OPEN-ENDED EXPERIMENTS IN DEVELOPING COGNITIVE ABILITIES

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Laboratory activities play a very important role in Physics and hence efforts are continuously made all over the world to improve laboratory instruction. This paper discusses open-ended approach for doing Physics experiments and examining its effectiveness by field tests.

Laboratory activities play a very important role in Physics instruction because they are aimed to develop:

(i) Scientific knowledge, cosnceptual understanding and ability to apply scientific knowledge to life-situations.

(ii) Skills—organisational, manipulative, communicative and constructional.

(iii) Creative ability, intellectual ability, problem solving techniques, processes of Science, curiosity to know 'why', 'what' and 'how' of thing, belief in cause and effect relationships, impartial judgements, etc.

Efforts are continuously made all over the world to improve laboratory instruction. Many are of the opinion that approaches emphasising some amount of divergent thinking and openness in the activities are more advantageous than the traditional approach to promote the above objectives. Accordingly, we have been working on open-ended approach for doing Physics experiments and examining its effectiveness by field tests.

The open-ended approach of performing experiments has been defined differently by different authors. Horowitz[1] defines openness as style of teaching involving flexibility of space, student's choice of activity, richness of learning materials involving more individuals or small group activity than large group interaction. This description compares well with our definition of open-ended experiments[2]. But pure open-ended experiments may not be feasible in a real classroom situation in a developing country like India. Hence we have suggested a guided discovery approach for doing practicals[3]. The general format for doing experiments by this approach is as follows:

(i) Area

(ii) Topic

(iii) Pre-requisite knowledge

(iv) Apparatus and materials

(v) Outlines of the possible activities

(vi) Evaluatory questions

(vii) Suggestions by the student for further

activities

Some guidance is provided to them by suggesting outlines of the possible activities and by listing suitable evaluatory questions. In a previous project, we have developed a series of open-ended experiments according to the above format.[4]

In this project[5] we have made a comparative study of the effectiveness of open-ended approach versus traditional approach for doing Physics practicals at the P.U.C. (Higher Secondary) level. Five guided open-ended experiments were tried out in Saradavilas College and Marimallappa's Junior College of Mysore city. The sample size was limited to 92 students comprising of 66 boys and 26 girls.

Procedure: To start with, an experimental and a control group of students were formed by the help of following tests:

(i) Raven's progressive matrices (Intelligence test)

(ii) Kuppuswamy's socio-economic status scale as modified by Shri Parthasarathy of Mysore University

(iii) An achievement test prepared by us.

These tests were used to make approximately two equal homogeneous groups, the Guided Open-ended Group (GOG) and the Traditional Laboratory Group (TLG) among boys and girls in the two colleges. The homogeneity of the groups was ascertained by calculating the F-ratios and t-values.

The two homogeneous groups worked for 38 contact hours in the laboratory during a period of one year. Many activities were done by the students on five different topics. The activities of one such topic, namely bending of light rays are briefly described below.

Students of guided open-ended group were given the following student-sheet at the beginning of the laboratory session.

Student Sheet

Roll No.: Time: 10 hours

College: Date:

I. Area	Light
II. Topic	To study the bending of light rays in optically transparent media
III. Pre-requisite knowledge	Laws of refraction, critical angle, parallex
IV. Apparatus and materials	Glass slab, prism, rectangular glass tank, hollow glass prism, convex lens, plane mirror, concave mirror, pins, travelling microscope, protractor, slits, liquid, light source, wooden board, spherometer.
V. Activities	Hint: Some of the possible methods to obtain refractive index are: 1. By finding the minimum deviation angle 2. By finding apparent depth 3. By critical angle method 4. By using hollow prism

5. By using a concave mirror
6. By adjusting the volume of the liquid, etc.

Use at least one method for each medium and describe the rest by discussing with other students.

VI. Evaluatory questions

1. Does the refractive index of a substance depend on the colour of light?
2. Does the refractive index of a medium depend on the shape of the substance?
3. It is possible to find the refractive index of glass using critical angle method by keeping the object in air? Explain.
4. Why do the parallel rays of light converge to a point after refraction through a convex lens?
5. On what factors does the lateral shift of the light ray depend while propagating through a glass slab?
6. List the factors which influence the maximum deviation angle in the prism?

VII. List further activities in this topic:

The students of guided open-ended group were asked to study this sheet very carefully. Some reference books were also provided to them. Relevant apparatus and materials were provided and explained to them. They were given freedom to choose the relevant activity and the necessary apparatus and materials. They were also allowed to choose the procedure they thought best.

Each student in guided open-ended group did 4 to 5 activities from the following:

I. Determination of refractive index of the transparent solid material by pin-method, shift-method, critical-angle method, spectrometer method and convex lens method; and

II. Determination of refractive index of transparent liquid by shift method, hollow-prism method, concave mirror method and liquid lens method.

