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Effects of Practical Work Approach on the Performance of College Students in Graph Theory

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Abstract— The role of mathematics in man's life is an established fact. However, the marked difficulty experienced by students in learning mathematics as noted by the researcher calls for the need of alternative approaches to enhance performance. This paper dealt with the effects of practical work approach on the performance of college students in Graph Theory, specifically on the interaction effects of teaching approach with mathematical ability and manipulative skills. The post test-only control group true experimental design was used. Findings showed that below-average and above-average mathematical ability students taught by practical work approach performed better than their counterparts in the conventional approach. Moreover, the students with high and low manipulative skills taught by the practical work approach performed better than those students with high and low manipulative skills taught by the conventional approach. Furthermore, results of the ANCOVA revealed a significant interaction between teaching approach and mathematical ability. Overall, the practical work approach as a teaching strategy was shown to be significantly effective in improving performance of the students in Graph Theory. Practical work approach should be adopted by teachers to enhance performance of students in said course.

Index Terms—.analysis of covariance, effects, graph theory, interaction, manipulative skills, mathematical ability, performance, practical work approach

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1 Introduction

The vital role of Mathematics to almost all aspects of man's life is an established fact. However, the sad reality remains, that most students perform low in mathematics. A recent study revealed the number of Filipino students who lag behind their foreign counterparts in terms of their achievement levels in science and mathematics. Results of the Third International Mathematics and Science Study 2011 conducted by the International Association for the Evaluation of Educational Achievement show that Filipino students scored below average against the international average standard (TIMMS, 2011). Having taught the course Graph Theory to BS Mathematics students for so many years, the researcher observed the marked difficulty experienced by students in learning the course. This difficulty was evidenced by poor examination results and inability of students to correctly interpret answers to solutions. The same observations have been expressed by other instructors in Mathematics on several occasions, namely, departmental meetings and deliberations of final grades. The above-mentioned findings and observations call for remedial measure in order to raise the level of science and mathematics achievement to one that is at par with developed countries.

The training of mathematics teachers has been identified as among the specific steps to improve instruction. The conduct of implementation programs and the implementation of innovative teaching strategies can also be used to uplift the quality of mathematics instruction. No single technique or approach has been proven to maximize student performance. Hence, it is an added responsibility of a teacher to select, organize and present the lessons in a developmental manner tailored to the objectives of the course and the needs of the students.

Cognizant of the need for alternative teaching approaches, this study investigated the effects of one of the new trends in mathematics instruction. This is called the practical work approach.

The practical work approach highlights the dynamic nature of teaching and learning mathematics. This dynamism advocates the teachers as facilitators of learners' active construction. The students' ideas are elicited and discussed. They must be able to think for themselves, to reason and explain, to discover connections and consolidate their learning. In the end, they develop confidence in their ability to do and create mathematics, recognize and apply mathematics in their everyday activities and appreciate the importance of mathematics

Realizing the potential usefulness of practical work approach in instruction, this research was focused on the effects of this approach on students' performance in Graph Theory. Viewed in this context, the effectiveness of practical work approach was tested in teaching Graph Theory to determine whether it can help lessen the students' difficulties in learning concepts and processes which could lead to enhanced mathematics performance. Hence, the researcher aimed to provide useful data through the results of this experimental study that could help teachers to be more effective in mathematics teaching.

Specifically, the study determined the following: the profile of the students taught by the practical work approach and those taught by conventional approach in terms of School ability (IQ), Mathematical Ability, Manipulative Skill; the performance of the students in Graph Theory taught by the practical work approach and those taught by the conventional ap-

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proach when grouped according to mathematical ability and manipulative skill; a significant difference in the performance in Graph Theory of the students taught by the practical work approach and those taught by the conventional approach in terms of mathematical ability and manipulative skill; and a significant interaction effect of teaching approach and mathematical ability and teaching approach and manipulative skill on performance in Graph Theory.

