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Lab in Bag for Higher and Technical Education

[1] Lochan Jolly [2] Sukruti Kaulgud [3] B. K. Mishra
[1 2 3] Electronics and Telecommunication Thakur College of Engineering and Technology Mumbai, INDIA
[1]lochan.jolly@thakureducation.org [2]sukruti.kaulgud@thakureducation.org [3] tcet.principal@thakureducation.org

***Abstract*—** In order to generate future entrepreneurs capable of resolving challenges with the use of technology, institutions must implement programs that foster students' holistic development. To facilitate holistic development of students, NEP 2020 emphasizes on collaboration, communication, research, problem solving, critical thinking, and creativity skills that students need to be successful in today's world. NEP 2020 suggests to introduce blended learning environment which shows students the scientific method that can be applied to everyday life with emphasis on more practical oriented education unlike traditional science and math education. Students will become solution providers if they spend time in laboratories for experimentation and research. According to the current situation, higher and technical education curriculum provide limited time for practical work, and even if a student wishes to work extra during free periods, there are few resources available during working hours because there are very few labs and they are occupied with the regular curriculum conduct. Due to these limitations, students have fewer number of opportunities to discover solutions for real-world issues and applications. Access to the laboratory and laboratory equipment beyond working hours is the need of the hour. This is the reason for developing "Lab in Bag" to provide learning environment beyond working hours. Through these laboratory equipment's, students will have access to a variety of hardware devices at home to explore and expand their knowledge. This will develop innovation and creativity in them. This philosophy can be achieved with the advantages of miniaturized and low-cost equipment and facilities. The focus of "Lab in Bag" is technical subjects involving hardware Experiments. The expected outcome of this setup is that it will provide students with a flexible platform which gives them opportunities to learn using reliable and economical setups. To measure performance of the "Lab in Bag" devices, experimentation is done using traditional equipment and equipment provided in Lab in Bag. This study explains that results with 0.002% error margin can be achieved with 30MHz-2Channel Oscilloscope and Digital Oscilloscope for Analog and Devices Electronics experiments. It further establishes positive correlation of flexibility, connectivity and reliability with usability. Positive correlation of these parameters shows that students are highly interested in using "Lab in Bag" for continuing research and innovation.

Keywords—Innovation, "Lab in Bag", experimentation, Analytical Study, Statistical Analysis, Correlation.

I. INTRODUCTION

Economic growth and social progress rely on innovation. In addition to technical know-what and know-how, the core skills for innovation are critical thinking, creativity, problem-solving, global collaboration and communication [1]. The challenge for education is to develop these different skills simultaneously. This calls for innovation in education – for example new or improved educational technology tools, instructional methods, curricula, assessment approaches or ways for teachers to work together [2,3].

One of the solutions is Remote Access Laboratories (RAL) which allows for offsite control of state-of-the-art science and technology experiments [4]. RAL are online interactive multimedia platforms that allow students to access and control devices and experiments at distant locations remotely. The remote laboratory approach is currently studied by several researchers around the globe and has been implemented in several institutions for different subject courses [5-11].

Previous research has shown that current RAL systems are deficient in features to support blended education [12]. But looking into the digital divide where all students do not have internet facilities and resources required to use remote laboratories from their home. For such students, conducting actual experiments with large equipment is not as easy to do if they are not in the laboratory or in a similar environment. The problem arises particularly in the case of hardware laboratories with high-cost equipment requiring significant space. So, Lab in Bag is a concept of miniaturize low cost equipment and facilities which can be used by these students.

In this paper, "Lab in Bag" concept is demonstrated with a case study on its use to perform experiments for the subjects like Electronic Devices and Circuits (EDC), Electrical Networks (EN), Digital Logic Design (DLD), Basic Electronics and Electrical Engineering (BEEE), Basic Instrumentation (BI), ADC Analog and Digital Circuits (ADC) that can support student learning continuity efficiently.

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This study establishes high positive correlation for flexibility and usability in addition to moderate positive correlation for connectivity and reliability with the usability of Lab in Bag. This concept of Lab in Bag will be useful for students of higher and technical education as it is a flexible, reliable and economical solution. “Lab in Bag” will be a boon for both students and universities because it will give flexibility in learning to students and encourage students to do research and innovation. So, to make a platform to give flexibility in learning we need to give access to resources needed. Lab in Bag is the solution to the problems identified through root cause analysis.