They did these activities in five laboratory sessions of two contact hours each. At the end they were asked to discuss with others about their activities and findings.

It may be pointed out that although some guidelines or hints were given to the students, the experiment remained open-ended because:

(i) The methods adopted by students were different in doing the same activity. For example, in the hollow-prism method, some students adopted the pin-method to determine 'D' the angle of minimum deviation and 'A' the refracting angle and some others followed the spectrometer method. Similarly, while calculating the focal length, some students followed the plane mirror method, some followed the UV method, some obtained the image of an object at infinity and some obtained 'F' by shift method. Again

while calculating the radius of curvature some used the spherometer, some used the protractor and some others adopted the Boy's method. Further,

(ii) The methodology of doing the experiment was their own.

(iii) Observational steps were not given to them.

(iv) Freedom was given for recording, tabulating and calculating their results in their own way.

(v) Different groups of students used the different transparent materials like rectangular glass slab, semi-circular glass-slab, rectangular glass tank with different quantity of liquid, lenses and mirror of different focal lengths etc.

The students of traditional laboratory group also did these experiments in five laboratory sessions of two contact hours each. They were provided with instructional sheets which contained the aim of the experiment, apparatus and materials required for the experiment, theory and procedure of the experiment, observational steps, tabular columns and essential formulae to calculate the required variables. Besides, experiments on bending of right rays in optically transparent media were demonstrated to them. Then they were asked to:

(i) Determine the refractive index 'μ' of glass by shift method using travelling microscope

(ii) Determine the 'μ' of water shift method by using travelling microscope

(iii) Determine the 'μ' of given material by using a convex lens

(iv) Determine the 'μ' of liquid by liquid lens method

(v) Determine 'μ' of the material of the prism by using spectrometer.

After the students of both the groups had done the experiments in five different topics for a period of 38 hours, they were given post-achievement and creativity tests.

Achievement Test

According to Good[5], achievement is an accomplishment or proficiency in a given body of knowledge and it is a measure of the students ability in terms of standardised test results. Hence achievement test is an evaluating tool used to measure the students' performance in the cognitive domain in the beginning and end of the programme.

In this project, post-achievement test comprises of suitable questions pertaining to the activities performed. The questions were finalised after administering them to 42 students and carrying out a detailed item analysis. Out of the 98 questions, originally administered to them only 76 questions were retained for the post-achievement test. Out of this 39 questions were at knowledge level, 22 at understanding level and 15 at application level. Care was taken to see that the questions covered only those concepts which were covered in both the groups. After administering this test, the answers were scored by using a scoring sheet and a scoring key.

Creativity test: Creativity test (verbal) developed by Professor Baqer Mehdi was used in our investigation. It helped in estimating the creative abilities of the students and in making high and low creativity subgroups.

Primary and Secondary variables

In this investigation the methods of performing practicals were considered as independent variables and the effect due to these methods on the acquisition of knowledge, understanding and application of facts, principles and concepts, development of certain creative abilities were considered as dependent variables. However there are other variables such as intelligence levels, socio-economic status levels, school achievement, age, sex, contact periods, interests of students and class instructor which may also contribute for the outcome of the investigation. So care has been taken to control these secondary variables. Accordingly the following null hypotheses have been made.

Hypotheses

It is hypothesised that no significant differences are identifiable between the GOG and the TLG:

Ho 1: In the mean scores of post-achievement test in Physics.

Ho 2: In the mean scores of post-creativity test.

Ho 3: With respect to their performance in post-achievement test when the different subgroups are made according to their intelligence levels.

Ho 4: With respect to their performance in post-achievement test when the different subgroups are made according to their socio-economic status levels.

Ho 5: With respect to their scores in post-achievement test when different sub-groups are made according to their creativity levels.

Ho 6: With respect to their scores in post-achievement test when different sub-groups are made according to sex.

Tools: The null hypotheses listed above have been tested by statistical methods. Null hypotheses Ho 1 and Ho 2 have been tested by 't-test' and the remaining hypotheses have been tested by 'F-test'.

Results

The results pertaining to testing of the above six hypotheses have been tabulated in the following tables.

Table 1

Experimental approach versus achievement and creative abilities

Hypotheses	Ability	Groups	Mean	S.D.	r	t-value	Significance level	Remarks
Ho 1	Achievement	GOG	56.00	52.14	0.9380	6.800	0.05	Significant
		LTG	32.70	30.80				
Ho 2	Creativity	GOG	150.00	5.960	0.9590	0.8300	0.05	Not
		LTG	149.9	5.080				

significant

df = degree of freedom = 45

The table shows that:

(a) Mean and standard deviation of GOG is greater than TLG on post-achievement test and post- creativity test,

(b) High degree of positive correlation (r) between the two groups, GOG & TLG,

(c) 'T' – value is significant at 0.05 level of significance for the null hypotheses Ho1 and hence it is rejected and

(d) 'T' - value is not significant at 0.05 level of significance for the null hypotheses Ho2 and hence it is accepted.

studied by making the following sub-hypotheses.

