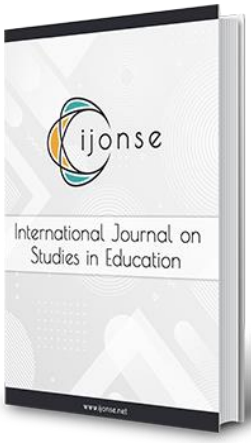

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A Meta-Analysis of the Effectiveness of Video-Based Instruction on Students' Academic Performance in Science and Mathematics

Christian H. Dipon
Magallanes National Vocational High School, Philippines

Ryan V. Dio
Graduate School, Sorsogon State University, Philippines

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Christian H. Dipon, Ryan V. Dio

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Abstract

Video-based instruction has been a necessary part of teaching and learning in 21st-century education. However, as video-based instruction continues to evolve, evaluating its effectiveness in improving students' performance in various disciplines is deemed necessary. This study analyzed empirical research on the effectiveness of video-based instruction in improving students' performance in Science and Mathematics. The study filtered 4,874 research articles gathered using various meta-search engines. Using the inclusion and exclusion criteria set, only 14 research articles conducted from 2019 to 2023 qualified for this meta-analysis with a classic fail-safe N analysis value of 2627, $p<0.001$, obtaining non-susceptible to publication bias. The Jamovi software version 2.4 was used in determining the effect size (Hedge's g), the forest plot, and the funnel plot analysis of the gathered data. The collected studies showed that video-based instructions were utilized in the primary (n=355), secondary (n=611), and tertiary (n=72) level education in various topics of Science and Mathematics subjects. The analysis of the k=14 empirical studies obtained from 2019 to 2023 denotes a large-positive effect of video-based instruction in Science (k=7), g = 2.28, and Mathematics (k=7), g=1.79, subjects with an average effect size of g=2.03 (95% CI: 1.2991 to 2.7657).

Introduction

Technological innovations in education promote improvements in the classroom experience and academic performance of students. It has been a necessary part of the 21st-century learning. Mynbayeva, Sadvakassova, and Akshalova (2018) stressed that conventional educational practices are not enough to manage how learners to learn nowadays. Teachers need to innovate their pedagogical practices to help today's generation of students better learn the subject (Iwuanyanwu, 2019). Therefore, teachers must find meaningful ways to incorporate technology into their classrooms.

The use of technology through video-based instruction has been a necessary part of teaching and learning. Instructional videos have been proven effective in enhancing students' academic performance. YouTube (YT) videos, as an example, have already been employed by teachers as instructional support in teaching. These videos help students who are having difficulty in understanding abstract science concepts (Astriyani & Fajriani, 2020)

and motivate students to learn and improve their critical thinking (June, Yaacob & Kheng, 2014). In addition, the sounds, colors, and graphics make the videos ideal for all types of learning styles among students (Vural, 2013). The cognitive theory of multimedia learning states that integrating words, pictures, and sounds through video promotes deep learning compared to words alone (Rudolph, 2017), thus, proving instructional videos as an effective tool for learning across the curriculum.

Science and Mathematics, a particular field of study in the curriculum, are considered the hardest subjects for students. Science lessons are never interesting for many students, and they find the process difficult making their achievements in this discipline relatively poor (Salviejo, Aranes & Espinosa, 2014). Cayuna (2017), considered Physics the least learned subject in all areas of science. It has many concepts that students have difficulty learning (Achor, 2019). Similarly, students find mathematics difficult for many reasons such as poor conceptual comprehension, memorization, and problem-solving (Gafoor & Kurukkan, 2015). Further, the negative perception of students towards the subject (Kunwar, 2020). To address this, teachers utilized various instructional tools such as instructional videos to enhance the performance and interests of students in this field particularly those who have difficulty learning the subject.

