Laboratory Integration to Aid Experiential Learning

N.Vijayakumar[1], Madhusudhana H.K [2], Anand R L[3], Jangali Satish G[4], S. V. Khandal[5]
Department of Industrial and Production Engineering,
B.V.B. College of engineering & Technology,
Hubli-580 031, Karnataka India

Vijaykumar@bvb.edu[1], madhusudhana@bvb.edu[2], anandl@bvb.edu[3], jsatish@bvb.edu[4], khandal@bvb.edu[5]

***Abstract*— The function of the engineering profession is to manipulate materials, energy and information, thereby creating benefit for humankind. In the present day situation, one of the major problems in the society is 'Unemployment.' It is not out of lack of opportunities, but lack of proper training. In view of the globalization, opportunities are aplenty. Yet the problem is growing by leaps and bounds. Corporate sector opines that the students are graduating from colleges without proper training and hence are 'unemployable.' Activity based teaching shall penetrate these students to impart training make them industry ready professionals. This work is part of experiential learning through integration of courses in metrology & machine shop laboratory by redesigning experiments for the students of IV Semester of Industrial and Production Engineering of BVBCET Hubli.**

Keywords: Statistical approach, redesigning of experiment, activity based Learning, integration of courses.

I. Introduction

There is increasing recognition that Engineering education is improved by greater use of experiential learning methods, i.e. active, student-centered learning opportunities are superior to direct instruction. The advantages of experiential learning include higher student motivation and better retention of knowledge compared to traditional lectures [1]. Industry is giving plenty of opportunities to the students to get placed across the world in view of the globalization and advent of technology. Industries need professionals who can cater to the needs of the clientele spread across the world. Under these circumstances, identifying the problem in an industry or identifying the factors which affect the process play vital role.

Metrology& Quality Engineering Lab: To give exposure to the students how statistical tools can be used to analyze experiments, the present experiment on calibration of instruments is redesigned with use of statistical tools.

As the students of earlier batch used to conduct experiment on calibration in traditional way and the type of the experiment is at demonstration level. In this semester the calibration experiment is redesigned to take to the structured enquiry level through use of statistical approach (T-test).

Integrating experience: As part of giving integrating experience of Manufacturing and measurement for the students are given an problem of identification of batch to batch manufacturing variations in a process of manufacturing a part according to the given specification (where the students of batch 1 manufactured part in machine shop, compared the same with batch2 using statistical approach (T-test)). Similarly another initiative in machine shop is undertaken which is fallows

Machine Shop: The problem statement was given for the students to study the effect of the skills of an operator in a machine shop to produce a desired specification using Design of Experiments (DOE), which they have to solve after conducting experiments in machine shop in batches. Students had to take the experimental data to decide whether there is a significant difference between the operators in terms of specified dimension on machined components. At the end of this work students could realize percentage contribution of a factor i.e. operator's skill. Assessment for the above activity is done through rubrics for attainment of ABET outcome 3b.

Outcome 3b of Accreditation Board for Engineering and Technology is an ability to design and conduct experiments, as well as analyze and interpret data

- Designing experiments: Develop a methodology which will produce high quality data that can be used to evaluate a specific process or parameter.
- Conducting experiments: Operate laboratory equipment appropriate to the course or discipline to demonstrate appropriate laboratory technique to collect data
- Analyzing data: Perform appropriate data manipulations and calculations to present final data in an appropriate format
- Interpreting data: Use good engineering judgment to determine if data is reasonable and draw appropriate conclusions from data.

A. Statistical tools

Z-test and t-test are basically the same, they compare between two means to suggest whether both samples come from the same population. There are however variations on the theme for the t-test. If you have a sample and wish to compare it with a known mean (e.g. national average) the single sample t-test is available. If both of your samples are not independent of each other and have some factor in common, i.e. geographical location or before/after treatment, the paired sample t-test can be applied. There are also two variations on the two sample t-test, the first uses samples that do not have equal variances and the second uses samples whose variances are equal.

- Data types that can be analyzed with z-tests: Data points should be independent from each other. Z-test is preferable when n is greater than 30. The distributions should be normal if n is low, if however n>30 the distribution of the data does not have to be normal. The variances of the samples should be the same (F-test). All individuals must be selected at random from the population. All individuals must have equal chance of being selected. Sample sizes should be as equal as possible but some differences are allowed.

