FLEXIBLE VERSE TRADITIONAL EXPOSITORY LABORATORY IN TEACHING DIGITAL ELECTRONICS COURSES

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Abstract
Practical laboratory experiments is an important approach to teaching engineering courses however, massive admission of students, shortage of lecturers, lack of enough practical equipment and inadequate collaboration between industries and schools makes teaching these courses difficult. Evidence suggests that the traditional expository laboratory, as used in engineering courses today, has lost its instructional value because it is teacher centered, while emerging technologies such as simulations are been proposed to serve as robust replacements. However, certain accreditation processes do not recognize these as a legitimate alternative because graduates may not fit very into the real world. Recently, several attempts to find an alternative to learning such as open, blended, engaged, flexible, computer-supported, resource-based, and mobile learning have been proposed. This paper, therefore investigates the application of flexible learning to expository experiments to enhance student centered learning. The study presents the use of available and affordable small-scale replicas components to implement and validate results of two digital electronic experiments. The student's performances for over four years, (two using the traditional and two using the flexible) show that 97% and 94% pass for traditional and flexible approach were achieved respectively. The results of the experiments also revealed significant conformity with theories, improved student learning and retention of basic concepts, with 47% high class graduates (Distinction and Upper Credit) for both approach while, 47% low class graduates (Lower Credit and Pass) for the flexible approach as against 50% for the traditional. The results suggest that the flexible expository laboratory can serve as a legitimate teaching aid, 'a bridge', and or alternative to the traditional expository laboratory where facilities are not available. It is therefore recommended that current accreditation practices requiring engineering courses to have mainly "traditional expository" laboratories facilities need to be revisited. Teaching methodologies be modified to guide students towards flexible learning, which are student centred and very necessary in the training of future Engineers.

Keywords: flexible Laboratories, Expository Laboratories, small-scale replicas, logic level, Digital Electronics courses, Learner-centered.

Introduction
Engineering education by its nature is a costly program in university environments. Perhaps the most costly component is the laboratory facility, usually consisting of specialized equipment (Mihaela et al, 2004). Laboratory experiment has been a central component of science instruction since the early 20th century (Singer et al, 2006). It has been used to teach experimental methods and techniques that clarify and or validate existing scientific principles and theories. Typical laboratory experiments are considered to be expository in nature (Lagowski, 2002). Expository environment utilizes rote procedures which inhibit students from forming a genuine understanding of the connections between the data they collect and the theories the data describe (Eylon & Linn, 1988).

According to National Board for Technical Education (NBTE), 2001, engineering courses gives the student, the theory and practical skill, needed to practice and the practical should account for between 60-70% of contact hours. Insisting that the teaching of the theory and practical work should as much as possible be integrated on a ratio of 50:50 or 60:40 or the reverse. Similarly the National Universities Commission (2017) declared that by the nature of the disciplines in Engineering and Technology, laboratory practicals are very important in the training of the graduates. Furthermore, it is very important to determine performance of the student in the practical component of the programme. These practicals must follow the trend in the current development of the programmes.

Barau, (2015), stressed the need to enhance teaching and learning for graduate of Electrical Engineering in Nigerian Higher Institutions, with emphasis on how low quality graduates are produced due to massive admission of students, shortage of Lecturers, lack of enough practical equipment and inadequate collaboration between industries and schools. Though, time multiplexing of laboratory schedules and teamwork are possible solutions, the author concluded that survival of education in Nigeria depends on effective use of new teaching and learning technologies for instruction. Therefore best possible means to enhance the teaching and learning of electrical engineering courses is to interweave the traditional method of teaching with inquiry method of teaching.

Mihaela et al, (2004) suggested, scheduling flexibility for laboratory classes should be considered since many students have extended commitments. Citing the need to develop laboratories from which real experiments can be conducted at any time, without instructor surveillance or guidance. Each of these solutions has their drawbacks—mainly relating to providing each student with hands-on experiences in a way that can practically fit into their education schedule.