Instructional videos have been very helpful during the implementation of blended learning and modular distance approach during the COVID-19 pandemic. According to Jackman and Roberts (2014), using videos as part of an integrated learning strategy or a Learning Delivery Modality (LDM) improves student learning. Different video-based instructions such as video lessons, animation videos, video clips, etc. were used as supplementary tools in teaching particularly in Science and Mathematics education. This justifies the effectiveness of instructional videos in various LDMs especially during the pandemic. However, as instructional video utilization in education continues to evolve, the need to evaluate its effectiveness in improving students' performance is deemed necessary. With this rationale, this meta-analysis evaluates empirical research relative to the effectiveness of video-based instruction in improving students' academic performance specifically in Science and Mathematics. This aimed to answer the following questions:

1. What is the frequency distribution of students' grade levels and subject matter on the collected and screened articles about video-based instructions in Science and Mathematics?
2. How effective the use of video-based instruction is in improving students' academic performance in Science and Mathematics?
3. What does the meta-analysis forest plot and funnel plot show about the effect sizes of video-based instruction on students' performance in Science and Mathematics?
4. What does the classic fail-safe N analysis suggest regarding the robustness of the observed effects of video-based instruction on students' performance in science and mathematics?
5. Is there a significant difference between the effect sizes in Science and Mathematics relative to students' academic performance using video-based instruction?

This meta-analysis aims to give significant insights into the effects of video-related instructions on students' performance in Science and Mathematics. In accordance, this may help teachers and policymakers in planning appropriate instructional tools that they may use to improve the performance of students across the curriculum.

Further, the findings may contribute new knowledge and encourage innovative pedagogical practices in all fields of education. In conducting this meta-analysis, relevant studies were systematically reviewed, focusing on various research that investigated the effects of all video-related instructions as a primary tool in teaching Science and Mathematics. The researchers carefully analyzed the selected research and identified possible areas for further investigation.

Methods

This study utilized findings from empirical research that investigated the effects of video-based instruction on students' performance in Science and Mathematics. This study's approach includes the research design, the study search procedure, the inclusion and exclusion criteria, the coding procedures, and the effect size calculation.

Research Design

This study made use of meta-analysis research design to determine the effectiveness of video-based instruction in improving students' academic performance in Science and Mathematics. Meta-analysis is a quantitative research method where findings from previous studies are systematically synthesized. It is a systematic review of literature where numerous existing relevant studies are identified, evaluated, and interpreted by the researchers based on their specified research question and topic area of interest (Kitchenham, 2004). Moreover, meta-analysis is done by analyzing primary studies' quantitative data. The lists of research articles needed for the meta-analysis were collected using the Publish or Perish software (Harzing, 2007). Other meta-search engines such as Google and Google Scholar were also used. Results were evaluated, synthesized, and interpreted by the researchers.

Study Search Procedure

This meta-analysis consists of three stages, the inclusion and exclusion stage, the data gathering stage, and the data analysis stage. The first stage includes the setting of the criteria for inclusion and exclusion based on the research articles' publication, design, and quantitative results. The second stage includes the data gathering where journal articles needed for the meta-analysis were gathered through various meta-search engines. The search was limited to 2019 to 2023 using the descriptors: *effectiveness video-based instruction, instructional video, supplemental video, video lessons, and video lecture* in Science and Mathematics. The articles obtained were divided according to discipline, grade level, and subject matter. The third criterion, the data analysis stage, determines the effect sizes of the reviewed articles. The outcome measure was identified using the standardized mean difference (Hedge's g).

Inclusion and Exclusion Criteria

This meta-analysis evaluated 14 quantitative research articles that focused on video-based instruction's effectiveness in improving students' performance in Science and Mathematics. The articles examined in this study were published in 2019-2023. The inclusion criteria were set to select journal articles, to wit: (1) published in a

journal from 2019 to 2023; (2) focused on any video-related instructional tools (title, abstract, and content); (3) used students' performance as dependent variable; (4) utilized experimental or quasi-experimental research design; (5) focused on Science or Mathematics education; and (6) provided enough quantitative data for effect size calculations. These inclusion criteria were used in filtering journal articles for this meta-analysis. The study used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) search strategy (2020) diagram as shown in Figure 1.