II. Analytical Study

Although a laboratories are the traditional arena for exploration and experimentation, other venues, such as interactive science centers, do exist. For some time now we have been taking advantage of yet another setting: the home. Using simple materials, our students are encouraged to do science experiments with family and friends. The benefits of at-home science activities are many. They increase the time students are thinking about and doing science.

For higher and technical education related experimentation, more specialized equipment are needed. To cater this need a "Lab in a Bag" is created by packing required materials in bag. Using the "Lab in bag" approach, students take home miniature equipment and materials relating to a given concept in small bag pack. Everything needed to investigate phenomena ranging from resistor to Function generator is contained in a single bag.

The "Lab in Bag" experiments are intended to be engaging, thought provoking, and enjoyable experience. While fun is not the principal goal of science education, these activities allow students, and their families, to experience science in a less-structured, more playful manner. All activities are designed to be straightforward and materials are chosen with safety in mind. The low-cost nature of the simple equipment used in these kits eliminates worry about loss.

“Lab in bag” overcomes the major concerns and achieves the objectives identified unlike remote access laboratory which needs lot of investment, expertise and resources to not only develop but also use it.

A. Major objectives of “Lab in Bag” concept

Fig. 1 shows the major objectives of this concept.

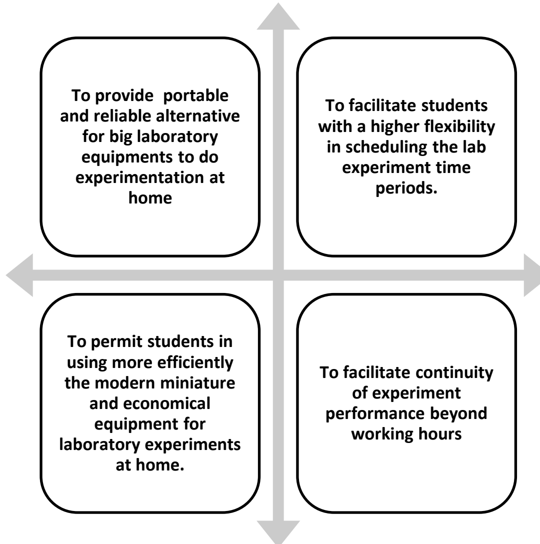


Fig. 1. Major Objectives

III. “Lab in Bag”: (Case Study)

Prior to presenting the students with their first activity, all students are briefed about “Lab in Bag” concept. Complete instruction manual is shared with all students. The experiments for Analog and Digital circuits are performed using Miniaturised Oscilloscope, Signal Generator and power supply. Fig. 2 shows the measuring instruments used in laboratory setup and Fig. 3 shows measuring instruments used in Lab in Bag.

A. Components List in Lab in Bag:

1. Traditional Measuring instruments:

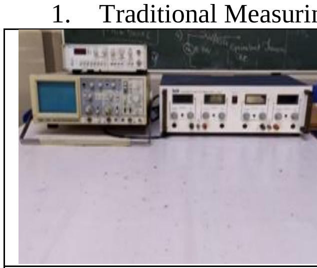
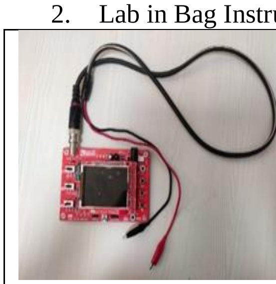
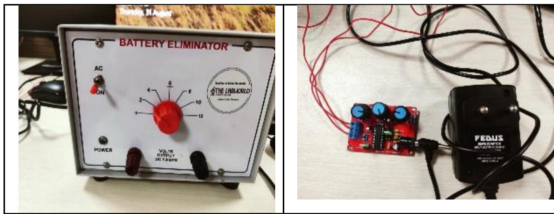
	
CRO, Function Generator and Power Supply	Multimeter

Fig. 2. Traditional Measuring Instruments

2. Lab in Bag Instruments:

	
Digital Oscilloscope	Portable DSO



Battery Eliminator	Signal Generator

Fig. 3. Lab in Bag instruments

B. Case 1: Experiment 1

- Experiment 1 is to design different types of Biasing Circuit for CE amplifier.
- In this experiment a circuit is designed for a BJT amplifier in Fixed bias, Collector bias and Voltage divider bias and analyzed to determine DC operating point. Current (IC) and voltage (VCE) is set using external components & sources, are known as the Q point values. Ideally once set, the Q point should be stable. But it is not and the factors affecting it are:
    1. Temperature.
    2. Device variations.