2 FRAMEWORK

The practical work approach uses hands-on, minds-on and hearts-on activities to develop concepts, investigate relationship among these concepts, solve problems and engage the teacher and the students in mathematical thinking. The students perform practical activities to develop concepts and relationships among these concepts. Learners are given enough time to think. Classroom tasks are student-centered. They are active participants in the learning process. They manipulate objects and experience real life situations and from the insights derived from these, they discuss, explore and construct mathematical ideas. Such a dynamic activity provides a concrete basis for the development of abstract mathematical ideas and higher order learning skills among the learners. Thus, practical work deepens the students' understanding and appreciation of the rigors and application of mathematics and engages them in life-long learning(Practical Work Sourcebook, 1998).

Based on Bloom's Taxonomy, there are 3 student-learning outcomes associated with well-design activities in the practical work approach. They are as follows:

1. Psychomotor outcomes include all manipulative, 'hands-on' and 'minds-on' skills like construction of figures, graphing and using measuring devices.
2. Affective outcomes relate to students' interests, attitudes, motivation and values. Examples include following instructions correctly, willingness to consider alternative solution in problem solving and finding practical work as an enjoyable and rewarding experience.
3. Cognitive outcomes focus on student acquisition of content, process and higher order thinking skills. Examples include discovering, analyzing relations among figures, formulating a conjecture using specific areas, testing a relation conjectured from a specific case to a general case, justifying the conjectures, applying a discovered relation to solve problem, visualizing relationships, making conjectures and proving relationships and finding and symbolizing patterns.

The research paradigm in Fig 1 shows the probable relationship among the variables of this investigation and drawn based on an input-process-output model.

The input variables are the students' mathematical ability, manipulative skill, and school ability (IQ). The process variable was the teaching approach. Practical work approach was used for the experimental group and conventional approach for the control group. The output variable was the performance of the students in Graph Theory as measured by the scores of the students in the posttest in Graph Theory.

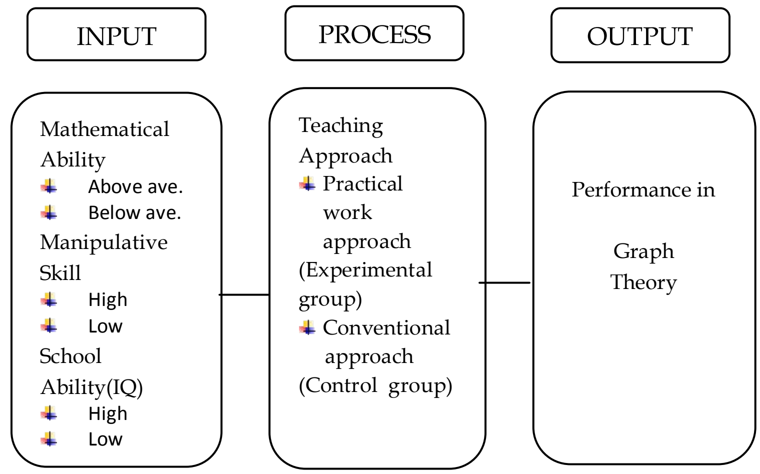

Fig 1 Paradigm of the Study

3 MATERIALS AND METHODS

A post test-only control group true experimental design was employed in this study. Two intact classes of BS Mathematics sophomores of Don Mariano Marcos Memorial State University-South La Union Campus were taken as subjects of the study and that they are not equivalent at the start of the experimental period. The experimental group with 29 students was taught by the practical work approach and the control group with 31 students was taught by the conventional approach.

Aside from the teaching approach, mathematical ability and manipulative skill were considered in analyzing the posttest scores of the students. Above-average and below-average mathematical ability and high and low manipulative skill students were separated. Thus, students with above-average mathematical ability and below-average mathematical ability were taught the practical work and conventional approaches as well as those with high manipulative and low manipulative.

A performance test in Graph Theory consisting of 50-item multiple choice test with four options was developed and validated. The reliability coefficient of the performance test was 0.804, high reliability using Kuder-Richardson Formula 20. The test covered the topics in the study, namely, trees, paths and distance in graphs, Eulerian graphs, Hamiltonian graphs, planarity and coloring graphs (Chartrand& Santos, 1993).