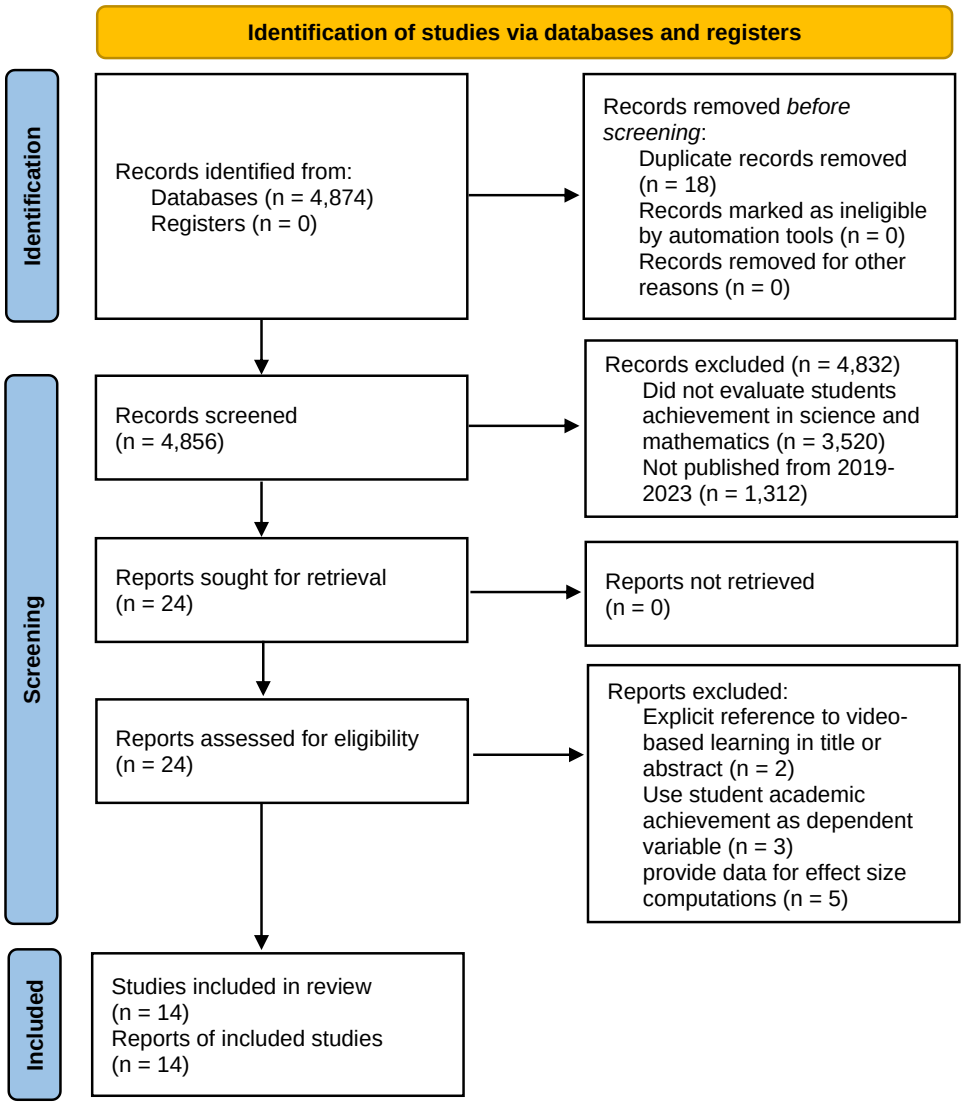

Figure 1. PRISMA Search Diagram for Video-based Instruction in Science and Mathematics

This meta-analysis filtered 4,874 research articles related to video-based instruction but only k=14 of these articles qualified; k=7 articles in science and k=7 articles in mathematics. The qualified articles were conducted in the Philippines (k=7), Nigeria (k=3), India (k=1), Turkey (k=1), Indonesia (k=1), and Ghana (k=1). The limited number of qualified articles was due to the inclusion criteria set for this study. Most of the papers reviewed lacked the essential statistical data needed for the analysis.

Coding Procedures

To ensure a correct and reliable coding process, coding procedures were used. These include; (a) author/s name and publication year; (b) subject matter; (c) grade level; (d) subject matter (Science and Mathematics); (e) country; (f) study design; and (g) descriptive data of the control and experimental groups.

