What does Graduate Researches Tell about Mathematics Teaching Pedagogies? A Meta-analysis Study

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Abstract

This research aimed to look for the effectiveness of the devised mathematics teaching pedagogies in the different State Universities and Colleges (SUCs) in Region I from 2007 to 2016 through a meta-analysis. The following are the findings of the study. Most of the selected researches were written in the years 2013-2014. The researcher found out that the common pedagogies in teaching mathematics which were subjected to analyses were the Classroom Voting Approach, Collaborative and Cooperative Teaching Strategies. It was also found out that these interventions were effective in teaching Mathematics.

Keywords: *Cohen's d, characteristics, classroom-voting approach, collaborative and cooperative approach, effectiveness, graduate mathematics theses.*

Background of the Study

Pedagogical knowledge as one of the attributes of professional teachers is a very important aspect in teaching and learning process because it talks about the way how they will teach their lessons. Often, teachers design new approaches, strategies, methodologies and techniques through research studies to improve learning.

Research help teachers understand what approaches in teaching works and how these works. It should be future-oriented and designed to benefit learners rather than the researchers themselves. Policy makers understand what the short and long term implications are, and provide a justification and rationale for making judgment and actions.

On one side, in the Philippines, many studies conducted focus on experimental studies talking about classroom interventions which aim to improve quality of instruction. In this case, researchers usually devise and construct specific teaching technique, approach or strategy in teaching the subject. These constructed teaching interventions are usually tested for its effectiveness.

Meanwhile, meta-analysis is a process of reviewing researches and considered as a quantitative study wherein a set of statistical procedures is used to summarize and synthesize the results of a number of independently conducted research studies. If done well, it can be very valuable to a researcher because it provides an extensive bibliography of existing research on a topic while also providing a combined analysis of the results of a number of studies.

In the meta-analysis study conducted by Johnson et al. (2000), they pointed out that cooperative learning is one of the most widespread and fruitful areas of theory, research, and practice in education. An extensive search found 164 studies investigating eight cooperative learning methods. The studies yielded 194 independent effect sizes representing academic achievement. All eight cooperative learning methods had significant positive impact on student achievement. When the impact of cooperative learning was compared with competitive learning, Learning Together (LT) promoted the greatest effect, followed by Academic Controversy (AC), Student-Team-Achievement-Divisions (STAD), Teams-Games Tournaments (TGT), Group Investigation (GI), Jigsaw, Teams-Assisted-Individualization (TAI), and finally Cooperative

Integrated Reading and Composition (CIRC). When the impact of cooperative lessons was compared with individualistic learning, LT promotes the greatest effect, followed by AC, GI, TGT, TAI, STAD, Jigsaw and CIRC. The consistency of the results and the diversity of the cooperative learning methods provide strong validation for its effectiveness.

The study conducted by Chuanchai (1989) was to synthesized the findings of studies comparing the academic achievement of subjects taught by individualized instruction and those taught by the conventional method, using Glass' meta-analytic technique. Teaching effectiveness was measured in terms of effect size, a standardized difference between the individualized and the lecture classes.

The sample of this study included 124 primary studies conducted in Thai schools during the period 1963 to 1987. A research summary form was used to code the research study according to its substantive characteristics and its methodological characteristics. Then the effect sizes were calculated.

The meta-analysis study on effectiveness of teaching and learning with technology on student outcomes which was conducted by Waxman et al. (2003) revealed that teaching and learning with technology has a small, positive and significant (at 0.05 level) effect on student outcome when compared to the traditional instruction.

Another study was conducted by Horak (1984). Where he investigated the effects of individualized instruction on Mathematics achievement at the elementary and secondary school levels. The meta-analysis technique developed by Glass was applied to the same sample of studies used by Schoen in his previous voting-method analysis of individualization. The analysis of 129 effect sizes revealed important trends for the use of self-paced modular instruction in mathematics.

