THE USE OF A LABORATORY APPROACH FOR TEACHING ENGINEERING STUDENTS

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Keywords: Experimental research, laboratory based teaching; statistical analysis

Abstract: In this paper, the objective was to investigate the effectiveness of an alternative teaching method – lab-based teaching with a group of sub-degree students. A research experiment was designed, implemented and evaluated. The overall design for this experimental research is based on pretest-posttest model. In the design of this quasi-experiment, much effort was made to reduce the impacts of threats and practical constrains. Details teaching plan and delivery of the teaching are also discussed. At the end of the experiment, all students were examined on the module as part of their final year examination. This is the instrument used to collect students' attainment. Data analysis was carried out to investigate whether there are aspects of significant difference caused by the effect of the lab-based teaching. In conclusion, although there was greater improvement in attainment in the experimental group, it may be due to the initial difference of these two groups. Hence, there is no strong evidence that lab-based teaching is better than conventional teaching for cognitive learning.

1. OBJECTIVES OF THE RESEARCH

Teaching in a large lecture class seems to be successful in many higher education establishments[1,2]. Lectures with student size up to 100 are not uncommon. In this type of type of teaching, lecturers are the only people who do most of the talking in lectures. In fact, many students feel bored in this type of one-way communication. It was felt that some alternatives might be used to enhance the learning outcome of the students at Hong Kong Institute of Vocational Education (HKIVE) [3,4].

This study tries to achieve the following objectives:

1. To evaluate the effectiveness of lab-based teaching by carrying out a research experiment on two groups of students and study the difference of outcomes.
2. To determine whether lab-based teaching can be an alternative to conventional classes.
3. To identify any practical problems associated with lab-based teaching and suggest ways to tackle them.

2. METHODS AND TECHNIQUES

A research experiment was set up such that a group of students was divided into two sets. Half of the class took the traditional approach while the other half took the lab-based approach on an engineering module. The time-span of the experiment was one term (15 weeks). At the end of the experiment, all students were examined on the module as part of

their final year examination. This is the way the experimenter measured the student's attainment in that module. In addition to the examination, careful experimental design was done to assess the learning outcomes of students and evaluate the effect of the teaching of two different approaches.

The main emphasis in this paper is the design experimental research and its evaluation. This experiment is a useful approach for analysis the effectiveness of lab-based teaching.

3. OVERALL DESIGN PLAN

Multi-groups model is being one of the most robust techniques for the design of an education research. Due to the limited resources, researcher has to compromise in which he/she has to trade threats to practicality.

The overall design for this experimental research is based on pretest-posttest model. It is commonly used in educational research. Usually, the requirements of pretest and posttest model require initial randomized group. For administration requirement, quasi-experimental research was carried out without the initial random assignment.

In the design of this quasi-experiment, much effort was made to reduce the impacts of threats and practical constrains. In this experiment, 38 students had been grouped into two tutorials groups. Tutorial Group A had 18 students while Group B had 20 students. It was more convenient simply to carry out the experiment without re-grouping these students.

Because of the time-tabling constraint, it was decided Group A would have conventional teaching while Group B would go through the lab-based teaching. That is Group B is the experimental group while Group A is the control group (Table 1).

Tutorial Group	Group	Student Gp Size
A	Control Group	20
B	Experimental Group	18

***Table 1**: Grouping of the students*

4. THREATS TO THE EXPERIMENTAL DESIGN

The overall design of the research consists of the following steps and it can be depicted in Figure 1. The pitfalls of the design come from the lack of initial randomization of participants to form two equal groups, that is, the two groups may not be equal before the experiment is implemented. The main threat to the design is the possibility that group differences on the posttest are due to initial differences rather than the treatment. In many education researches, it may not be possible to choose the "best" designs due to practical constraints. The quasi-experiment mentioned above seems to be the most "suitable" design. As will be shown in section 9, the technique of analysis of covariance is used to handle this problem.