Literatures suggest that expository (teacher-centered) approaches can be enhanced using virtual or simulated (learner-centered) approaches, hence impacting on learning in positive ways (Cheng, et al., 2010; Hessley, 2004; Huppert, et al., 2002; Kennepohl, 2001; Mencer, 2002). Yannis, (2010) stated that modern students are used to immediate gratification, delay in practical demonstration could lead to lose of motivation, develop frustration and many become passive learners. Similarly, Ertugrul (2010) puts it that, as the roles of teachers and students is changing, so there are undoubtedly ways of learning not yet discovered. Hence the use of highly interactive user interfaces and facilities which are not deliverable in the conventional methods could enhance learning.

WGDEOL (Working Group on Distance Education and Open Learning) (2002) explained some principles of learning which includes; open learning, blended learning, engaged learning, flexible learning, computer-supported learning (distance education, on-line learning, e-learning and web-based learning), resource-based learning, mobile learning, and other main educational principles such as student and learning centeredness.

Ushie & Ogbulezie (2016) Learner-centered technique which is concentrated on learning through students carrying out activities as reported by Laguador and Dizon, (2013) is characterized by involving the students in the messy, hard work of learning. It empowers and motivates students with some level of control in the learning process. Ushie & Ogbulezie (2016) also cited Petty (2004), as saying that Statistic from National Teaching Laboratory US as presented in a learning pyramid shows that 75% remembering rate for learning activities is achievable, through students doing (carrying out activities) what has been taught to them. However the 75% remembering rate may not be achievable in Nigeria, due to the numerous problems as listed by Barau (2015).

Flexible learning (FL) is very much the same as the student-centered learning which is based on the philosophy that recognizes the diversity of learning styles and student's needs. The flexible method uses a range of approaches to accommodate student diversity, giving students greater choice in terms of when, where, and how they learn. Flexible learning could include, among others, online learning (e-learning), distance education, self-directed learning, mixed-mode delivery, mobile learning, and self-paced learning. One of the major advantages provided by flexible learning is its ability to help students develop technical skills and confidence. The users manipulate small-scale replicas devices (components) to develop proficiency for operating the corresponding real world system. Some institutions consider initially utilizing the simulation (flexible) method to train the student before his/her use of the equipment for in-laboratory experiments purposes. This will help students to practice utilizing the small-scale replicas devices in a tutorial mode, before they actually perform the experiments (Keith, 2003).

Markan et al (2013) reported that currently most universities have Online-learning environments ready to be remotely accessed through the internet. Remote labs have emerged as a viable alternative for developing skills and to learn how to deal with laboratory instruments in the absence of real labs. Remote labs can provide remote access to hardware and simulators, and can allow students to perform experiments without time and location restrictions. In addition, they provide the necessary guidance and also constrain user operation in order to avoid dangerous situations (both from set-up integrity and from the user's point of view).

Mihaela et al (2004) reported that engineering education by its nature is a costly program in university environments. Perhaps the most costly component is the laboratory facility, usually consisting of specialized equipment. That however, effective instruction of some topics such as in power engineering will require experience with actual equipment, rather than small-scale replicas or simulation which is imperative for scheduling flexibility for laboratory classes.

Pyatt & Sims, (2007) stated that simulation laboratory can serve as a legitimate alternative to the expository, "hands-on" laboratory which is frequently used in science courses and the study also indicated that the simulation version of a "hands-on" laboratory may actually provide more freedom for students to explore and deviate from prescribed procedures. Such approaches are consistent with 21st Century learning environments whereby students construct their understanding of the expository world in learning environments that are active, digital, virtual, and online (flexible approach). However, certain accreditation processes do not recognise the simulated laboratory as a legitimate alternative to expository high-school and college-level laboratories. Ushie & Ogbulezie (2016) says the students' outcome in terms of quality of graduates as regard teaching and learning determines whether the existing methods should be reviewed or not, and recommended that institutions should design and plan learning activities or program of study using the current world technology.

The learning environment of the 21st century must embrace the changes that have occurred over the last century in terms of laboratory goals, student needs, job skills, and technology. With less laboratory time spent on manually collecting data, students can focus on the educational objectives of the experiment such as understanding, building confidence, and analyzing data (Sherry & Lord, 2002).