The aforementioned studies conducted tell us that conducting a meta-analytic research is beneficial for us educators because we do a thorough research review on the literatures. The main focus of this type of study is to give a summary and synthesis about the conducted theses and dissertations of graduate studies along mathematics education of SUCs in Region I. It will further identify areas of concerns that are over studied and what to be focused in conducting future researches. Hence, this research is very useful especially researchers in promoting new knowledge and information about mathematics education.

Objectives of the Study

This study analysed completed graduate mathematics education researches in State Universities and Colleges (SUCs) in Region I. Specifically, the researcher determine the effectiveness of mathematics teaching pedagogies in SUCs Region I through a meta-analysis study. The researcher determined the effect sizes (Cohen's d) of the commonly identified researches along mathematics teaching pedagogies.

Methodology

The researcher made used of the descriptive-quantitative method of research to systematically review and analyse the completed theses and dissertations in mathematics education from the SUCs in Region I offering graduate education programs.

The descriptive method of research was used in the study since it involves gathering information by going over and examining completed researches in the graduate level. It also provides an accurate description or picture of the status or characteristics of the researches conducted (Burke, et al. 1941).

It is also quantitative research because it focuses on testing theories and hypotheses using quantitative data to see if they are confirmed or not (Burke, et al. 1941). It also involves several statistical procedures in reviewing and analyzing the completed researches, particularly it used the meta-analysis procedures.

Out of 310 completed researches in the region, only thirteen (13) completed theses were reviewed because these were the only researches conducted focusing on the effectiveness of mathematics teaching pedagogies. However, only six (6) underwent met-analyses.

The completed researches were taken from all graduate studies libraries of the state universities and colleges in Region I (Table 1).

Table 1
Distribution of Researches along the Three Classifications of Mathematics Teaching Pedagogies

Major areas of concern included in the study	**n**
a. Classroom-Voting Approach	2
b. Collaborative and Cooperative Approach	4
c. Others	7
Total	13

To organize the meta-analysis procedure, the researcher identified the unit of analysis. The unit of analysis of the study were the completed theses of graduate mathematics education of SUCs in Region I. After which, the researcher retrieved the lists of the available studies considering proper procedures and ethics. The flow of the meta-analysis is presented below.