	Time →	→	→
Group under investigation	T1	*X*	T2
Control Group	T1	*Y*	T2

Where T1 : pretest
T2 : posttest
X : lab-based teaching
Y : conventional teaching

Figure 1: Overall design methodology

Subsequently, the null hypothesis of the research is proposed - the mean examination score for students with lab-based teaching is equal to the mean examination score for students with conventional teaching. That is:

$$H_o : \mu_x = \mu_y$$

where H_o : the null hypothesis

μ_x : mean attainment score of students with treatment X (i.e. lab-based teaching)

μ_y : mean attainment score of students with treatment Y (i.e. conventional teaching)

The implementation of experiment can be summarized as the following steps in Table 2:

Step	Task	Details implementation
Step 1	Theory	Student attainment can be affected by different modes of teaching (dependent variable = teaching methodology independent variable = student attainment)
Step 2	Hypothesis	The hypothesis is defined with the characteristics "teaching methodology" with the level of attainment. When the level of attainment is understood to be unrelated to other factors, this can also decided their causal relationships.
Step 3	Main Operations	Experimental design – development of the quasi-experiment
		Delivery of both conventional and lab-based teaching to different groups of students
Step 4	Collect observation	Tabular the attainment score from pretest and posttest results from students' examinations.
Step 5	Data analysis	Apply data analysis techniques to investigate the relationship between the dependent and independent variable.
Step 6	Inference	Draw conclusions on the hypothesis from the data analysis. Examine the attainment level and change of attitude Infer possible causal cause-effect relationships.

***Table 2**: Summary of implementation of the experimental research*

5. TEACHING PLAN

Once the experimental design framework had been set up, detailed teaching plans for the lab-based teaching were made to accommodate the delivery of syllabus based on the objectives of the module. The details can be shown in Table 3 with comparison of the conventional teaching and lab-based teaching.

Teaching Plan of conventional teaching class (for Control Group)	**Teaching Plan of the lab-based class (for Experimental Group)**
The following strategies that should be used in teaching conventional class (Lecture) The use of conventional lecture The use of tutorial style for helping student to dissimulate and solve problem The following strategies that should be used in teaching conventional laboratory class. These were the normal standard practice for laboratory. Emphasis of skill based learning in which students learn the basic skills for equipment operation that re-enforcement of theory.	The following strategies that should be used in teaching lab-based class The use of discovery teaching tactics The including of problem solving activities within the laboratories Emphasis of student involvement in open-ended laboratory exercises The laboratory is divided into many laboratory sessions that cover all the topics mentioned in the syllabus. For each laboratory, it is followed by exercises. This can reinforce a particular concept. Coverage of the related theory is provided leading up to each exercise. Unlike the conventional procedure used in lecture, the students are expected to learn the theory intuitively.

***Table 3**: Comparison of teaching strategies between conventional and lab-based teaching*

6. DELIVERY OF THE TEACHING

After careful study, the module entitled “Discrete-time Signal Processing” (DSP) was chosen. The module is a third-level course for students of Higher Diploma in Communications Engineering. Before the commencement of the research experiment, a series of lab-based teaching materials were prepared [5,6]. Many efforts were made to ensure teaching is relevant and the attainment is comparable to that of conventional teaching. In the design of the laboratory teaching, the ethical issues have been considered. It is hoped that the impact can be reduced in case lab-based teaching proved to be a failure.

Table 4 shown below compares the teaching plan of conventional and lab-based teaching. It is noticed that the amount of contact hours of these two methods is comparable.