- Data types that can be analyzed with t-tests: Data sets should be independent from each other except in the case of the paired-sample t-test where n<30 the t-tests should be used.

B. Design of Experiments

In general usage, design of experiments (DOE) or experimental design is the design of any information-gathering exercises where variation is present, whether under the full control of the experimenter or not[3]. However, in statistics, these terms are usually used for controlled. In the design of experiments, the experimenter is often interested in the effect of some process or intervention (the "treatment") on some objects (the "experimental units"), which may be people, parts of people, groups of people, plants, animals, etc. Design of experiments is thus a discipline that has very broad application across all the natural and social sciences and engineering. In statistics, one-way analysis of variance (abbreviated one-way ANOVA) is a technique used to compare means of two or more samples (using the F distribution). This technique can be used only for numerical data.

The ANOVA tests the null hypothesis that samples in two or more groups are drawn from populations with the same mean values. To do this, two estimates are made of the population variance. These estimates rely on various assumptions. The ANOVA produces an F-statistic, the ratio of the variance calculated among the means to the variance within the samples. If the group means are drawn from populations with the same mean values, the variance between the group means should be lower than the variance of the samples, following the central limit theorem. A higher ratio therefore implies that the samples were drawn from populations with different mean values.

II. OBJECTIVES

The overall objective of this activity is to build competency among students towards solving industrial related issues. Specific objectives are as follows:

- To help students acquire deeper understanding of experiment and to equip them with different statistical techniques
- To develop the expertise in the area of manufacturing and measurements through integration of courses.
- To engage in life-long learning including learning in the workplace.
- To design, collect data, organize, analyze and interpret the result using software package.

III. METHODOLOGY

A. Metrology and Quality engineering lab

Redesigning experiment: To give an exposure to students how statistical tools can be used to analyze the experimental data the present experiment of calibration of instruments is redesigned.

Firstly students are given an demonstration about conventional way of carrying calibration experiment was given to the students later how same experiment can be done using statistical tool is explained to them. One batch of students were given two instruments which are calibrated and another batch is given one calibrated and one non calibrated instruments and they have to verify whether there is any significant difference between the performance of the two instruments statistically were each students measured a standard dimension slip gauge using two instruments and collected data which as shown in table I and table III respectively later the experimental data are analyzed using MINI-TAB software through T-test and inferences are drawn based on p-value whether is there any significant difference between performance of two instruments.

Integrating experience: To facilitate integrating experience for the students in the machine shop and metrology students were given an problem to verify is there any significant difference between one batch of production to other batch of production of part which they have machined in machine shop laboratory in the regular lab sessions which is as shown in figure1 and the measurements of individual students jobs in an batch is as shown table V.

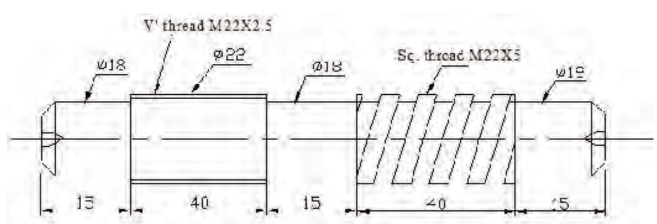

Fig. 1. Profile of the job done by students

B. Machine Shop

Individually students will machine a component in a machine shop lab to obtain the given profile a component for the required specification which is as shown fig. 1. The activity is begun with formation of five members group in practical batch. All students in a group need to collect the same dimensional reading at five different positions on the profile they have generated in a machine shop lab. Students had designed the process in terms of selection size of subgroup, sample size, profile and type of operation before going for manufacture the profile. They have selected step-turning operation for conducting this exercise, and selected a subgroup size of 5 and samples of 5 in each subgroup and machined the component and taken the dimensions of the product and data are as shown in table I. Later the students analyzed the data using MINI-TAB software and concluded the significance difference between the operators and percentage contribution of factor. Each batch has presented their finding in front of the faculty member.