It's however, not possible to substitute the work that the student performs during a practical class of laboratory (Rodrigo, et.al, 2002). Instead students should conduct both, to make comparison on the outcome of the experiments (Miller, 2000). Pearce et al, (2004), reported, the simulation device allows the instructor to show circuit solutions in real time using real physical devices, with attendant certainties in component values. These demonstrations make the circuit behaviour real during lecture rather than being completely a theory, a distinct advantage for that subset of students (modern students) whose learning styles are more practically based rather than conceptual.

Though, accreditation processes do not recognise the simulated laboratory as a legitimate alternative, this study is designed to investigate the extent to which flexible laboratories using small scale devices can achieve learning outcome as successfully as the heavy equipment expository laboratory and to serve as a teaching aid. Concurrently, this study addresses the differences and similarities in possible student laboratory experiment, using a flexible and an expository laboratory. The results of the study provides insight into whether or not a flexible laboratory should serve as an effective bridge to the expository laboratory, based on conformity of results, flexibility, accessibility and availability of equipment

Methodology

This study used a comparative methodology in which students performed laboratory investigations in an expository and a flexible environment. To carry out the test and acquire data; test was carried out based on the multisampling test method to get the exact value of quantity under measurement and for a better statistical treatment of data (Sawhney, 2005). Two criteria were used to select the laboratory experiment for this study. First, it was established that a "typical" engineering laboratory should be integrated in the curriculum (Singer et al., 2006) as recommended by NBTE (2001) and NUC (2017). These experiments are integrated in the Electrical/Electronic Engineering and Computer Engineering curriculum.

Secondly, in the case of general Digital Electronics courses, the laboratories chosen reflected the central theme of Digital Electronic Engineering curriculum. Specifically, the two laboratory experiments chosen for these studies are standard Laboratory referred to as solderless experiments and an Electronic Education Curriculum designed for the 21st century student. (ETron Circuit Labs, 2001). These experiments were chosen because they are easy to implement and they demonstrate important concepts presented in most of introductory courses of Digital electronics.

Sample

Students of National Diploma (ND) II classes of Computer Engineering, Kaduna Polytechnic participated in this study. The students for the 2012/2013 and 2014/2015 sessions were trained, assigned and examined based on the traditional expository while; the 2015/2016 and 2016/2017 sessions were used the flexible. The scheduled three hours laboratory period per week on the departmental time table was used for the four academic calendar; students were assigned as shown in table 1.

Table 1: Distribution of Groups

Laboratory	Sessions
Traditional Expository laboratory 1	2012/2013
Traditional Expository laboratory 2	2014/2015
Flexible Expository laboratory 1	2015/2016
Flexible Expository laboratory 2	2016/2017

The motive for having expository to flexible for two academic sessions each was adopted to obtain average comparative performance data from each student for each experience, and as well eliminate Hawthorne effects (Pyatt, & Sims, 2007).

Testing process

The present study is a pilot study, rather than conducting a thorough usability test evaluating all aspects of the possible laboratory test, emphasis was given on the conformity of the test approaches utilized. For the expository approach, the following equipment and materials were use: (i) Digital trainer (iv) connectors (v) auto range digital multimeters (ix) Digital Integrated Components. While for the flexible approaches, the following equipment and materials were use: (i) battery power supply. (iii) Bread Board (iv) connectors (v) auto range digital multimeters (xi) Digital Integrated Components. The circuit used as shown in fig. 1 and 2, where bread boarded as in fig 3 and 4, and produced the results shown in table. 2 and 3, using the expository (fig. 5 and 6) and flexible experiment for observation under the conditions of; (i) clock signals are triggered at intervals of 1 second (clock) to allow for stable readings and (ii) power was not interrupted in the course of testing.