Observation Table:

TABLE I. Voltage and Current values for different biasing in laboratory setup and Lab in Bag

Binary Type / **Port Meter**	**Fixed bias**		**Emitter Bias**		**Potential Bias**	
	Laboratory	**Lab in Bag**	**Laboratory**	**Lab in Bag**	**Laboratory**	**Lab in Bag**
V_B	1.5	1.6	2.5	2.4	2.8	2.9
V_C	5.3	5.3	6.2	6.1	7.57	7.58
V_{CE}	2.4 v	2.5 v	5.0 v	5.1 v	5.0 v	5.1 v
I_B (Base Current)	24.6 mA	24.5 mA	37.6 mA	37.4 mA	13.7 mA	13.5 mA
I_C (Collector Current)	4.8 mA	4.7 mA	3.5 mA	3.5 mA	3.7 mA	3.6 mA

Table I compares the results obtained in laboratory setup and Lab in Bag.

- It is observed that in Fixed bias this circuit has very poor thermal stability. Also, with change in devices the Q point keeps on shifting in both cases.
- In Collector to Base bias there exists voltage feedback from collector to base in the circuit. Because if this feedback exists, there exists an AC degeneration and hence gain is affected in both the cases.
- In Voltage Divider Bias a resistance is present in the emitter circuit. Because of this resistor RE, there exists feedback in the circuit which also causes AC degeneration in both cases.

C. Case 2: Experiment 2

Experiment 2 is to Verify I/O Characteristics of BJT.

In this experiment a circuit is designed to study the input and output characteristics of BJT in CB & CE Modes.

Observation Table:

Input Characteristics:

TABLE II. Input Characteristics in laboratory setup and Lab in Bag

V_{BB} (V)	**V_{BE} (V)**		**I_B**	
Laboratory	**Laboratory**	**Lab in Bag**	**Laboratory**	**Lab in Bag**
0	-	129 mV	0	0
0.1	-	196	0.37	0.36
0.2	272	270	1.2	1.1
0.3	348	347	1.53	1.54
0.4	0.47	0.45	1.62	1.61
0.5	0.53	0.52	1.64	1.62
0.6	0.58	0.57	1.65	1.63
0.7	60	61	1.67	1.65
0.8	0.62	0.6	1.69	1.67
0.9	0.63	0.61	1.7	1.6
1	0.67	0.65	1.71	1.72
2	0.68	0.68	1.73	1.74
3	0.69	0.7	1.74	1.74
4	0.69	0.68	1.76	1.77
5	0.69	0.67	1.79	1.78
6	0.697	0.698	1.8	1.81
7	0.7	0.6	1.81	1.8
8	0.71	0.73	1.82	1.83
9	0.71	0.72	1.823	1.822
10	0.72	0.72	1.826	1.825

Output Characteristics:

TABLE III. Output Characteristics in laboratory setup and Lab in Bag

V_{cc}	V_{ce}		I_c	
Laboratory	**Laboratory**	**Lab in Bag**	**Laboratory**	**Lab in Bag**
1	1.06	1.04	0.91	0.9
2	2.037	2.035	1.88	1.87
3	102.8 mv	102.7 mv	2.85	2.83
4	117.4 mv	117.2 mv	4.89	4.9
5	130 mv	129 mv	7.65	7.64
6	145.7 mv	145.5 mv	8.91	8.93
7	162.3 mv	162.6 mv	11.87	11.86
8	184.2 mv	184.5 mv	10.17	10.18

9	225.5 mv	225.7 mv	12.63	12.65
10	330.2 mv	330.5 mv	13.79	13.8
11	0.651 v	0.653 v	14.63	14.65
12	1.441 v	1.440 v	14.87	14.88
13	2.214 v	2.212 v	15.91	15.92
14	3 v	3 v	15.93	15.94
15	3.83 v	3.80 v	16	16.2
16	4.86 v	4.85 v	16	16.01
17	5.45 v	5.42 v	16	16.2
18	7.48 v	7.46 v	16	16

From Table I and II it is seen that as V_{CE} increases from zero, I_C rapidly increases to a near saturation level for a fixed value of I_B in both the cases.