Effect Size Calculation

This meta-analysis utilized Hedge's g in computing for the effect sizes. This compares the means of two groups of data using the standardized mean difference (Vallespin & Prudente, 2023). Hedges and Olkin (1985) and Glen (2016) claimed that Hedge's g is a more accurate tool to use compared to Cohen's *d*, especially with smaller sample numbers (<20). In analyzing the data, Jamovi software (2023) version 2.4 was utilized. Descriptive data of each research article such as sample size, means of the control and experimental groups, and standard deviation were encoded. The software automatically generated the needed statistics, tables, and figures. The overall effect size was determined and a forest and funnel plot to illustrate the publication bias were analyzed and interpreted by the researchers. Data were also clustered to compare the effect sizes between Science and Mathematics. The statistics were tested within 95% confidence interval and alpha value p=0.05 level of significance.

Findings

To explore the effectiveness of video-based instruction on students' academic performance, the gathered data were analyzed and synthesized. This gives the researchers valuable insights into the efficacy of using video-related instructions in Science and Mathematics. The following summarizes the findings of the study.

Frequency distribution of students' grade level and subject matter

Upon analysis, video-based instructions were utilized across grade levels from primary to tertiary education level and were used in various topics in the field of science and mathematics Table 1 reveals the frequency distribution of the students' grade level and subject matter. As shown in Table 1, the study's characteristics were derived from k=14 published journal articles that utilized video-based instruction in teaching Science and Mathematics. The research included 1038 participants; 515 from the experimental groups and 523 from the control groups. One (k=1) of the studies focused on tertiary-level students and had a sample size of 72 participants. Nine (k=9) studies utilized secondary-level students, having a large sample size of 611 students. Four studies focused on primary-level students (k=4), having a sample size of 355 participants.

The subject matters covered various topics in Science and Mathematics education. The data evidently showed that video-based instructions were used in the aforementioned fields of education. The topics explored in the studies for science included Biology, Chemistry, Earth and Space, General Science, and Physics, and for Mathematics, topics included Basic Mathematics, Geometry, Probability and Statistics, and Random Variables. Each topic represents essential concepts and principles in the field of Science and Mathematics. It is evident as well that the

subject of investigation was distributed across the field of Science and Mathematics in all grade levels. This also means that video-based instructions are and can be utilized in any field and any subject matter.

Table 1. Frequency Distribution of Students' Grade Level and Subject Matter

Grade Level		**Frequency**	**Percentage**
Primary Level		4	28.57
Secondary Level		9	64.29
Tertiary Level		1	7.14
Topics			2.41
Science	Biology	2	14.29
	Chemistry	1	7.14
	Earth and Space	2	14.29
	General Science	1	7.14
	Physics	1	7.14
Mathematics	Basic Mathematics	3	21.43
	Geometry	1	7.14
	Probability and Statistics	2	14.29
	Random Variables	1	7.14
Total		14	100.00

Effectiveness of Video-based Instruction in Improving Students' Performance in Science and Mathematics

The average effect size value and heterogeneity statistics of the gathered studies (k=14) were analyzed using the software. Table 2 depicts the general statistics of the study.

Table 2. Overall Effect Size and Heterogeneity Statistics

Random-Effects Model (k = 14)						
	Estimate	**Se**	**Z**	**p**	**CI Lower Bound**	**CI Upper Bound**
Intercept	2.03	0.374	5.43	< .001	1.299	2.766
Tau	**Tau²**	**I²**	**H²**	**Df**	**Q**	**p**
1.361	1.8508 (SE= 0.77)	95.89%	24.328	13.000	217.063	< .001

The computed standardized mean difference was g=2.03 (95% CI: 1.2991 to 2.7657), interpreted as very large, indicating that utilizing video-based instruction in Science and Mathematics is highly effective. The overall result varied substantially from zero ($z = 5.43$, $p < 0.001$). In analyzing the data, random-effects model was used since it shows significant heterogeneity (Borenstein et al., 2021) which means that the data used in this study do not share common effect sizes. This is shown in the Q-test result [$Q(13) = 217.063$, $p < 0.001$, $tau^2 = 1.8508$, $I^2 = 95.89\%$] which shows heterogeneity of the data. The heterogeneity value was calculated using Hedges' estimator (tau^2) (Hedges 1985), Q-test (Cochran 1954), and I^2.

Based on the results, the use of video-based instruction significantly affects students' performance in science and mathematics. This shows that utilizing video-related tools in teaching helps in improving students' academic performance, as shown by the large overall effect size. This suggests the need for educational policymakers and implementers to use video-based instructions to enhance students' learning.

