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A Proposed Categorization of Meta-Analysis, Their Respective Example Conceptual Frameworks, and Applicable R Packages for Education Research: A Review

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Abstract

The paper has three major objectives. The first objective of the paper is to synthesize and define common categories of meta-analysis. The second objective is to propose a way to comprehend these common categories of meta-analysis through learning from their respective generic conceptual frameworks. The third objective is to point out which R packages to use to conduct a meta-analysis for each category presented in this paper. In practice, research novices may not know where to begin to learn a topic of meta-analysis for their research. Furthermore, they may not know how the topic of meta-analysis progresses from basics to advanced. This makes it almost next to impossible to use meta-analysis in their research. Certainly, this is problematic. Thus, this paper intends to help research novices overcome this problem. To achieve this, the three objectives mentioned at the beginning were implemented. To propose a synthesis of common categories of meta-analysis along with their respective definitions, a literature review was used as a method to synthesize and define the common categories of meta-analysis presented in this paper. Here, synthesizing meta-analysis categories in one figure would make it much easier for research novices to see the breadth of the subject in question. To propose an easy way to understand the concepts of meta-analysis through learning from their respective generic conceptual frameworks, personal experience was used as a method to make that offering. Here, it is encouraged that research novices should go beyond the definitions of categories of meta-analysis. They can try to frame their research by using example conceptual frameworks presented in the paper as a starting point. To point out which R packages to use with what categories of meta-analysis, a literature review was used as a method to identify those appropriate R packages available. Here, it would be useful for research novices to know which R packages they may need for their meta-analysis research. In summary, the contributions of the paper here would make research novices see and understand the common categories of meta-analysis from the bottom to the top of the pyramid, also offers an easy way to understand the common categories of meta-analysis by illustrating how to develop conceptual frameworks for the common categories of meta-analysis, and finally recommending the R packages to be used with the categories of meta-analysis. Ultimately, we hope that research novices will be able to use meta-analysis successfully in their research.

Keywords: Categorization, Meta-Analysis, Conceptual Framework, R

1. Introduction

Meta-analysis methods have evolved, leading to the emergence of different categories of meta-analysis. However, classifications of meta-analysis are rarely documented in existing literature. This can be viewed as a significant gap. If a classification is not clear, it makes it difficult for research novices to come to terms with the different categories of meta-analyses. Thus, a classification of meta-analysis is needed and must be adequately explained. Another omission is that meta-analysis studies do not typically make use of conceptual frameworks to explain the foundation of their respective studies. However, it may be will very helpful to include a conceptual framework in a meta-analysis study. This would make it easier for a wider audience to comprehend a meta-analysis study. Therefore, this review article aims to propose a classification of common categories of meta-analyses with explanations for each category. In addition, conceptual frameworks will also be included to accompany each category of meta-analysis in our proposed classifications. Finally, R packages suitable for these categories of meta-analyses will be presented. After reading this article, it is anticipated that our audience will gain an understanding of the categories of meta-analyses from basic to advanced, know how to develop a conceptual framework for their meta-analysis studies, and know which R packages are suited to their meta-analysis studies. Hopefully, our presentation in this paper will serve as a good starting point for novice researchers to learn about meta-analysis and be able to use it in their meta-analysis research.

1.1. Definition of Meta-analysis

A meta-analysis is a quantitative technique that combines the results of multiple primary studies and ends with a summative figure/estimate (i.e. pooled effect size). A meta-analysis essentially is a summary, in effect, of numerous studies to form one finding that covers the area of study (Pigott & Polanin, 2019). The pooled effect can be computed in two ways: fixed- and random-effects models. The fixed-effects model assumes that the true effect size is fixed across studies. The random-effects model assumes that the true effect sizes are varied across studies. The latter is preferred when the studies of a meta-analysis study are heterogeneous.

2. Conceptual Framework and Hypothesis

It is not common to include a conceptual framework in a meta-analysis study. However, we think, for learning purposes, an understanding of conceptual frameworks would help learners who are less familiar with meta-analysis to understand the concept of analyzing meta-analysis data much more easily. When prompted with “define, a conceptual framework for research”, the Bard-generated text indicated that a conceptual framework is a “visual representation of the key variables and [their] relationships involved in your [meta-analysis] study” (Google, 2023). In addition, based on Google, conceptual frameworks can take different forms including diagrams, flowcharts, tables, or even written descriptions. Finally, a conceptual framework can serve as a base for further hypothesis development for a meta-analysis study.

2.1. R Packages for Meta-Analysis

Several R packages can conduct meta-analyses, such as meta package, dmetar package, metafor package, NetMeta package, rmeta package, MAd package, metaSEM package, and esc package. These packages are the common ones that are used to conduct meta-analysis. However, they have different strengths. It is recommended that users explore their strengths to make certain that the packages chosen will fit their meta-analysis needs. The R packages suitable for which meta-analysis categories will be recommended after the introduction of each category of meta-analysis presented ahead.