Teaching plan of the conventional class		**Teaching plan of the lab-based class**	
The teaching plan to satisfy the above syllabus is as follows:		The teaching plan to satisfy the syllabus is as follows :	
2-hour lectures	x 8	3-hour laboratory-based class	x 8
2-hour tutorials (for a short test, and revision before examination)	x 2	2-hour tutorials (for a short test, and revision before examination)	x 2
3-hour laboratory	x 3		
Total	29 hours	Total	28 hours
• Each of the lectures is covered in lecture room. The teaching consists of • 15 mins of reviews of topics covered in last sections • 20-30 mins to cover the each of the main topics • Re-enforcement of the topics by solved examples. • Conclusion at the last 5 mins.		• The integrated lab-based teaching consists of • 15 mins of reviews of topics covered in the last sections • 20-30 mins of introductory topics and overview of the difficult concepts that • Allow time for students for laboratory exploration using computer. • At the last 15 mins, short quiz to probe student understanding of the topics.	

***Table 4**: Comparison of overall teaching plan of teaching sessions of the two methods*

7. MEASUREMENT OF THE COGNITIVE OUTCOMES - PRETEST AND POSTTEST

In this experimental research, students' examination results were used as their pretest and posttest scores. Although it is very difficult to have reliable pretest score that can exactly identify students' attainment before the commencing the experiment, it is necessary that we have to make the assumption the pretest is valid and it can produce a set of reliable data.

Precaution has been made to alleviate the possible problems. The pretest score can be obtained from results of the pre-requisites unit "Signal in Systems". It was the examination result of students in their 2nd year. There are many factors that can affect the reliability of this data after 8 months. It was later decided the pretest score was extracted from the examination result another module "Information Systems" taught by the author. Although the result from this examination cannot guarantee the pretest is actually measuring the learning attainment in the experiment module, it does certainly reflect the students' general ability to comprehend technical content in a related area.

At the end of the experiment, posttest was designed to measure the cognitive outcome. Since all students were examined on the module as part of their final year examination, the examination score is used as posttest result. It is a natural choice as the examination supposes to measure students' attainment of the module. To moderate the validity of the instrument to measure posttest result, the examination paper had gone through the normal procedures of internal and external moderation within the EE department.

8. ANALYSIS OF STUDENT'S COGNITIVE OUTCOMES

Data shown in the following tables indicate the elementary result of students' cognitive outcomes. Table 5 is the descriptive statistics of the module "Information System". This is a

technical module taught in the first term (i.e. before the experiment). Note that the only the examination result was used as the pretest score. Data in Table 6 shows the continuous assessment and examination result of module "Digital Signal Processing". Again, the examination score is used as to measure students' attainment. The posttest result show the average attainment score of students in Group B (experiment group) is 55.5% while it is only 50.2% for students in Group A (control group). Note that also the pretest result (average) of Group B is 57.1% which is slightly higher the average score of Group A (54.5%).

Unit code : EE315	**Group A – control group**		**Group B – experiment group**	
Title : Information systems	Average	Standard Deviation	Average	Standard Deviation
EXAM (pre-test)	**53.7**	**8.8**	**61.1**	**6.2**
CA	52.8	11.5	62.1	9.0
Total	54.5	5.9	57.1	5.5

***Table 5**: Descriptive statistics of pretest score*

Unit code : EE351	**Group A – control group**		**Group B – experiment group**	
Title : DSP	Average	Standard Deviation	Average	Standard Deviation
EXAM (post-test)	**50.2**	**13**	**55.5**	**12**
CA	48.0	9	51.0	9
Total	49.5	11	54.2	11

***Table 6**: Descriptive statistics of posttest score*

From the descriptive statistical data shown Table 6, one can say Group B (55.5 marks) is better than Group A (50.2 marks) after the experimental treatment. There are many possible reasons that can cause students with such better learning attainment. Reasons such as statistical variations, initial difference of the groups, experiment treatment cannot be ruled out. It is necessary to carry out further data analysis to examine the causes of the difference. The data are evaluated using Statistical Package for Social Science (SPSS)[7,8].