Meta-analysis Forest Plot of the Effect Sizes of Video-Based Instruction on Students' Performance in Science and Mathematics

To show how the effect sizes are distributed, the researchers present the forest plot (Figure 2) and the meta-analysis result (Hedges' g) of the selected studies. All within the 95% confidence interval. This provides context for the analysis of data.

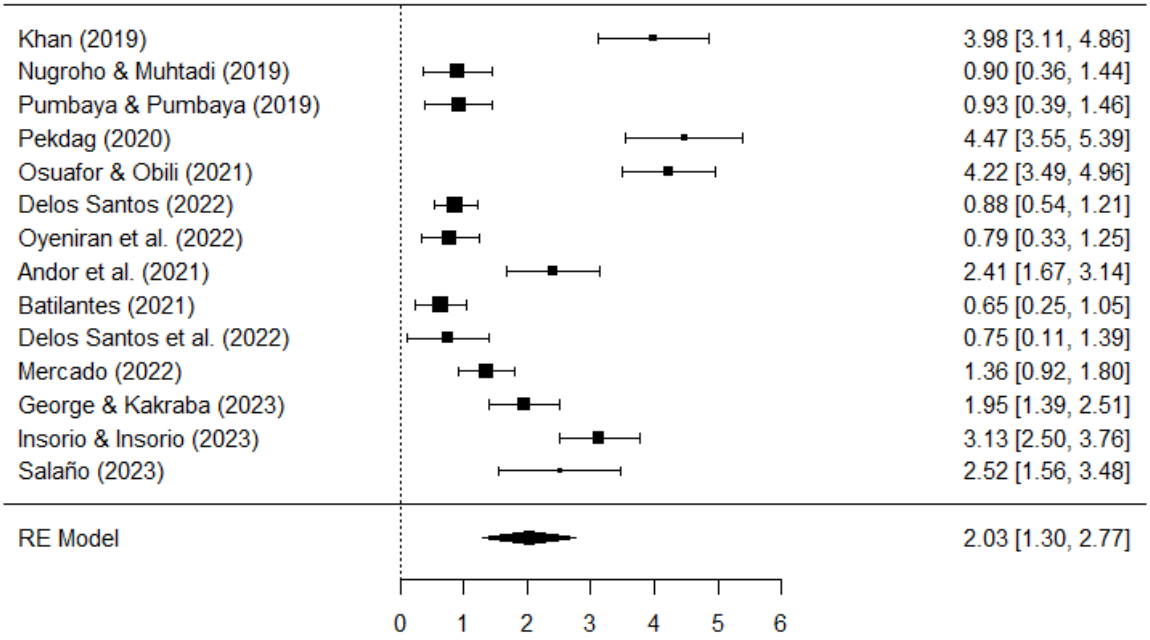

Figure 2. Meta-Analysis Forest Plot of Effect Sizes

This study compared the effect size results of k=14 qualified empirical studies from 2019 to 2023. The computed effect size values (standardized mean differences) were all positive (100%) ranging from 0.65 to 4.47. The general weighted average effect size of g=2.03 (95% CI: 1.2991 to 2.7657) signifies the significantly large and favorable effect size of using video-based instruction on students' performance in Science and Mathematics (Figure 2).

As shown in the plot, some studies significantly contribute to the overall findings of the study. Notably, the studies in the field of Science conducted by Khan (2019), Osuafor & Obili (2021), and Pekdag (2020) with an effect size of 2.98, 4.22, and 4.47 respectively, played a substantial role in shaping the outcomes, as evidenced by their large effect sizes. These provide strong support on the effectiveness of video-based instruction in improving students' academic performance in Science.

To assess whether the data contain outliers that may influence the result of the study, studentized residuals and

Cook's distances were used. Figure 3 shows the funnel plot of the study.