D. Case 3: Experiment 3

Experiment 3 is to implement CE Amplifier and study the frequency response

In this experiment a circuit is designed to study the Frequency response of a single stage BJT amplifier. It is analyzed to find out Voltage Gain and Bandwidth.

Observation Table:

TABLE IV. Frequency Response in laboratory setup and Lab in Bag

Frequency	**output voltage**		**gain = vo/vi**		**gain D_B =20log$_{10}$ (vo /vi)**	
	Laboratory	Lab In Bag	Laboratory	Lab In Bag	Laboratory	Lab In Bag
0	0.02	0.03	1.5	1.6	3.52	3.5
50	0.83	0.81	40	39	32	33
100	1.97	1.95	95	94	39.5	39.7
500	5.53	5.55	275	276	48.7	48.5
1k	5.57	5.55	275	274	48.7	48.6
5k	5.84	5.83	290	289	49.2	49.5
10k	6.02	6.02	300	300	49.5	49.5
100k	6.15	6.13	305	305	49.6	49.8
500k	2.97	2.95	145	144	47.9	47.8
1 M	1.47	1.45	75	76	37.5	37.4
10 M	0.5	0.7	10	11	28.7	28.5

From Table IV it is observed that the circuit provides the amplification factor of 100 at mid frequency gain and the frequency response of the CE amplifier is 249.97 kHz.

E. Assessment

To understand the usability of the lab in Bag setup with respect to connectivity with students, flexibility to use and reliability of results, after students performed ADC experiments using "Lab in Bag" a survey was conducted to measure these parameters. The survey had 9 questions and a total of 39 students took survey after using the setup and gave answers for each question on a lither scale from strongly agree to strongly disagree. Following are the responses.