The school ability (IQ) was indicated by the score of each student in the Otis-Lennon School Ability Test (OLSAT) Advance prepared by Arthur S. Otis and Roger T. Lennon. Reliability coefficient for the OLSAT was 0.93.

The mathematical ability was indicated by the score of each student in the numerical ability portion of the College Admission Test which consisted of 50-items with four options.

The manipulative skill is indicated by the score of each student in the space relation and mechanical reasoning portions of the Differential Aptitude Tests (DAT). All DAT tests are essentially power tests and the reliability coefficients are high. The test which consisted of 60 items with four options was administered to the students by the guidance counselor of the College of Sciences before the experimental period.

Both the experimental and control classes took up the same topics. They were given the same set of exercises, assignments and parallel quizzes. The teaching strategy, however, differed for the two groups. The practical work approach used in the experimental class involved hands-on and minds-on activities to develop concepts, investigate relationships among these concepts, solve problems and engage the teacher and the learner in mathematical thinking. On the other hand, the combination of lecture-discussion and the discovery methods which involved confirmation and practice was used in the control class.

The main data gathering instrument which was the posttest in Graph Theory and instructional materials which included worksheets were prepared by the researcher. The posttest was validated and the reliability of the test was 0.83, highly reliable. The experiment lasted for 6 weeks. The performance test was administered to the experimental and control groups which was used to compare their performance after the experimental period.

The necessary data for the school ability and mathematical ability were taken from the Guidance Office.

Validation of the performance test was done by pilot-testing to 40 randomly selected students who have finished Graph Theory. Results were subjected to item analysis which included computing the indices of the item's level of difficulty (P) and discrimination (R). Items with discrimination values lower than 0.20 do not yield much information about differences among the abilities of the students and should be improved or discarded (Clark, et al.,1999). Items with discrimination values 0.30 and above were retained. Items whose difficulty levels approximate the optimal difficulty value of a 4-alternative multiple-choice item which is 0.62 were retained. This range was from about 0.50 to 0.90. Items with difficulty close to 1 or below 0.25, the guessing level of the items were rewritten.

Scores obtained by the students in the 50-item posttest were given the following descriptive rating: 45-50 , excellent; 36-44, above average;27-35, average; 18-26, below average;9-17 fair; and 0-8, poor.

The mathematical ability and manipulative skill scores of the students were given the following descriptive rating:

Range		Descriptive Rating
Math Ability	Manipulative Skills	
42-50	51-60	Excellent
34-41	41-50	Very Satisfactory
26-33	31-40	Satisfactory
17-25	21-30	Good
9-16	11-20	Fair
0-8	0-10	Poor

Mean, standard deviation, skewness, and kurtosis were used to describe the respondents in terms of the following: school ability, numerical ability score in the College Admission Test (CAT), manipulative skill, scores of the students in the posttest according to mathematical ability groups, manipulative skill groups and teaching approach.

Two-way Analysis of Covariance (ANCOVA) was used to determine the significant differences in the performance in Graph Theory between the above-average and below-average mathematical ability groups, between the high and low manipulative skill groups, between the experimental and control groups, the significant interaction effects of teaching approach and mathematical ability and teaching approach and manipulative skills on the performance of the students using school ability (IQ) as covariate.

4 RESULTS AND DISCUSSION

School Ability (IQ)

The distribution of students according to school ability school ability, indicated by the score of each student in the Otis-Lennon School Ability Test (OLSAT) Advance reflects that the students taught by the practical work approach had a mean school ability of 27.52 with a standard deviation of 7.90 signifying that most of the group members ranged within 27.52 ± 7.90, that is, from 19.61 – 35.41 indicating 'fair' to 'good' school ability. The students taught by the conventional approach had a mean school ability of 23.39 with a standard deviation of 5.36 indicating that most of the control group members ranged within 23.39 ± 5.36, that is, from 18.03 – 28.75 signifying 'fair' school ability.