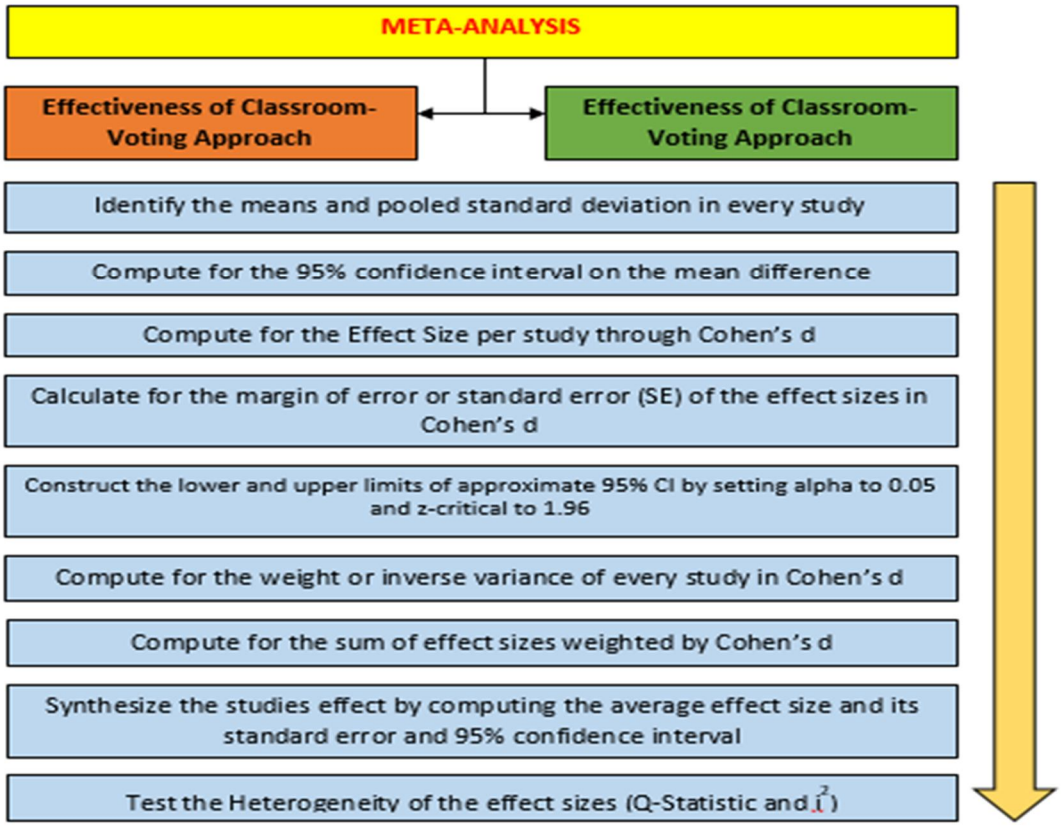

Figure 1. *Flow of the Meta-analysis*

Moreover, the results were extracted, coded and recorded through the use of a constructed Research Summary Form.

In the gathering of information, the included researches were classified according to the areas of concerns relevant to the effectiveness of mathematics teaching pedagogies set by the researcher.

The researcher characterized the included researches as to year when the research was conducted, educational level of the subjects, locale where the research was conducted, type of school where the subjects were taken, research design used, research instrument/s used, and number of subjects used.

Findings of the Study

1. Characteristics of the selected mathematics education researches along effectiveness of mathematics teaching pedagogies

Table 2 revealed the characteristics of the graduate mathematics education researches along effectiveness of mathematics teaching pedagogies which are included in the meta-analysis study.

Table 2
Characteristics of the Selected Studies on Effectiveness of Mathematics Teaching Pedagogies

Characteristics	f	%
	n=13	100
Year when the research was conducted		
2007-2008	2	15.38
2009-2010	2	15.38
2011-2012	1	7.69
2013-2014	5	38.46
2015-2016	3	23.08
Educational level of the subjects		
Elementary	1	7.69
Secondary	10	76.92
Tertiary	2	15.38
Locale where the research was conducted		
Ilocos Norte	-	-
Ilocos Sur	6	46.18
La Union	6	46.18
Pangasinan	1	7.69
Type of school where the subjects were taken		
Public	8	61.54
Private	5	38.46
Research design		
Experimental only	12	92.31
Experimental coupled with correlation	1	7.69
Research instrument		
Constructed test instruments only	10	76.92
Constructed test instruments with personal information sheet	3	23.08
Number of respondents		
18-35	3	23.08
36-53	2	15.38
54-71	3	23.08
72-89	3	23.08
90-107	1	7.69
108-125	1	7.69

The table shows that, SUCs in the region produced 5 or 38.46% graduate mathematics education researches about the effectiveness of teaching pedagogies from 2013 to 2014.

It is important to note that only one or 7.69 percent research study was conducted during the years 2011-2012.

Moreover, from 2007 to 2010 different SUCs in the region produced about four or 30.76 percent graduate theses and dissertations in mathematics education.

Recent studies (2015-2016) which are three or 23.08% are focused on effectiveness of teaching approaches, strategies, methodologies and techniques.

The findings imply that only few researches about effectiveness of teaching pedagogies in mathematics were produced from 2007-2016.

As seen on the table, great majority of the identified researches on the effectiveness of teaching pedagogies tested the secondary students while only one or 7.69 percent used elementary pupils as the respondents and two or 15.38 percent used the college students.

This implies that researchers of this set of studies were more interested in studying the effectiveness of teaching interventions to the secondary students. This may be attributed to the fact that students in the secondary level need a lot of teaching interventions in learning mathematics due to their difficulty in the subjects, and diversity of learners.

2. Mean Difference for the researches along effectiveness of Mathematics teaching approaches, strategies, methodologies and technique

Table 3 shows the measured 95 percent Confidence Interval (95% CI) of the mean differences within the identified researches along effectiveness of teaching approaches, strategies, methodologies and techniques in teaching mathematics.