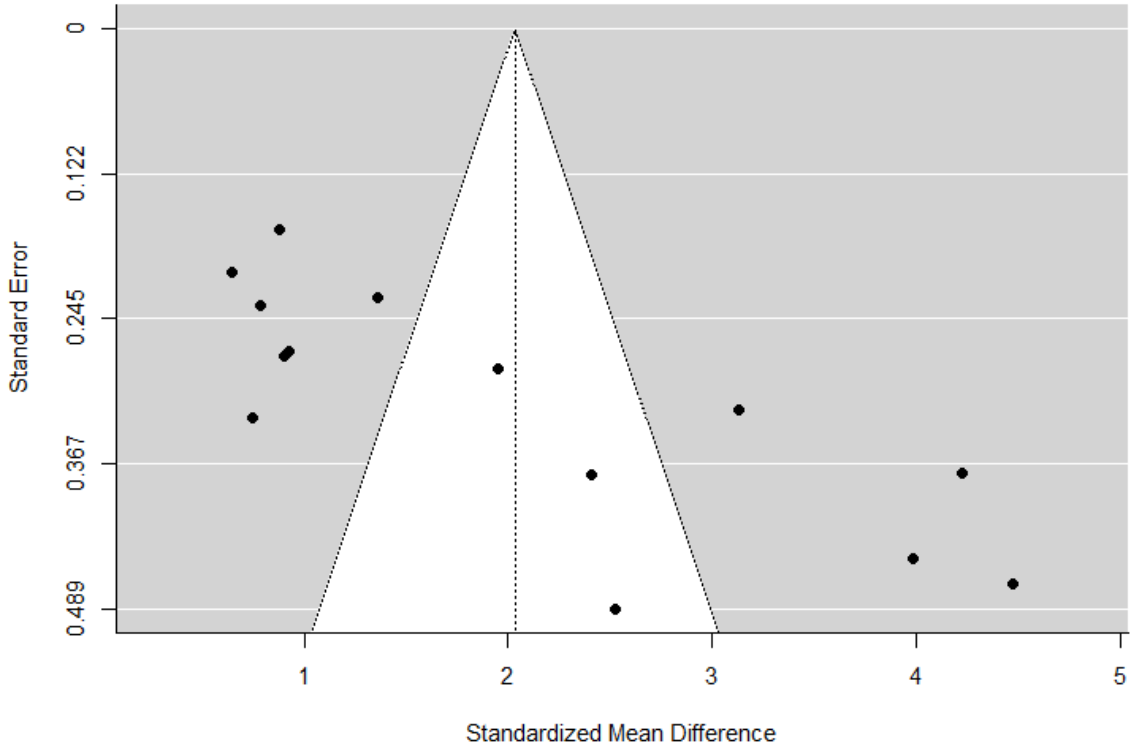

Figure 3. Funnel Plot of Effect Sizes

The funnel plot presents the graph of the computed effect sizes vis-a-vis standard errors. Examining the studentized residuals, the data revealed that no study exceeds the ± 2.9137 value which indicates that there are no outliers identified in the model. Based on Cook's distances, neither of the studies could be regarded as highly significant.

The data also shows potential funnel plot asymmetry which means that the distribution of the effect sizes of the obtained studies is symmetrical as indicated by the rank correlation ($p = 0.0030$) and the regression test ($p < 0.0001$), demonstrating no publication bias. However, as stated by Harbord et al. (2009), funnel plot, in terms of screening for publication bias, is not reliable, particularly in meta-analysis with a limited number of articles.

Classic Fail-Safe N analysis and Publication Bias Assessment of the Observed Effects

A classic fail-safe N analysis using Rosenthal approach was conducted to check the publication bias. This approach is effective when assessing the obtained studies' impact on the findings. The result of the analysis is shown in Table 3. As shown in the result, the effect sizes of the k=14 empirical studies used in this study are sufficient and therefore valid for meta-analysis. The computed p-value ($p<0.05$) implies that the study is not susceptible to publication bias. Thus, no studies are needed to invalidate the stated conclusion. This means that this meta-analysis is robust and is not unduly influenced by unpublished or missing research.

Table 3. Fail-Safe N Analysis and Publication Bias Assessment

Publication Bias Assessment

Test Name	Value	p
Fail-Safe N	2627.000	< .001
Begg and Mazumdar Rank Correlation	0.582	0.003
Egger's Regression	4.364	< .001
Trim and Fill Number of Studies	0.000	.

Note. Fail-safe N Calculation Using the Rosenthal Approach

Significant Difference between the Effect Sizes in Science and Mathematics

To determine the significant difference in effect sizes between Science and Mathematics, the researchers used the Jamovi software version 4.2 to obtain the overall effect size of each discipline. Table 3 provides the summary effect size for Science and Mathematics.