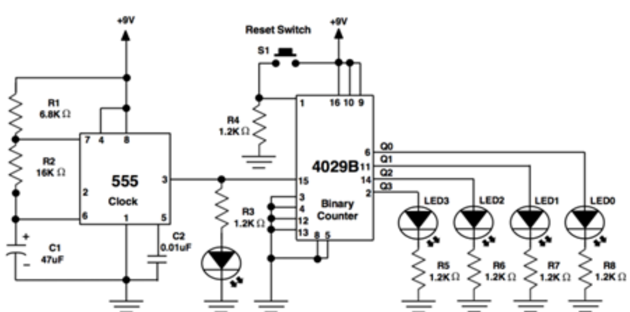

Fig. 1: Binary Counter Circuit (MOD-16)
(source: ETron Circuit Labs, 2001)

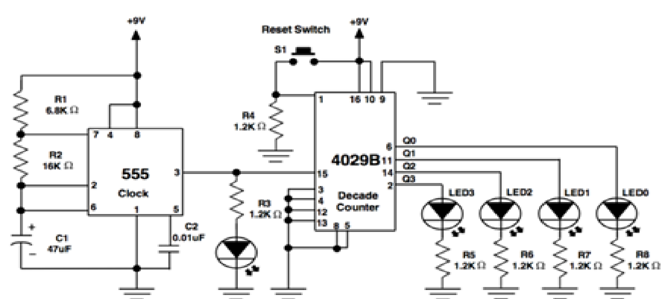

Fig. 2: Decode Counter Circuit (MOD-10)
(source: ETron Circuit Labs, 2001)

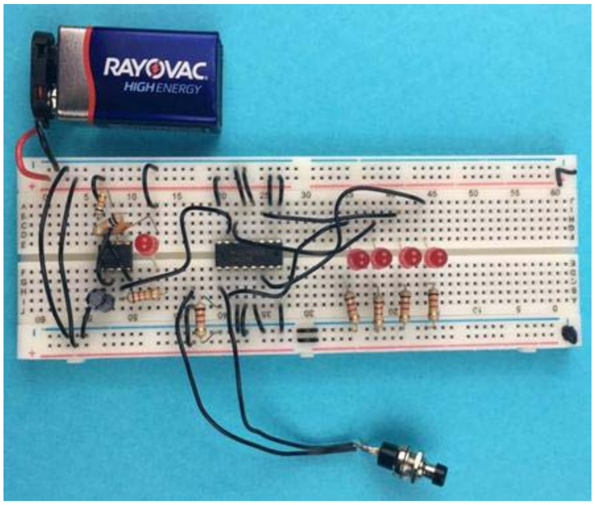

Fig. 3: MOD-16 Bread Board Layout
(source: ETron Circuit Labs, 2001)

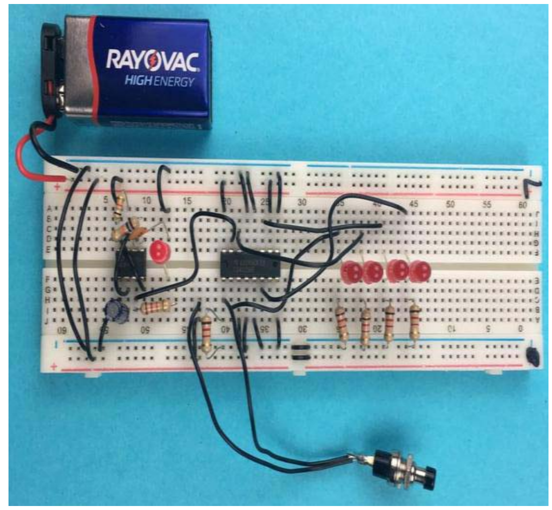

Fig. 4: MOD-10 Bread Board Layout
(source: ETron Circuit Labs, 2001)

