TABLE II COMPARISION OF ATTAINMENT FOR CONVENTIONAL AND PROPOSED DE LABORATORY.

ABET a-k	Description	Conventional DE Laboratory	Proposed DE Laboratory
a	Apply maths, science and engineering	✓	✓
b	Design and conduct experiments	✓	✓
c	Design a system, component	✓	✓
d	Function on multidisciplinary teams		
e	Identify, formulate, solve engineering Problems		
f	Professional & ethical responsibility		
g	Communicate effectively	✓	✓
h	Impact of engineering Solutions		
i	Lifelong learning		✓
j	Contemporary issues		
k	Modern engineering tools		✓

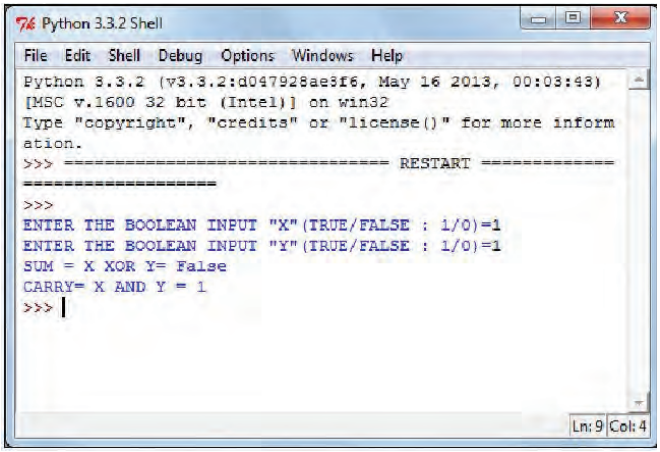


Fig.9.Result of modeling of half adder in Python shell

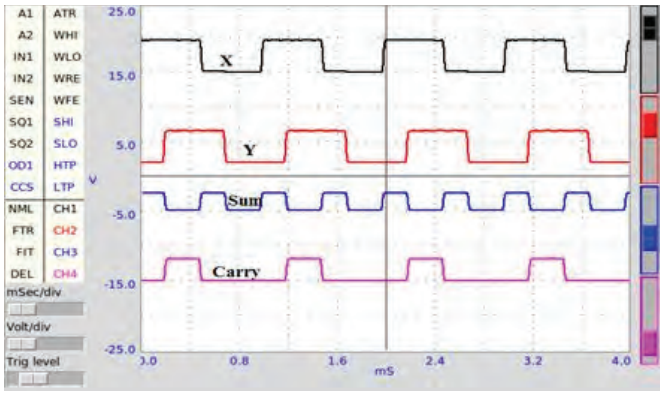


Fig.10.Experimental results of half adder using expEYES Junior

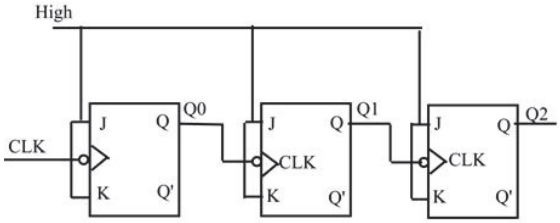


Fig.11.Logic circuit of 3 bit synchronous counter

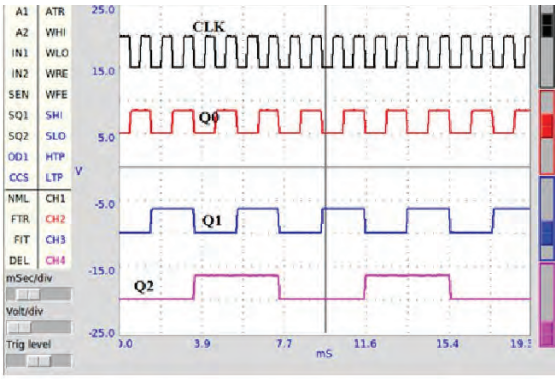


Fig.12.Experimental results of 3 bit asynchronous counter using expEYES Junior

VI. CONCLUSION

This paper highlights the significance and need of experiential learning in present day engineering education. An innovative method adopted for delivery of DE laboratory is discussed using open source platform expEYES Junior and Python. These open source platforms help in creating experiential learning environment at an afford-able price. It is evident that the proposed methodology promotes the hardware skills and programming skills of students by encouraging them to use a microcomputer (expEYES Junior) and universal scripting language (Python). The usage of expEYES Junior can be taken to next level, to design and implement embedded system at a very low cost. Compatibility of expEYES Junior with tablets (with Android operating system version 4.0.0 and above) helps students to set up mobile laboratory beyond college hours. Proposed methodology compels the use of modern engineering tools hence helps in attaining outcomes (i and k) over traditional methodology for DE laboratory.

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