Table 4. Summary Effect Size for Science and Mathematics

Discipline	Article	Effect Size	Summary Effect Size	Category
Science	Khan (2019)	3.98	2.28	Large
	Nugroho & Muhtadi (2019)	0.90		
	Pumbaya & Pumbaya (2019)	0.93		
	Pekdag (2020)	4.47		
	Osuafor & Obili (2021)	4.22		
	Delos Santos (2022)	0.88		
	Oyeniran et al. (2022)	0.79		
Mathematics	Andor et al. (2021)	2.41	1.79	Large
	Batilantes (2021)	0.65		
	Delos Santos et al. (2022)	0.75		
	Mercado (2022)	1.36		
	George & Kakraba (2023)	1.95		
	Insorio & Insorio (2023)	3.13		
	Salaño (2023)	2.52		

As shown in Table 4, three of the largest effect size values were from Science. Notably, Pekdag (2020) for Chemistry, Osuafor & Obili (2021) for General Science, and Khan (2019) for Biology, conducted a study among secondary students, which obtained large effect sizes of 4.47, 4.22, and 3.98, respectively. In Mathematics, the study of Insorio & Insorio (2023) for Basic Mathematics at the secondary level, got the highest effect size value of 3.13. These results only prove that video-based instruction is highly effective when used in secondary-level

education, especially in Science education.

Furthermore, Pumbaya & Pumbaya (2019) (ES=0.93), Nugroho & Muhtadi (2019) (ES=0.90), Delos Santos (2022) (ES=0.88), and Oyeniran et al. (2022) (ES=0.79), in the field of Science shows a very close effect size values. For Mathematics, Andor et al. (2021) (ES=2.41), George & Kakraba (2023) (ES=1.95), and Mercado (2022) (ES=1.36) also show very close values. However, the lowest effect size values were seen in Mathematics. The research conducted by Batilantes (2021) and Delos Santos et al. (2022) along Probability and Statistics both at the secondary level gained an effect size of 0.65 and 0.75 respectively.

Overall, it can be seen that the biggest influence of using video-based instruction is in science education, with an effect magnitude of 2.28 compared to Mathematics with an effect magnitude of 1.79, both in the large category. Seeing the high results summary effect size from the two disciplines, it can be interpreted that video is very influential in the learning process and is also well used to improve student learning outcomes.

Discussion

Video-based instruction has been a necessary part of teaching in the 21st century education. It has proven effective in enhancing students' academic performance. The results of the 14 qualified empirical studies used in this meta-analysis showed that video-based instructions were utilized across grade levels from primary to tertiary education level. They were used as part of the instructional materials, particularly during the discussion of concepts of the lesson. They were also used in various topics in the fields of Science and Mathematics. The study included 1038 samples; 515 in the experimental groups and 523 in the control groups. This demonstrates that video-based instructions may be utilized in any field, in any subject matter at different levels of education.

The findings of the study recommend that utilizing video-based instruction in Science and Mathematics positively affects students' academic performance. This is shown in the large overall effect size of g=2.03 (95% CI: 1.2991 to 2.7657), interpreted as large effect size, proving that video-based instruction is highly effective. Further, the result of the analysis shows significant heterogeneity with observed effect sizes ranging from g=0.65 to g=4.47. This further indicates that despite the differences in effect sizes, video-based instruction has positive (100%) impact to students' learning.

The meta-analysis of the k=14 empirical studies conducted from 2019 to 2023 focused on the fields of Science (k=7) and Mathematics (k=7). The overall effect size of g=2.03 for Science (g=2.28) and Mathematics (g=1.79) denotes a large and positive effect. Pekdag (2020) (ES=4.47), Osuafor & Obili (2021) (ES=2.22), and Khan (2019) (ES=3.98) in the Science group have the largest effect size values. On the contrary, Delos Santos et al. (2022) (ES=0.75) and Batilantes (2021) (ES=0.65) in Mathematics along Probability and Statistics show medium effect sizes. It can be seen that the biggest influence of using video-based instruction is in science education compared to Mathematics though both fall in the same large category. Seeing the high results summary effect size from the two disciplines, it can be interpreted that video is very influential in the learning process and is also well used to improve student learning outcomes for both Science and Mathematics.