As observed from the table, all the identified studies on effectiveness of teaching approaches, strategies, methodologies and techniques in teaching mathematics showed to have a positive mean difference which means that the overall mean scores of the control groups used by the researchers are smaller than the mean scores of the treatment group.

Table 3
Mean Difference within the Identified Researches along Effectiveness of Teaching Approaches, Strategies, Methodologies and Techniques in Mathematics

Study Code	Mean Difference	95% Confidence Interval (CI)	Pooled Variance (s^2_p)	Pooled sd (s_p)
T36	18.63	(15.07 , 22.19)	45.77	6.77
T37	5.5	(0.92 , 10.08)	51.09	7.15
T38	9.2	(7.13 , 11.27)	7.67	2.77
T39	2.73	(0.64 , 4.82)	25	5
T40	4.45	(2.74 , 6.16)	16.37	4.05
T41	4.73	(3.46 , 5.10)	10.59	3.25
T42	1.6	(-1.57 , 4.77)	17.94	4.24
T43	6.3	(2.80 , 9.79)	61.69	7.85
T44	5.33	(3.84 , 6.82)	8.28	2.88
T45	11.03	(9.28 , 12.78)	12.73	3.57
T46	7.25	(4.15 , 10.35)	13.44	3.67
T47	3.41	(0.07 , 6.77)	15.53	3.94
T48	2.17	(0.55 , 3.79)	13.25	3.64

Meanwhile, the study T36 shows to have the highest mean difference of 18.63 with a 95 percent CI (15.07 , 22.19) while T42 has the least mean difference of 1.6 with a 95 percent CI of -1.57 to 4.77. This could imply that the sample mean difference derived from the study T36 lies between 15.07 and 22.19. While the calculated mean difference derived from the study T42 lies between -1.57 and 4.77. Going deeper on the 95 percent CI, T37 shows to have the widest range of confidence interval while T41 displays most narrowed range of 95 percent CI of 1.64. Moreover, it is noteworthy that the study T42 exceed 0 in the lower bound of the 95 percent CI. Lastly, when the variances and standard deviations of the studies were pooled, data revealed that the study T43 has the highest $\left(s_p^2 = 61.59 \; and \; s_p = 7.85\right)$ while T38 presents to be the least $\left(s_p^2 = 7.67 \; and \; s_p = 2.77\right)$.

3. Effect Size Indices (Cohen's d) per Study

Table 4 shows the computed effect size in Cohen's d index, standard error (SE) and 95% Confidence Interval.

The table shows that T36 tested the effectiveness of Classroom Voting Approach and shows to have an effect size of 2.75 which indicate that the score of the average participant/s of the author in her experimental group is about 2.75 standard deviations above the average person in her control group. The SE of the effect size index is 0.37 which means that 0.37 reliable the effect size as reflection to the actual population effect size. Based on the data, the researcher has shown a 95 percent confidence that the true effect size lies between 2.03 and 3.47.

Moreover, T37 displays a 0.75 effect size index which implies that the average person in the experimental group would score higher than 77.5 percent of the control group. The SE of T37 study shows to have 0.33 which means that the accuracy of the effect size to reflect on the actual population effect size of 0.33. Lastly, the author reveals that he is 95 percent confident that the effect lies between 0.12 and 1.38.

Table 4
Effect Sizes (Cohen's d) within the Researches along
Effectiveness of Teaching Pedagogies

Study Name Code	Effect Size	Standard Error (SE)	95% Confidence Interval for the Effect Sizes (95% CI)	
	Cohen's d		Lower	Upper
T36	2.75	0.37	2.03	3.47
T37	0.77	0.33	0.12	1.38
T38	3.32	0.56	2.16	4.31
T39	0.55	0.21	0.13	0.97
T40	1.1	0.23	0.65	1.55
T41	1.45	0.22	1.02	1.89
T42	0.38	0.37	-0.34	1.07
T43	0.74	0.23	0.29	1.2
T44	1.85	0.31	1.25	2.46
T45	3.09	0.36	2.38	3.81
T46	1.98	0.498	0.97	2.85
T47	0.87	0.43	0.03	1.64
T48	0.596	0.23	0.15	1.04

It is observed from the table that among the effect size estimates presented, T38 study has the highest effect size index of 3.32 which implies that the score of the average participants/s in experimental group is 3.32 standard deviations above the average person in the control group. It is also reveals that the effect size index lies between 2.16 and 4.31 which is reflected from 95% CI.