The computer printout of Figure 2 shows the posttest results of the two groups of students; these are Group 3 (control group) and Group 4 (experiment group). The next part of the output shows the *t*-test itself. It shows that the group sizes and the groups had comparable means (i.e. 50.2778 and 55.4500 respectively). The standard deviation is 13.38 and 12.12 respectively. Using the pooled variance estimate, the *t*-value is –1.25. The negative sign arises simply because of the order of listing the groups and is not of itself of any significance. The *t*-value is 1.25 and it has a probability of 0.219. That is the probability of these set of data are drawn from the same population is 0.219. We can say it is likely that the difference of the mean of these two groups (i.e. 50.2778 and 55.4500) is due to statistical variation. From the initial analysis, the null hypothesis H_o is **accepted**.

$$H_o : \mu_x = \mu_y$$

Where H_o : the null hypothesis

μ_x : mean attainment score of students with treatment *X* (i.e. lab-based teaching)

μ_y : mean attainment score of students with treatment *Y* (i.e. conventional teaching)

```
t-tests for independent samples of  GP


                          Number
          Variable       of Cases    Mean        SD       SE of Mean
       -----------------------------------------------------------------
          EXAM (posttest)

         GP 3  (control)     18      50.2778     13.389       3.156
         GP 4  (experiment)  20      55.4500     12.120       2.710
       -----------------------------------------------------------------

         Mean Difference = -5.1722

         Levene's Test for Equality of Variances: F= .003   P= .956


      t-test for Equality of Means                           95%
  Variances  t-value   df    2-Tail Sig    SE of Diff      CI for Diff
 ------------------------------------------------------------------------
  Equal     -1.25     36          .219        4.138       (-13.565, 3.221)
  Unequal   -1.24     34.52       .222        4.160       (-13.619, 3.275)
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***Figure 2** : Data analysis using SPSS – t-test of posttest result*

Figure 3 shows pretest results of the two groups of students; these are Group 1 (control group) and Group 3 (experiment group). The next part of the output shows the *t*-test itself. It shows that the groups had the means 53.7222 and 61.0500 respectively. Again, using the pooled variance estimate, the t-value is 2.99. It has a probability of 0.005. That is to say it is unlikely (0.5%) these samples are drawn from the same population. We can conclude these two groups were not initially equal. It is necessary to carry out further analysis to take into consideration of un-equal groupings.

```
t-tests for independent samples of  GP


                          Number
          Variable       of Cases    Mean        SD       SE of Mean
       -----------------------------------------------------------------
          EXAM - pretest

         GP 1 (control)      18      53.7222      8.837       2.083
         GP 2 (experiment)   20      61.0500      6.160       1.377
       -----------------------------------------------------------------

         Mean Difference = -7.3278

         Levene's Test for Equality of Variances: F= 2.107  P= .155


      t-test for Equality of Means                           95%
  Variances  t-value   df    2-Tail Sig    SE of Diff      CI for Diff
 ------------------------------------------------------------------------
  Equal     -2.99     36          .005        2.451       (-12.299, -2.356)
  Unequal   -2.93     29.99       .006        2.497       (-12.429, -2.227)
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***Figure 3** : Data analysis using SPSS – t-test for the pretest result. (note that there is initial difference between two group of student before experiment)*

9. ANALYSIS OF COVARIANCE

Data analysis shown in Section 8 indicates the initial grouping (not random assignment) does not produce groups with equal pretest means. It is not the deficiency of the design of the experiment. In many cases, random allocation does not guarantee it produces equal groups at the start especially if group size is small.

As shown in section 8, *t*-test is useful to find whether the means of two groups differed significantly. But it is also necessary to compare the difference of pre-test and post-test score of two different groups of students. *Analysis of variance* is useful as it takes consideration of initial difference. The one-factor analysis of variance (ANOVA) procedures is used because there is just one independent variable and one dependent variable. Details of the analysis is shown in Figure 4.

```
Variable  EXAM
   By Variable  GROUP

- - - - -  O N E W A Y  - - - - -

      Variable  EXAM
   By Variable  GP     (1=pretest-control; 2=pretest-experimental;
                        3=posttest-control; 4=posttest-experimental)

                              Analysis of Variance


                                    Sum of         Mean             F      F
        Source           D.F.      Squares       Squares          Ratio  Prob.

Between Groups              3     1160.5094      386.8365       3.5314  .0190
Within Groups              72     7887.1222      109.5434
Total                      75     9047.6316
```

Figure 4*: Data analysis using SPSS – analysis of variance for four groups*

The first part of the computer printout shows an *F*-test on the data. The *F*-ratio, the ratio between groups is 3.5314 with low associated probability (0.019). This is the low probability indicates that it is unlikely that the groups come from the same population.