In general, the use of video-based instruction significantly affects students' performance in Science and Mathematics. This shows that utilizing video-related tools in teaching enhances students' academic performance, as shown by the large overall effect size.

Conclusion

Based on the result of the meta-analysis, the use of video-based instruction is effective in improving students' academic performance, particularly in the fields of Science and Mathematics. The results of the 14 qualified empirical studies proved that video-based instruction is an effective tool for learning regardless of what grade level, subject matter, and learning modalities it may be implemented. The overall large effect size of 2.03 suggests that video-based instruction can be an effective instructional tool that teachers may use as instructional support in teaching. This instructional tool may further be used in Science and Mathematics education as well as in other fields of education. The educational policy and curriculum makers and classroom implementers may incorporate video-based instructions into the teaching-learning process across different levels of education to improve students' performance. A more robust study may be conducted further to test the effectiveness of video-based instruction in education.

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Author Information

Christian H. Dipon
https://orcid.org/0009-0005-1725-4490
Magallanes National Vocational High School
Binisitahan Del Norte, Magallanes, Sorsogon, 4705
Philippines
Contact e-mail: *christian.dipon@deped.gov.ph*

Ryan V. Dio
https://orcid.org/0000-0002-4170-8828
Graduate School, Sorsogon State University
Sorsogon City, Sorsogon, 4700
Philippines

APPENDIX. List of Research Articles Included in the Meta-analysis

Author/s & Publication Year	Subject Matter	Grade Level	Video-Based Instruction Used	Country	Experimental Group					Control Group				
					Sample Size	Pretest	Standard Deviation	Post Test	Standard Deviation	Sample Size	Pretest	Standard Deviation	Post Test	Standard Deviation
Pekdag (2020)	Chemistry	Secondary	Video-Based Instruction	Turkey	32	20.30	3.68	83.10	4.60	32	20.90	3.53	65.1	3.24
Khan (2019)	Biology	Secondary	Video-Based Instruction	India	30	3.00	1.96	26.13	2.64	30	3.00	1.94	17.06	1.77
Delos Santos (2022)	Earth and Space	Primary	Instructional Video	Philippines	76	23.13	3.79	39.60	4.72	76	24.60	4.28	35.57	4.42
Osuafor & Obili (2021)	General Science	Secondary	Digital Video	Nigeria	42	22.24	6.45	74.05	10.76	50	21.16	5.4	35.35	7.41
Nugroho & Muhtadi (2019)	Biology	Primary	Video Lessons	Indonesia	29			22.10	5.47	29			16.79	6.11
Oyeniran et al. (2022)	Physics	Secondary	Instructional Video	Nigeria	39	11.37	2.92	34.97	3.89	40	11.58	2.72	31.69	4.34
Pumbaya & Pumbaya (2019)	Earth & Space	Secondary	Video Clips	Philippines	30	16.33	2.76	25.37	2.86	30	14.77	4.76	21.23	5.54

Delos Santos et al. (2022)	Prob & Stat	Secondary	Video Tutorials	Philippines	20	13.85	4.99	17.05	6.99	20	14.25	4.74	12.7	3.97
Salaño (2023)	Random Variables	Secondary	Teacher-Made YT Video	Philippines	15	9.33	1.63	41.53	3.29	15	9.67	1.54	32.93	3.35
Batilantes (2021)	Prob & Stat	Secondary	Video lecture	Philippines	50	5.08	1.77	9.54	2.10	50	5.26	2.05	8.2	2
Insorio & Insorio (2023)	Basic Math	Secondary	Video Lessons	Philippines	43	8.93	2.39	22.70	2.64	43	9.60	2.97	15.15	2.11
George & Kakraba (2023)	Geometry	Tertiary	Video-Aided Instruction	Ghana	37	36.76	7.47	68.92	9.29	35	34.86	7.22	53.71	5.6
Andor et al. (2021)	Arithmetic	Primary	Video-Aided Instruction	Nigeria	24	8.63	1.05	14.25	2.40	25	8.84	1.52	9.48	1.39
Mercado (2022)	Basic Math	Primary	Video Clips	Philippines	48	20.40	3.61	41.44	2.32	48	17.31	5.67	37.08	3.85