IV. Results & Discussions

Here are some of the details of work done by students:

A. *Metrology and Quality Engineering Lab*

Redesigning of experiment:-

Case 1: Instruments used Micrometerr1 and Micrometer 2 both are callibrated, Standard dimension: Slip gauge (10mm)

TABLE I. Micrometer Readings

Inspector	Micrometer 1 Readings (mm)	Micrometer 2 Readings (mm)
1	10.02	10.02
2	10.04	10.02
3	10	10.1
4	10	10
5	10	10
6	10.04	10.04
7	10.05	10.09
8	10	10.04
9	10	10.01
10	10	10
11	10	10
12	10	10
13	10	10
14	10	10
15	10	10
16	10	10

TABLE II. Results of T-test for Micrometer data

Two-sample T for Micrometer 1(mm) vs Micrometer 2(mm)				
	N	Mean	StDev	SE Mean
Micrometer 1 (mm)	16	10.0094	0.0177	0.0044
Micrometer 2 (mm)	16	10.0200	0.0325	0.0081
95% CI for difference: (-0.02950, 0.00825)				
T- Test of difference = 0 (vs not =): T-Value = -1.15				
P-Value = 0.259 DF = 30				

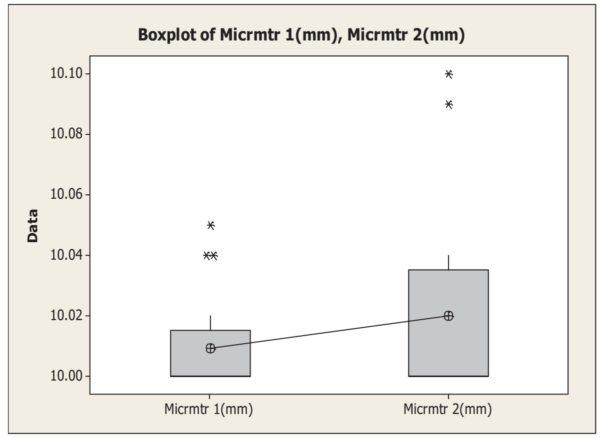

Fig. 2. Box plot of Micrometer

Inferences: Table II show that p value is greater than the significance level. Hence the null hypothesis (HO) is accepted. Hence there is no significant variation in the two batches. And is evident from box plot shown in fig. 2.

Case2: Instruments used Vernier caliper 1 and Vernier caliper 2 one is calibrated and 1 is noncalibrated

Standard used: Slip gauge of 20 mm

Number of inspectors:14

H_o= Null Hypothesis: There is no significant difference between the means of the population.

H_1 = Alternative Hypothesis: There is significant difference between the means of the population.

TABLE III. Vernier Readings

Inspector	Vernier caliper 1 (mm)	Vernier caliper 2 (mm)
1	20	19.6
2	19.98	19.96
3	20	19.71
4	20	19.62
5	20	19.4
6	20.82	20.2
7	19.92	19.6
8	20	19.6
9	20.02	19.04
10	20	19.6
11	20	19.52
12	20	19.6
13	20	19.06
14	20	19.1

TABLE IV. Results of T-Test vernier data

Two-sample T for Vernier caliper 1(mm) vs Vernier caliper 2(mm)				
	N	Mean	StDev	SE Mean
Vernier caliper 1 (mm)	14	20.053	0.222	0.059
Vernier calliper 2 (mm)	14	19.544	0.323	0.086
Estimate for difference: 0.509				
95% CI for difference: (0.294, 0.725)				
T-Test of difference = 0 (vs not =): T-Value = 4.86				
P-Value = 0.000 DF = 26				
Both use Pooled St Dev = 0.2773				

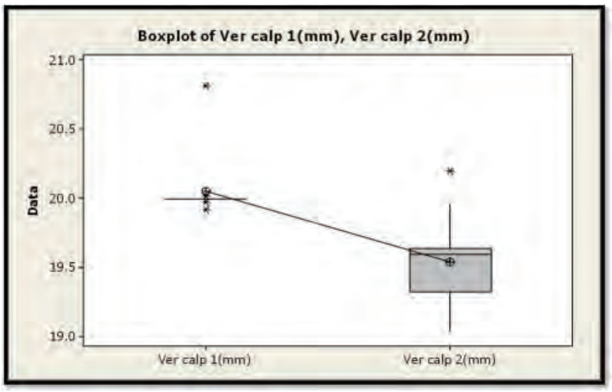

Fig. 3. Box plot of vernier

Inferences: from table IV it is observed that p value is less than the significance level. Hence the null hypothesis H_O is rejected. Hence there is significant difference between the performance two instruments which is evident from the box plot shown in fig. 3.