In order to determine the effect of each of the variables and their joint effect on achievement of students, and analysis of variance was used which is shown in Figure 5.

```
* * *  A N A L Y S I S   O F   V A R I A N C E  * * *

                POSTEXAM
            by  GP        (1 = control; 2= experimental)
            with PREEXAM

                UNIQUE sums of squares
                All effects entered simultaneously

                                    Sum of                 Mean             Sig
Source of Variation                Squares     DF         Square       F    of F

Covariates                        1306.427      1       1306.427    10.089  .003
   PREEXAM                        1306.427      1       1306.427    10.089  .003

Main Effects                         3.505      1          3.505      .027  .870
   GP                                3.505      1          3.505      .027  .870

Explained                         1559.866      2        779.933     6.023  .006

Residual                          4532.134     35        129.490

Total                             6092.000     37        164.649

38 cases were processed.
0 cases (.0 pct) were missing.
```

Figure 5 : Data analysis using SPSS – analysis of variance for2 groups (with pretest scores as the covariates)

The output shows a fairly high F-ratio 10.089 with a significance value of 0.003 for pre-exam score differences between the groups. It is highly unlikely ($p < 0.003$)that the groups of students were equal at the start of the research experiment. The next part of the output shows an F-ratio of 0.027 ($p < 0.87$) for the effects of teaching group on the posttest scores after correction for unequal value of pre-test. That is, after correction, the two teaching methods (conventional and lab-based) were statistically equal (i.e. 87%). As far as cognitive outcome is concern, with the consideration of unequal pretest score, the null hypothesis ($H_o : \mu_x = \mu_y$) is **accepted**.

10 SUMMARY

In this investigation, an experimental research was implemented to evaluate the effectiveness of lab-based teaching with respect to conventional teaching. The design for this research experiment is the “grouping-pretest-treatment-posttest” method. The different teaching methods were implemented using a one-term module known as “Digital Signal Processing”. The implementation of the syllabus was completed using these two different teaching approaches.

During the experiment, measurements of students’ attainment and attitude are collected. Data analysis was carried out to investigate whether there are aspects of significant difference caused by the effect of the lab-based teaching. Although there was greater improvement in attainment in the experimental group, it may be due to the initial difference of these two groups. Hence, it is concluded that there is **no strong** evidence that lab-based teaching is better than conventional teaching for cognitive learning. The data analysis of students’ attitude also indicates there is no evidence that the change in students’ perception is the result of the lab-based teaching.

11. REFERENCE

1. Beard, R.M. (1970), “Teaching and Learning in Higher Education”, *Penguin Books*
2. Cotton. J. (1995), “The theory of learning : an introduction”, *Kogan Page*
3. Wong, Y.L (1997), " The use of a laboratory approach for teaching engineering students", *MA(Ed) dissertation, University of Hull, UK*
4. Wong, Y.L (2000), "How effective is our teaching methods for vocational education", Summer 2000, IVETA 2000
5. McClellan. J.H. (1998), “DSP First – A Multimedia Approach”, *Prentice Hall*
6. Course Planning Team (1994), “Course Scheme Document Vol 2”, *Dept. of Electrical and Communications Engineering*, Hong Kong Technical College, HK
7. Hiuzingh, E. (1994), “Introduction to SPSS/PC+ 5.0 & data entry”, *Addison-Wesley*
8. SPSS inc. (1995), “SPSS Release 6.0 Syntax Reference Guide”, *SPSS Inc*

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