From the study T39, it shows that the score of the average person in his experimental group is about 0.55 in the d-index which has 0.21 mean accuracy to represent the population parameter. In addition, the effect size has a 95% CI of 0.13 to 0.79.

Meanwhile, T40 which examined the effectiveness of Activity-Oriented Instruction shows to have an ES estimates of 1.10 which indicates that the score of the average participant in the experimental group is 1.10 standard deviations above the average person in the control group. The SE of the ES is 0.23 which means that 0.23 reliable the ES estimate as reflection of the true effect size. Based on the data, the researcher has shown a 95% confidence that the true effect size lies between 0.65 and 1.55.

T41 showed to have a large ES when he examined the effectiveness of Numbered Heads Together Strategy in teaching mathematics as reflected from the computed ES of 1.45 in d-index and has a reliability of about 0.22 as representation of the actual population true effect size value. Furthermore, the study ES showed a 95% CI of 1.02-1.89.

T42 shows to have the least ES indices of d= 0.38 which means that the score of the average person in her experimental group is 0.38 standard deviation above the average person in her control group. It also reveals that the ES index lies between -0.34 to 1.07 as seen from the computed 95% CI.

In the study of T43 reveals to have a moderately higher ES estimate with a margin of error of 0.023. Also, the 95% CI has only bounded with a difference of 0.09.

A very large ES is observed in the study of T44 when he examined the effectiveness of Cooperative Learning Approach with an accuracy to represent the true effect of the population parameter of 0.31 in d-index and bounded with a 95% CI of 1.25 to 2.46.

T45 displays a very large ES index and shows to have 0.36 accuracy of the ES estimate to reflect on the actual population ES. Lastly, the author reveals that she was 95% confident that the true effect lies between 2.38 and 3.81.

The ES estimate in the study of T46 reveals to have ES of 1.98 which indicates that the score of the average participant in her experimental group is about 1.98 standard deviations above the average person in her control group. She showed 95% confidence that the true effect lies from the computed CI which ranges from 0.97 to 2.85.

Lastly, from the work of T48, it can be seen that the score of the average person in his experimental group is about 0.59 which has 0.23 mean accuracy to represent the actual population parameter on ES. In addition, the ES has a 95% CI of 0.15 to 1.04.

a. Meta-analysis for Classroom-Voting Approach

Table 5 presents the meta-analysis of studies that evaluated the effectiveness of the Classroom-Voting Approach in teaching mathematics.

As shown from the table, there were only two conducted researches that examined the effectiveness of Classroom-Voting Approach in teaching mathematics. On T39, displays a lesser SMD while T36 has a higher value of SMD. It terms of 95% CI of the two studies, T39 showed to have smaller confidence limits which ranges from -.42 to 0.97 while T36 displays a larger confidence limits of -0.72 to 3.47. It can be gleaned from the table that the 153 respondents demonstrate effectiveness of the Classroom Voting Approach as manifested from the positive effect of the average ES of 0.25 across the distribution of the two studies and having a 95% CI of 0.19 to 0.32 considered to be narrow as compared to 95% CI of the individual study effect size.

In addition, the ES of 0.03 is small which indicates that the total sample used is large. It further implies that the sample mean is an accurate reflection of the actual population mean.

Meanwhile, it is noteworthy that the statistical heterogeneity was identified between studies as manifested in the observed value of Q which is 48.40 which is greater than the expected value of 1. This implies that the observed variation is greater than what was expected based on the study error. In addition, the table also presents the excess of variation across studies of 45.40. This means that the p-value moves towards 0 as reflected on the computed p-value of 0.000 which is much lesser than the set probability level of 0.05 which indicates that the studies do not share a common effect size which means that the true effects vary.