Integrating Experience

To compare the performances of two batches (B1 & B2) and to analyze the data by using Hypothesis testing

Machine used: Centre lathe
Tool Material: Carbide tool
Work piece material: MS of ∅25mm
Diameter of raw material: 25mm
Required target diameter: 18mm
Tolerance selected for turning: ±0.3mm

TABLE V. MEASUREMENTS OF PART DIMENSIONS

Inspectors of Batch 1	Diameter (mm)	Inspectors of Batch 2	Diameter (mm)
1	18.1	19	17.7
2	17.9	20	17.9
3	17.8	21	18.2
4	18.1	22	17.7
5	18	23	18.2
6	17.5	24	17.7
7	17.8	25	18.1
8	18	26	16.8
9	18.2	27	17.9
10	17.8	28	19
11	18.3	29	18
12	18.2	30	18
13	17.9	31	19.9
14	18.1	32	17.9
15	18.4	33	17.8
16	18.3	34	17.1
17	18.3	35	17.8
18	17.6	36	18.9

TABLE VI. TWO-SAMPLE T-TEST FOR BATCH 1 VS BATCH2

	N	Mean	StDev	SE Mean
Batch 1	18	18.017	0.253	0.060
Batch2	18	18.033	0.691	0.16
95% CI for difference: (-0.369, 0.336)				
T- Test of difference = 0 (vs not =): T-Value = -0.10				
P-Value = 0.924 DF = 34				

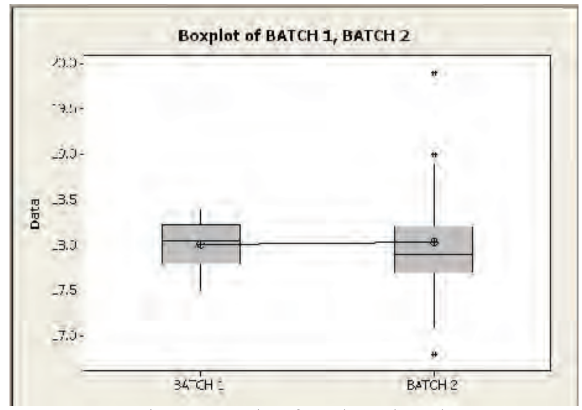

Fig. 4. Box plot of Batch1 and Batch2

Inferences: From the Table VI observed that the p value is greater than the significance level. Hence the null hypothesis H_O is accepted. Hence there is no significant variation in the two batches of production. And is evident from box plot shown in figure 4.

B. Machine shop Lab

The focus of the study was to study the effect of the skills of an operator in a machine shop to produce a desired specification in machining process on a lathe machine. Individually all the students carried out a machining operation in a machine shop. A group (5 students) collected the five readings at five different positions and these collected data is then analyzed using MINI-TAB software to know the significance difference between the operators.

Machine used: Centre lathe
Tool Material: Carbide tool
Workpiece material: MS of ∅25mm
Diameter of raw material: 25mm
Required target diameter: 18mm
Tolerance selected for turning: ±0.3mm

TABLE VII. EXPERIMENTAL DATA TO STUDY THE OPERATOR SKILLS

Operator	Measured values of a quantity in (mm) (Replications)				
	1	2	3	4	5
1	17.8	17.6	18.5	18.5	18.5
2	18.1	18.1	18.0	18.1	18.1
3	18.1	18.2	18.4	17.8	18.1
4	18.0	18.0	18.0	17.9	17.9
5	17.7	17.2	18.0	17.5	17.9