Mathematical Ability

Results reveal that the students taught by the practical work approach had a mean mathematical ability of 24.80 with a standard deviation of 5.49. This implies that most of the group members' mathematical ability ranged within 24.80 ± 5.49, that is, from 19.31 – 30.29 signifying ' fair' to 'good' ability. The students taught by the conventional approach had a mean mathematical ability of 22.36 with a standard deviation of 4.75. Thus, most of the group members' mathematical ability ranged within 22.36 ± 4.75, values from 17.61-27.11 also indicating 'fair' to 'good' ability.

Manipulative Skills

The students taught by the practical work had a mean manipulative skills of 25.57 with a standard deviation of 8.04. This means that most of the students in the practical work approach had manipulative skills scores which ranged within 25.57 ± 8.04, that is, from 17.53-33.61, indicating 'fair' to 'satisfactory' ability. The students in the control group had a mean manipulative skills of 23.87 with a standard deviation of 9.25. This implies that the manipulative skills ranged within 23.87 ± 9.25, values from 14.62 – 33.12 signifying 'fair' to 'satisfactory'.

Posttest Performance of the Students According to Mathematical Ability

The students with below-average mathematical ability in the experimental group had a mean posttest performance of 21 with a standard deviation of 2.31. This means that most of the group members' posttest performance ranged within 21 ± 2.31, values from 18.69-23.32 indicating 'below-average' performance. The students in the control group had a mean posttest performance of 15.67 with a standard deviation of 2.80. This implies that most of the group members' mathematical ability ranged within 15.67 ± 2.80, that is, from 12.87 - 18.78 signifying 'fair' to 'below-average' performance.

On the other hand, the above-average mathematical ability students taught by the practical work approach had a mean posttest performance of 38.1 with a standard deviation of 4.8. This implies that most of the group members' posttest performances ranged within 38.1 ± 4.8, that is, from 33.21 - 42.99 signifying 'average' to above-average' performance. The students in the control group had posttest performances which ranged within 27 ± 6.58, values from 20.41 -33.58 indicating 'below-average' to 'average' performanc

Posttest Performance of the Students According to Manipulative Skill

The low manipulative skill-experimental group obtained a mean posttest performance of 25.82 with a standard deviation of 5.93. This indicates that the group members' posttest performances ranged within 25.82 ± 5.93, values from 19.89 – 31.75 indicating 'below-average' to 'average' performance. The low manipulative skill students in the control group had a posttest mean performance of 17.09 with a standard deviation of 2.74. This suggests that the group members' posttest performances ranged within 17.09 ± 2.74, that is from 14.35 – 19.83 signifying 'fair' to 'below-average' performance.

The posttest performance of the high manipulative skill groups across the experimental groupings reflects that the students taught by the practical work approach had a mean posttest performance higher than those taught by the conventional approach by 10. The students in the conventional group had a mean posttest performance of 35.08 with a standard deviation of 6.39. This means that most of the group members' posttest performances ranged within 35.08 ± 6.39, values from 28.69-41.47 signifying 'average' to 'above-average' performance. Those in the control group had a mean posttest performance of 25.08 with a standard deviation of 8.94. This implies that most of the group members' posttest performances ranged within 25.08 ± 8.94, that is, from 16.14-34.02 indicating 'fair' to 'average' performance.

Effects of Teaching Approach, Mathematical Ability, Manipulative Skills and their Interactions on the Students' Posttest Scores

Effects of Teaching Approach and Mathematical Ability

The analysis on the differences between the performances in Graph Theory of the mathematical ability groups after they were given the teaching approaches was done by the Analysis of Covariance (ANCOVA), using school ability (IQ) as covariate as summarized in Table 1.

The table shows that Factor A, the two teaching approaches used had F-ratio of 10.8($p < .05$) which reveals that a significant difference is evident between the performances of the students taught by the practical work approach and those taught by the conventional approach.