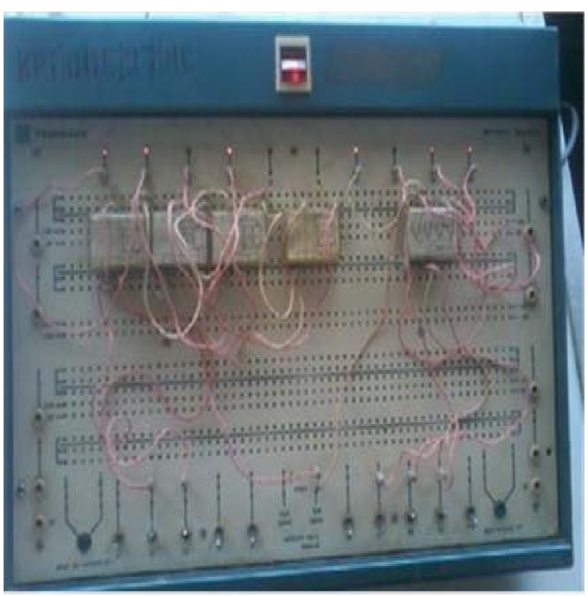

Figure 5(a) : Traditional MOD-16 Layout

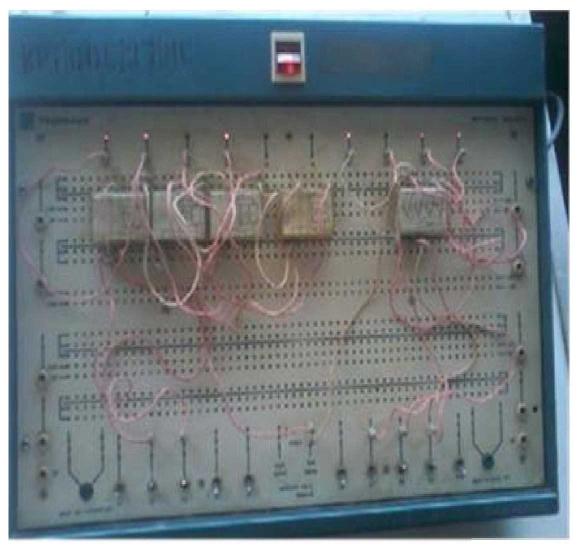

Figure 5(b): Traditional MOD-10 Layout

Table 2: Binary Counter

Clock pulse	Traditional (LED)	Flexible (LED)	Decimal number
	0000	0000	0
1st	0001	0001	1
2nd	0010	0010	2
3rd	0011	0011	3
4th	0100	0100	4
5th	0101	0101	5
6th	0110	0110	6
7th	0111	0111	7
8th	1000	1000	8
9th	1001	1001	9
10th	1010	1010	10
11th	1011	1011	11
12th	1100	1100	12
13th	1101	1101	13
14th	1110	1110	14
15th	1111	1111	15

Table 3: Decimal Counter

Clock pulse	Traditional (LED)	Flexible (LED)	Decimal number
	0000	0000	0
1st	0001	0001	1
2nd	0010	0010	2
3rd	0011	0011	3
4th	0100	0100	4
5th	0101	0101	5
6th	0110	0110	6
7th	0111	0111	7
8th	1000	1000	8
9th	1001	1001	9
10th	1010	1010	10

Table 4: Average Students Performances

Session/Grades	A	AB	B	BC	C	CD	D	F	Total Students
2015/2016-2016/2017	21	11	15	29	30	24	23	10	163
2012/2013-2014/2015	13	12	19	17	25	16	23	4	129