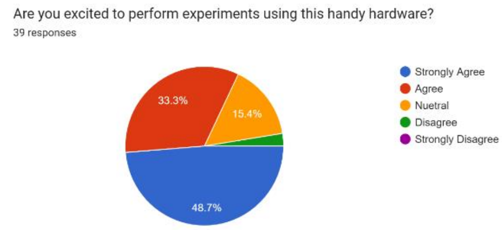


Fig. 6. Response for Q1

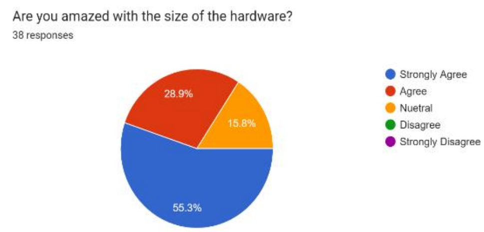


Fig. 7. Response for Q2

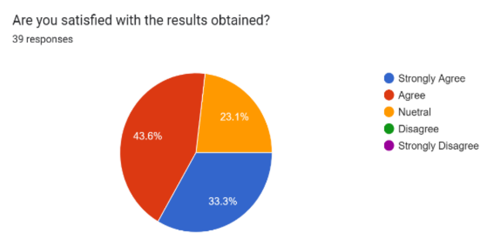


Fig. 8. Response for Q3

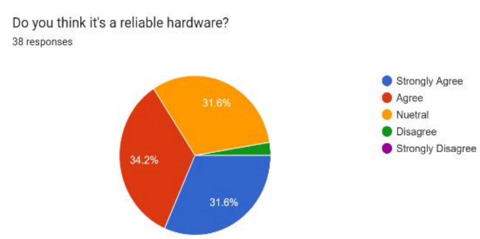


Fig. 9. Response for Q4

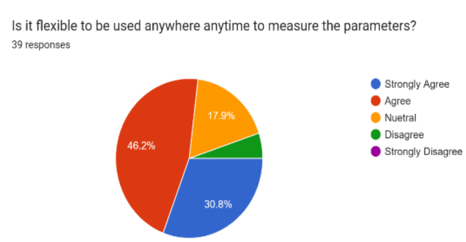


Fig. 10. Response for Q5

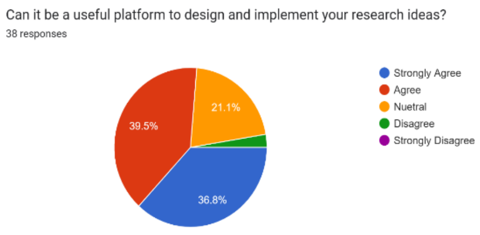


Fig. 11. Response for Q6

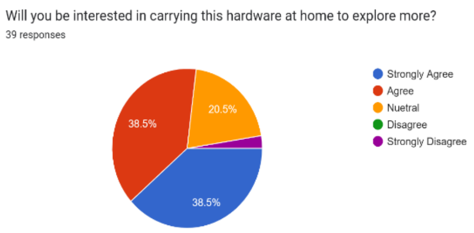


Fig. 12. Response for Q7

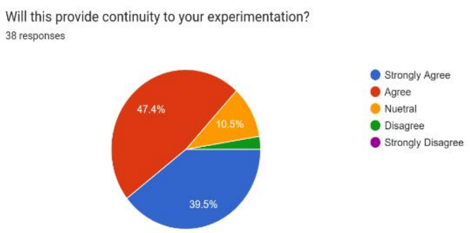


Fig. 13. Response for Q8

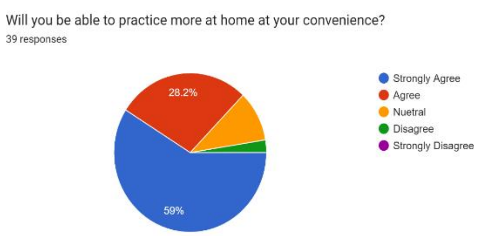


Fig. 14. Response for Q9

Fig. 6 to Fig. 14 shows students feedback about Lab in Bag experimentation. Students' satisfaction is very high, and they are more motivated to implement projects with "Lab in Bag" setup.

IV. Results and Discussion

1) *Experimentation and error Calculation:*

Analog and Digital Circuits subject involves practical experiments where basic hardware components and devices like Function generator, power supply and Oscilloscope are used. Here we have used two types of Oscillators. One is 30MHz 2 CH Oscilloscope in the lab, function generator and Power Supply and other is "Lab in Bag" setup containing Digital Oscilloscope, Signal Generator and portable Power Supply at home.

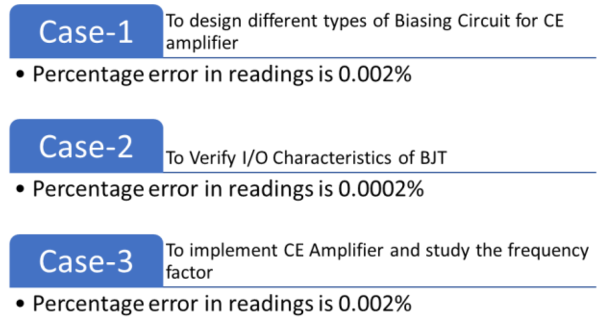


Fig. 15. Readings Comparison

From Fig. 15 it is observed that the percentage error in readings obtained by using ADC laboratory equipment's in college and "Lab in Bag" equipment at home for same set of experiments under similar bias condition is negligible.

2) *Cost Comparison:*

A major advantage of this concept is it is economical and can be afforded by technical institutes in rural areas as well. The following Table V shows comparison of cost of both setups.

TABLE V: Cost Analysis

Laboratory Set up in university		"Lab in Bag"	
Digital Oscilloscope	66393	Digital Oscilloscope	3650
Function Generator	13000	Signal Generator XR2206	3290
Power Supply	15000	Battery Eliminator	1000
Total	94393	Total	7940

It is evident from Table V that "Lab in Bag" setup is 90% cheaper than the laboratory setup at universities and also gives reliable results. This adds flexibility in learning and experimenting using low-cost equipment.

3) *Statistical Study:*

We did the statistical analysis of the survey results to measure the popularity of lab in the bag concept a correlation is established between four parameters flexibility, usability, connectivity and reliability.