Ho2a : No significant differences are identifiable between GOG and TLG in the mean scores in post-creativity test.

Ho2b : No significant differences are identifiable between GOG and TLG in the mean scores of flexibility in post-creativity test.

Ho2c : No significant differences are identifiable between GOG and TLG in the mean scores of originality in post creativity.

The above three sub-hypotheses also have been

Table 2

Experimental approach versus fluency, flexibility and originality

Hypotheses	Abilities	Groups	Mean	S.D.	r	t-value	Significance level	Remarks
Ho2a	Fluency	GOG TLG	59.28 44.00	129.8 89.81	0.9290	1.820	0.05	Significant
Ho2b	Flexibility	GOG TLG	38.60 31.60	73.94 51.99	0.7380	1.030	0.05	Not Significant
Ho2c	Originality	GOG TLG	28.85 18.90	107.6 64.78	0.8570	1.090	0.05	Not Significant

degrees of freedom = 45

Creativity ability can be further divided into certain primary traits like fluency, flexibility and originality. These aspects have been carefully

tested by 't-test' and the result pertaining to these hypotheses are given in table 2.

The above table shows that:

Table 3

Results on the ANOVA of post-tests for the achievement by students of high and low levels of intelligence, socio-economic status and creativity

Variables	Hypotheses	Source	Sum of Squares	df**	Mean Squares	F-value	Significance level	Remarks
Intelligence	HO_3	Total Between Within	9408.75 7311.90 2097.85	51 3 48	– 2437.30 43.7050	55.77	0.05	Significant
Socio-Economic Status	HO_4	Total Between Within	8560.98 6038.06 2522.92	51 3 48	– 2012.68 52.5600	38.29	0.05	Significant
Creativity	HO_5	Total Between Within	11652.9 9780.77 1872.15	51 3 48	– 3260.25 39.0000	83.59	0.05	Significant

df* = degree of freedom = 45

(a) High degree of positive correlation between the two groups, GOG and TLG

(b) Mean and standard deviation of GOG is greater than those of TLG

Table 4

Results on the ANOVA of achievement by boys and girls

Hypotheses	Source	Sum of Squares	df**	Mean Squares	F-value	Significance level	Remarks
HO_6	Total Between Within	16457.7 11888.9 4568.70	91 3 88	– 3962.98 51.9170	76.33	0.05	Significant

df* = degree of freedom = 45

(c) 'T'-value is significant at 0.05 level of significance for the null hypotheses Ho2a

(d) 'T'-value is not significant at 0.05 level of significance for the null hypotheses Ho2b and Ho2c.

These results lead to the rejection of hypothesis Ho2a and acceptance of hypotheses Ho2b and Ho2c.

From the above table, it can be seen that 'F-values' for the hypotheses HO_3, HO_4 and HO_5 are significant at 0.05 level of significance and hence these hypotheses are rejected.

From the above table it can be seen that 'F-values' is significant for the hypothesis HO_6 at 0.05 level of significance and hence these hypotheses are rejected.

Discussion

The rejection of the null hypotheses HO_1 shows that the superiority of GOG over TLG in acquisition of knowledge, understanding, application of certain concepts and principles in Physics.

The results on the hypotheses on creativity are interesting. Though in general creativity aspects seem to be independent of the experimental approach, the rejection of HO_2a shows slight superiority of GOG over TLG in acquiring fluency, that is, in developing the fertility of ideas.

The rejection of null hypotheses HO_3, HO_4 and HO_5 shows the superiority of GOG over TLG in an achievement of cognitive abilities for students of both high and low levels of intelligence, socio-economic status and creativity test.

The results on the hypotheses HO_3, HO_4 and HO_5, also show that the two approaches guided open-ended and traditional laboratory are themselves not affected by both high and low levels of intelligence, socio-economic status and creativity of students, indicating that the experimental approach is equally applicable to all kinds of students. However the rejection of null hypotheses HO_6 shows that girls are superior to boys in their performance of post-achievement test.

The above observations lead us to conclude that (a) the guided open-ended approach is better than the traditional laboratory approach in the promotion of cognitive abilities like knowledge, understanding and application to students of both high and low levels of intelligence, socio-economic status and creativity, (b) the guided open-ended approach does not have any marked superiority over traditional laboratory approach in developing creativity, except in developing fluency aspect of creativity, where a marginal superiority is indicated.

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