Table 5
Meta-analysis on Effectiveness of Classroom-Voting Approach

Study Name Code	No. of Respondents	Effect Size	Standard Error	95% Confidence Interval of Effect Sizes		Inverse Variance Weight (IVW)	Weight %	Effect Sizes Weighted by IVW
		Cohen's d	Cohen's d	Lower	Upper			
T36	58	2.75	0.37	-0.72	3.47	7.45	25.45	2.73
T39	95	0.55	0.54	-0.42	0.97	21.82	74.55	4.67
Total	153					29.83	100.00	7.40
Synthesis		0.25	0.03	0.19	0.32			
$z_{-critical}$	*1.96*							
Heterogeneity								
Q	48.40*							
df	1							
Q-df	45.4							
p-value	0.000							
I^2	93.81% (High)							

*Significant at 0.05 level

In the long run, i^2 or the ratio of true heterogeneity to total variation in observed effects was also displayed due to small number of studies. It can be seen that i^2 is high as reflected from the computed value of 93.81% which indicates that the observed variation is real.

b. Meta-analysis for Collaborative and Cooperative Strategies

Table 6 displays the result of the meta-analysis on the effectiveness of Collaborative and Cooperative Strategies (CCS) in teaching mathematics.

It can be seen from the table that there were four studies that were included in the meta-analysis on effectiveness of CCS with a total sample of 210 and inverse variance weight of 47.12.

The table says that on average, the CCS intervention caused more than a quarter (0.29) of standard deviation improvement in learning mathematics. It further implies that the 210 respondents demonstrated effectiveness of the CCS when compared to the traditional way of teaching mathematics. Meanwhile, the computed average effect size is shown to have a low standard error of 0.02 which means that there have been a relative spread in the sampling distribution. It further tells that the sample mean is an accurate reflection of the actual population mean. Moreover, the calculated 95% confidence interval ranges from 0.25 to 0.33 which indicates a narrow confidence limits as compared to the individual 95% CIs of the four studies.

In the meantime, the observed weighted sum of squares (WSS) of 29.88 is greater than the expected WSS of three tells that the observed variation is greater than what is expected based on within-study error. In addition, the computed p-value (0.000) is much lesser than the set probability level of 0.05.

This signifies that the studies do not share a common ES which means that the true effects vary in the studies.

To end, the ratio of true heterogeneity to total variation in observed effects (i^2) was also exhibited due to small number of studies. It can be seen that i^2 is high as reflected on the computed value of 89.96%. This manifests that the observed variation is real.

Table 6
Meta-analysis on Effectiveness of Collaborative and Cooperative Strategies

Study Name Code	No. of Respondents	Effect Size	Standard Error (SE)	95% Confidence Interval of Effect Sizes		Inverse Variance Weight (IVW)	Weight %	Effect Sizes Weighted by IVW
		Cohen's d	Cohen's d	Lower	Upper			
T37	40	0.77	0.33	0.12	1.38	9.69	20.57	3.11
T42	30	0.38	0.37	-0.33	1.07	7.78	16.52	2.79
T44	60	1.85	0.31	1.25	2.46	10.498	22.28	3.24
T48	80	0.596	0.23	0.15	1.04	19.15	40.64	4.38
Total	210					47.12	100	13.52
Synthesis		0.29	0.02	0.25	0.33			
z-critical	*1.96*							
Heterogeneity								
Q	29.88*							
df	3							
Q-df	26.88							
p-value	0.000							
I^2	89.96% (High)							

*Significant at 0.05 level

The findings go parallel with the findings of Johnson et al., (2000) that cooperative learning methods were found to have a positive impact on the achievement of students in school and concluded that all the cooperative learning methods were effective to improve students' achievement.

Conclusions

Based on the findings of the study, the researcher concluded that Classroom Voting Approach and Collaborative and Cooperative Approach are effective pedagogies in teaching mathematics.

Recommendations

In the light of the findings and conclusions, the researcher recommend that (1) all interventions studied in the meta-analysis should be used in teaching mathematics subjects. (2) Future research study on meta-analysis dealing with effectiveness of teaching interventions with a great number of included studies should be conducted to check if the excess of dispersion on the average effect sizes will decrease.

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