TABLE VIII. RESULTS OF ONE WAY ANOVA

Source	DF	SS	MS	F	P
Factor	4	0.8520	0.2130	3.03	0.042
Error	20	1.4080	0.0704		
Total	24	2.2600			
S=0.2653, R-Sq = 37.70%, R-Sq(adj) =25.24%					
Individual 95% CIs for mean based on pooled StDev					
Level	**N**	**Mean**	**StDev**		
O1	5	18.180	0.444		
O2	5	18.080	0.045		
O3	5	18.120	0.217		
O4	5	17.960	0.055		
O5	5	17.660	0.321		
Pooled StDev = 0.265					

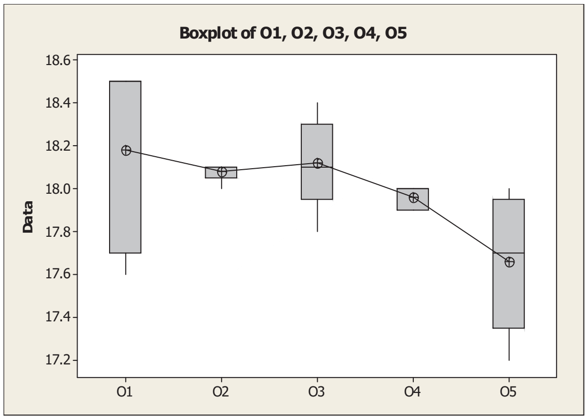

Fig. 5. Box plot of operators

From the above analysis of variance as well as box plots, shown Table 5 and figure 5, p-value < 0.05, the null hypothesis H_0 is rejected. Hence it is concluded that there is a statistically significance difference in between the operators in producing desired specification. However the variations between the operators is due to difference in the skill levels which can be addressed through the regular practice

V. ASSESSMENT

Assessment is done for attainment of program outcome '3b'. The performance indicators for the outcome are as follows.

i. Design an experiment to verify the conceptual understanding.

ii. Conduct (or simulate) an experiment and report the results.

iii. Analyze a set of experimental data.

iv. Interpret the data.

Students were evaluated for each of the indicators through demonstration, presentation and viva-voce examination. The attainment for each of the attribute of 3b was recorded. It was found that the overall percentage attainment of program outcome '3b' was 68.87% as shown in figure 7. howewever the measurments are done for attainment of each indicators wise are shown in figure 6 and these attainments are based on the performance of the students in each components of outcome 3b assesed through viva-voce.

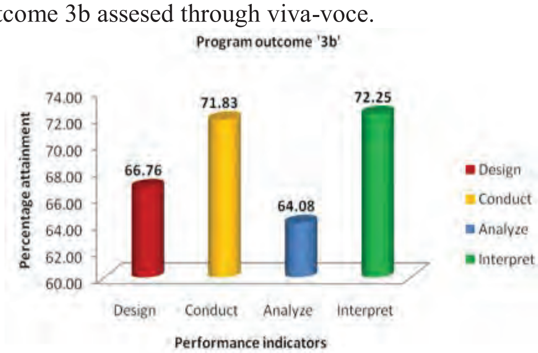

Fig. 6. Program outcome attainment

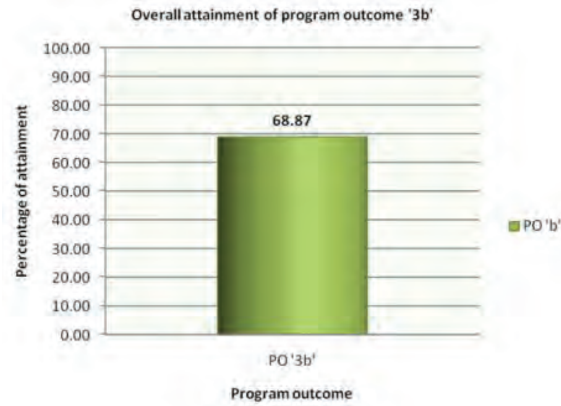

Fig. 7. Overall attainment of Program outcome '3b'

VI. CONCLUSION

Introduction to statistical tools(T-Test, DOE) in solving engineering problems in the laboratory helped the students in deeper understanding of the experiments and increased the analyzing skills among the students , apart from this activity helped the students to understand the industrial shop floor problems (to study the effect of operator skill in a machining process). Through this activity we are able to address the program outcome 3b.

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