To find correlation mean, standard deviations, covariance, correlation coefficient are calculated using following equations.

$$Mean = \frac{Sum\ of\ observations}{Number\ of\ Observations} \tag{1}$$

$$Standard\ Deviation = \sqrt{\frac{\sum(x_i-\mu)^2}{N}} \tag{2}$$

Where,

x_i = each value from the observation

μ = Mean

N = Number of observations

$$Cov_{x,y} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{N-1} \quad (3)$$

Where,

$Cov_{x,y}$ = Covariance between two variables x and y

x_i = data value of x

y_i = data value of y

$\bar{x} = Mean\ of\ x$

$\bar{y} = Mean\ of\ y$

$$\rho_{x,y} = \frac{Cov(x,y)}{\sigma_x \sigma_y} \quad (4)$$

Where,

Px,y = Correlation Coefficient

Cov (x,y) = Covariance of variables x and y

σ_x = Standard Deviation of x

σ_y = Standard Deviation of y

The survey response on lither scale from strongly agree to strongly disagree. is converted on a scale of 1 to 3 where strongly agree and agree is 3, neutral is 2 and strongly disagree and disagree is 1.

TABLE VI: SUMMARY OF RESPONSES

Sr. No.	Questions	% Response for strongly Agree and Agree	Average Response parameter wise in %	Parameters
1	Are you Excited to perform experiments using this handy hardware?	82%	**Connectivity** 83.1	**Connectivity** Mean=2.82 SD=0.35
2	Are you amazed with the size of the hardware?	84.2%		
3	Are you satisfied with the results obtained?	76.9%	**Reliability** 71.35	**Reliability** Mean=2.71 SD=0.40
4	Do you think it is reliable?	65.8%		
5	Is this setup flexible to be used anywhere to measure parameter?	77%	**Flexibility** 76.77	**Flexibility** Mean=2.74 SD=0.40
6	Can it be a useful platform to design and implement your research ideas?	76.3%		
7	Will you be interested in carrying this hardware at home to explore more?	77%		
8	Will this provide continuity to your experimentation?	86.9%	**Usability** 87.05	**Usability** Mean=2.85 SD=0.38
9	Will you be able to practice more at home at your convenience?	87.2%		

With respect to connectivity with the students the setup connects with the students because of size and ease to use and 83.1% agree with it as is reflected from the response of Q1 and Q2. With respect to results and reliability 71.35% of students agree with it as is reflected from the response of Q3 and Q4. With respect to flexibility of setup 76.77% agree with it as is reflected from the response of Q5, Q6 and Q7. With respect to usability of setup 87.05% agree with it as is reflected from the response of Q8 and Q9.

The mean (Eq.1) and standard deviation (Eq.2) results for Connectivity with students, flexibility to use, reliability of results and readiness to use “Lab in Bag” shows that students find this device very flexible and reliable.

Further to justify our findings we did statistical analysis to find a correlation (Eq. 3 and Eq.4) between the parameters i.e., Connectivity with students, flexibility to use, reliability of results and readiness to use.

A correlation matrix is generated for the parameter identified as shown in Table VII. using equation

TABLE VII: CORRELATION MATRIX

	Connectivity	**Reliability**	**Flexibility**	**Usability**
Connectivity	1.00	0.49	0.57	0.48
Reliability	0.49	1.00	0.55	0.43
Flexibility	0.57	0.55	1.00	0.77
Usability	0.48	0.43	0.77	1.00

The correlation matrix shows that flexibility and usability are highly correlated, that is because of flexibility to use students want to use it. Other parameters, that is connectivity and reliability are moderately positively related with usability. Hence, we can conclude that “Lab in Bag” can connect students and they would like to use this platform to explore more research ideas at home also.

V. Conclusion

NEP 2020 is designed to encourage discussions and problem-solving among students, developing both practical skills and appreciation for collaborations. But in today’s scenario access to resources in laboratories at the universities are limited for practical experimentation. This “Lab in Bag” solution enables students to carry miniature equipment and required material at home to perform experiment and explore various technical experiments and analyse their impact with changes in environmental conditions. This study discussed about three experiments for ADC subject are performed using Lab in the Bag concept. It is observed that the readings are almost same with only 0.002% error which is negligible.

The survey shows that the designed set can connect with the students and more than 80% students will be encouraged to use, more than 70% students find results reliable, more than 75% students find the setup flexible, and more than 85% students find setup usable. There is high positive correlation of flexibility, connectivity and reliability with usability. Hence it can be concluded that students will use this lab setup to attain their academic and research goals because of its ability to connect with the students, give reliable results, and flexibility to use.

The study shows that “lab in Bag” will help advancement of student's knowledge and competences. In future “Lab in Bag” concept can be extended to courses like microprocessors, logic design and network analysis for project and research purpose as well.

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