Factor B which refers to mathematical ability groupings of students into above-average and below-average had F-ratio of 9.6 ($p < .05$) which indicates significant difference between the performances of the above-average and below-average mathematical ability students.

The F-ratio for the interaction of teaching approach and mathematical ability of 6.24($p < 0.05$) is an evidence that significant difference exists between the two groupings. The significant interaction indicates that the difference in the performances of the above-average and below-average students depends on the teaching approach used. It implies further that one method was significantly more suitable in enhancing the performance of the students grouped as below-average and above-average, that is, one method was significantly more compatible with a particular group than the other method with respect to mathematical ability.

Table 1 .Summary of the two-factor analysis of covariance of the performance of the students with respect to mathematical ability and teaching approach

Sources of Variation	Adjusted Sum of Squares	df	Adjusted Mean Squares	F-ratio	p-value
Factor A (Teaching Approach)	267.115	1	267.115	10.8	0.000
Factor B (Mathematical Ability)	237	1	237	9.6	0.000
A x B (Interaction)	154.255	1	154.255	6.24	0.03
Error	864.6	35			

$\alpha = 0.05$

This suggests that the students who were taught by the practical work approach performed significantly better than those taught by the conventional approach.

Table 2 shows the difference in the adjusted score means of the students exposed in the practical work approach and those exposed in the conventional approach to be 5.125, in favor of the former, which according to ANCOVA is a highly significant difference.

Table 2 Unadjusted and adjusted posttest score means of students with respect to teaching approach and mathematical ability

	Factor A Teaching Approach		Factor B Mathematical Ability	
	Practical Work	Conventional	Above-Average	Below-Average
Unadjusted	29.55	22.9	34.15	18.3
Adjusted	28.775	23.65	29.8	22.65
Difference	5.125		7.15	

In terms of mathematical ability, Table 3 shows that the students with above-average mathematical ability exposed to the practical work approach had an adjusted posttest score mean higher by 6.43 than those above-average mathematical ability students exposed to the conventional approach.

Table 3 Unadjusted and adjusted posttest score means of the above-average and below-average mathematical ability students

Mathematical Ability	Teaching Approach	
	Practical Work	Conventional
Above-average	y= 38.1 y′= 33.01	y = 27 y′ = 26.58
Below-average	y = 21 y′ = 26.09	y = 15.67 y′ = 19.22

Legend: y = unadjusted posttest score mean
y′= adjusted posttest score mean

Scheffe test of significance between adjusted means in Table 4 exhibits the computed F-ratio for the above-average mathematical ability students in the experimental and in the control groups, 6.96 ($p < .05$) which implies that the difference in the adjusted posttest score means between the above average students in the experimental and control groups is significant.

Table 4 Scheffe test of significance between adjusted means

Group Combination	F
Above-Average-Expt'l vs. Above-Average-Control	6.96*
Above-Average-Expt'l vs. Below-Average-Control	32.014**
Below-Average-Expt'l vs. Above-Average-Control	.0404
Below-Average-Expt'l vs. Below-Average-Control	7.94*

*significant at .05
**significant at .01

Hence, the students with above-average mathematical ability taught by the practical work approach performed better in Graph Theory than those taught by the conventional approach.

The above-average mathematical ability students taught by the practical work approach had an adjusted posttest score mean higher by 13.79 than the below-average mathematical ability students taught by the conventional approach as shown in Table 3. The F-ratio for this group combination is 32.014 ($p<.01$), indicating that the difference in the adjusted posttest score means of the students with above-average mathematical ability taught by the practical work approach and those with below-average mathematical ability taught by the conventional approach is highly significant.As expected, the students with above-average mathematical ability taught by the practical work approach performed significantly higher than those with below-average mathematical ability taught by the conventional approach.

Furthermore, the slight difference in the adjusted posttest score means of the below-average students in the experimental group and above-average students in the control group of 0.49 as shown by Sheffe test in Table 12 reveals that the F-ratio for the two groups of .0404 ($p>.05$) signifies no significant difference between the adjusted posttest score means of the below-average students in the experimental group and above-average students in the control group. This implies that the students with below-average mathematical ability in the experimental group performed equally well with those with above-average mathematical ability in the control group.