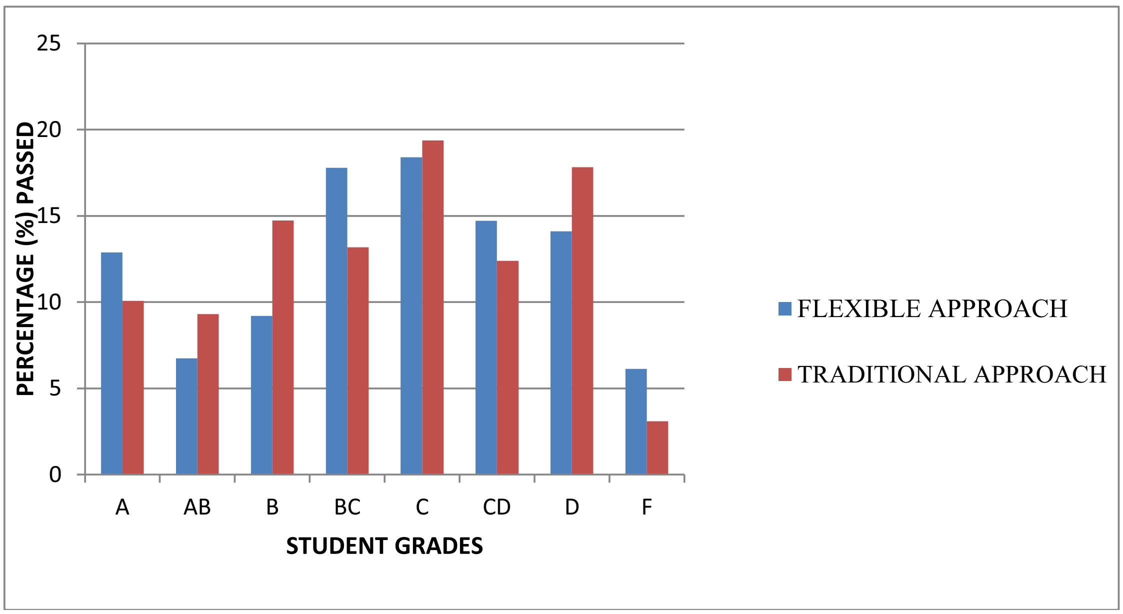

Figure 7: Average Students Percentage Pass

Results and discussion

The results of experiment 1(Binary Counter Circuit (MOD-16), as shown in Table 2 reveals that both flexible and expository approach could be used to demonstrate the theory of Binary Counter; the study shows, the maximum count of sixteen decimal numbers represented in binary forms (0000-1111) as the clock pluses changes. Results of experiment 2(Decimal Counter Circuit (MOD-10), as shown in Table 3 reveals that both flexible and expository approach could be used to demonstrate the theory of decimal Counter; the study shows, the maximum count of ten decimal numbers represented in binary forms (0000- 1001). The results for both experiments as obtained using voltmeter showed that the response both circuits (i)using a 9V battery for the flexible produces, the digital levels of 3V as '0' and 8.5Vas '1' (ii) using 5 V for the expository produces, the digital levels of 1.5V as '0' and 4.7V as '1'as legal and acceptable. The output voltages differed because of the supply voltages.

The average student's performances as shown in figure 7; for over four years, two using the traditional and two using the flexible show that 97% and 94% pass for traditional and flexible approach respectively. The results of the experiments also showed that 47% high class graduates (Distinction and Upper Credit) for both approach while, 47% low class graduates (Lower Credit and Pass) for the flexible approach as against 50% for the traditional. Thus it could be concluded that the flexible expository results reflect the true theory as being thought during lectures, despite the increase in students' population (163 as against 129) and could be used as teaching aid in classrooms before and or during practical.

Conclusions

The present study tried to compare traditional expository and flexible expository laboratory using small scale replica. Even though there was an initial inquiry of the principle theoretically, it was found that flexible expository using small scale replica approach reveals no deviation from the theory, and has similar performance as the traditional expository (above 75% pass). The finding that student's results using heavy traditional expository laboratories (97%) outperformed students who used using small scale replica (94%) suggests that there were learning differences between the two environments. Findings also showed that students can control the time, location, and pace of their interaction with the flexible than the traditional expository. It also showed that the flexible laboratories can serve as a legitimate teaching aid and a 'bridge' to the traditional laboratory and should be an integrated part of every professional course, not to substitute a traditional practical laboratory. Using small scale replica flexible approach makes it possible for as many students as possible to carry out experiments remotely and simultaneously, hence the challenges associated with man power, space and cost of heavy equipment is addressed.

7. Recommendations

It is recommended that, a new approach, based on an open-access, small scale replica, flexible laboratory policy be introduced as this could extend the frontiers of modern engineering teaching tools, among which experimentation is an important component. It is also recommended that current accreditation practices requiring engineering courses to have mainly heavy duty "traditional expository" laboratories facilities be revisited as this study has shown that flexible approach using small scale replica can adequately expose students to real time practical's. Teaching methodologies should be modified to guide students towards acquiring basic knowledge through the applications of flexible learning, which are student cantered and very necessary in the training for future understanding, building confidence, and analysing data.

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