Moreover, the difference between the posttest score means of the below-average students in the experimental and in the control groups of 6.87, in favor of the experimental group was shown to be highly significant as evidenced by the F-ratio of 7.94 ($p<.01$). Hence, the below -average mathematical ability students in the experimental group performed significantly higher in Graph theory than those in the control group.

As confirmed in Table 3, the below-average mathematical ability students benefited more from the practical work approach than the above-average mathematical ability students as confirmed by the significant adjusted posttest score mean difference of 6.87 against that of the above-average which is 6.4.

Overall, the students taught by the practical work approach performed better than those taught by the conventional approach as evidenced by the significant differences in the adjusted means.

Teaching Approach and Manipulative Skills

The differences between the performances in Graph Theory of the students with high and low manipulative skills after their exposure to the two teaching approaches were analyzed by employing ANCOVA, using the school ability as covariate as displayed in the table below.

Table 5 Summary of the two-factor analysis of covariance of the performance of the students with respect to manipulative skills and teaching approach

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Sources of Variation	Adjusted Sum of Squares	Df	Adjusted Mean Squares	F-ratio	p-value
Factor A (Teaching Approach)	102.86	1	102.86	4.36	.031
Factor B (Manipulative Skills)	100.4	1	100.4	4.25	.036
A x B (Interaction)	2.57	1	2.57	0.1089	.678
Error	991.01	30	23.59		

$\alpha=0.05$

The performances of the low and high manipulative skill students had F-ratio of 4.25 ($p<.05$) **which shows that** there is an evidence of significant difference between the performances of the students with low and high manipulative skills. This means that the students who had manipulative skills performed better in the posttest than those who had low manipulative skills.

The interaction between teaching approach and manipulative skills produced a F-ratio of 0.1089 ($p> .05$) indicating no significant interaction between teaching approach and manipulative skills. Thus, teaching approach did not vary with the different manipulative skill groups. The effect of any of the two teaching approaches was the same for the different manipulative skills groups. Further, it implies that no method was significantly more suitable in enhancing the performance of the students grouped as high and low manipulative skills, that is, none of the two methods was significantly more compatible with a particular group.

Hence, it is unnecessary to compute the adjusted posttest score means of the different manipulative skill levels since no particular combination of approach and grouping produced a significantly better performance in Graph Theory.

5 CONCLUSION

The following conclusions were deduced based on the findings of the study:

The BS Mathematics students enrolled in Graph theory possess the necessary school ability, mathematical ability, and manipulative skills.

The BS Mathematics students who possess the skills of mathematical reasoning and critical thinking have better performance in Graph Theory.

Furthermore, the BS Mathematics students with high manipulative skills have better performance in Graph Theory than those with low manipulative skills.

The practical work approach is significantly more effective than the conventional approach in teaching Graph theory.

The performance of the BS Mathematics students in Graph Theory whether they are exposed to practical work approach or conventional approach varies with the level of mathematical ability. The practical work approach is more effective to the below-average mathematical ability students than to the above-average mathematical ability students.

The performance of the BS Mathematics students in Graph Theory whether they are exposed to practical work approach or conventional approach does not vary with the level of manipulative skills. The high and low manipulative students exposed to the practical work approach performed equally well.

6 RECOMMENDATIONS

The following recommendations are offered based on the conclusions drawn: a) practical approach should be adopted by teachers to improve the students' performance in Graph Theory. Training programs regarding the use of practical work approach in mathematics instruction should be conducted by the school as part of the faculty development program; 2) since the use of school ability as covariate was shown to be effective in manifesting significant differences in performances, it is recommended that it should be the basis for grouping of students; 3) further study on the effects of practical work approach as strategy in other mathematics subjects using pretest-posttest experimental design and considering other factors like grade-point average (GPA) as covariate should be designed and undertaken.

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