2.2. A Proposed Categories of Meta-Analyses

This paper reviewed common categories of meta-analyses. Based on our literature review, different categories of meta-analyses exist. Thus, this paper proposes five common categories of meta-analyses, namely, univariate meta-analysis, multivariate meta-analysis, network meta-analysis, multilevel meta-analysis, and structural equation meta-analysis. These five common categories of meta-analyses are captured in Figure 1. The five categories of these meta-analyses are described following Figure 1. The categorization captured in Figure 1 is developed by the authors of this paper and does not exist in existing literature.

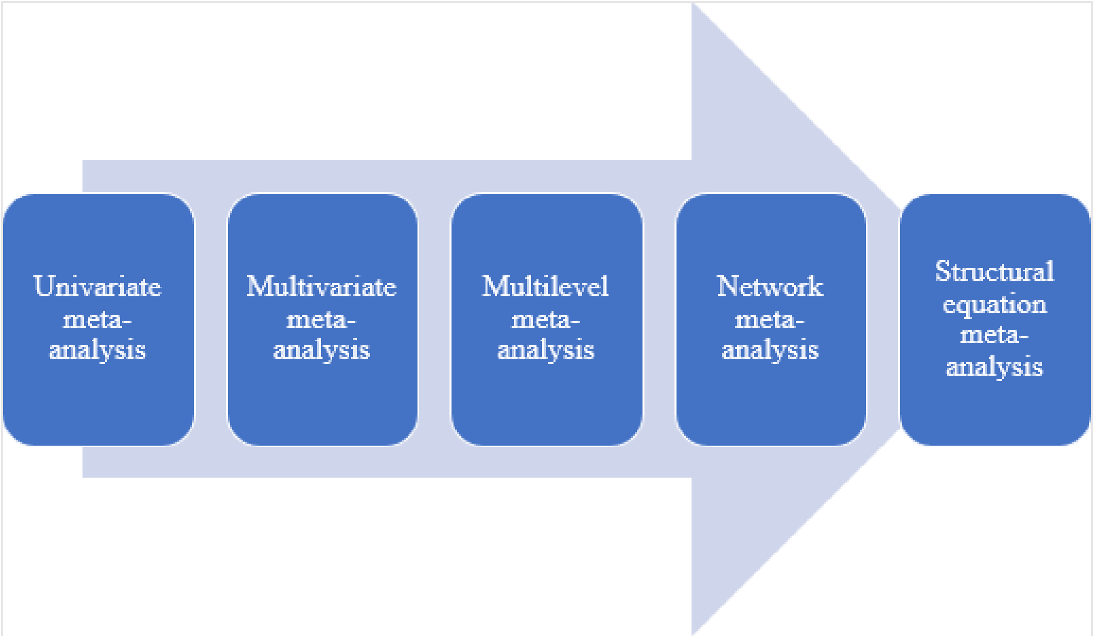

Figure 1. Category of meta-analyses

2.2.1. Univariate Meta-Analysis

The idea of univariate meta-analysis rests on pooling a single effect size of treatment/intervention of several primary studies. When prompted with "define, a univariate meta-analysis", the Bard-generated text stated that a univariate meta-analysis focuses on "synthesizing the evidence on a single outcome variable across multiple studies. It combines the results of these studies to provide a more comprehensive and statistically robust estimate of the effect size for that specific outcome" (Google, 2023). An example of a univariate meta-analysis conceptual framework is captured in Figure 2 below to help the audience of this paper see a univariate meta-analysis in a visual form. Figure 2 draws upon the work of Aloe et al. (2013). Their paper, however, does not provide an example of a univariate meta-analysis conceptual framework. Based on Figure 2, there is only one intervention called classroom management self-efficacy (CMSE) and one outcome (pooled effect size), emotional exhaustion (EE). In short, univariate meta-analysis focuses on one intervention and one outcome (pooled effect size) of multiple studies. The R package recommended for univariate meta-analysis is the meta package (Balduzzi et al., 2019). Based on Figure 2, a hypothesis is that the effect of CMSE on EE is significant.

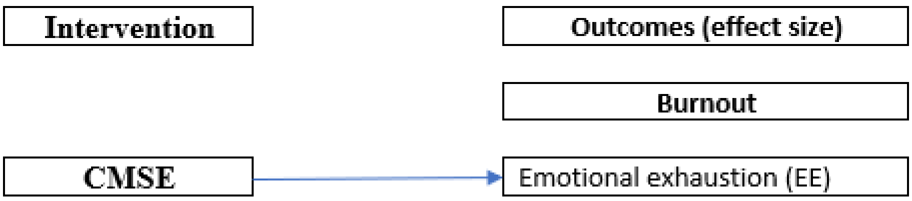

Figure 2. Univariate meta-analyses conceptual framework

2.2.2. Multivariate Meta-Analysis

The idea of multivariate meta-analysis focuses on measuring multiple outcomes (effect sizes) of one treatment/intervention. This differs from univariate meta-analysis which only focuses on measuring one outcome (effect size). When prompted with "multivariate meta-analysis", the Bard-generated text stated that "while univariate meta-analysis focuses on analyzing a single outcome across multiple studies, multivariate meta-analysis offers a more holistic approach. It delves into the complex interplay between two or more outcome variables measured in the same studies. This allows for a richer understanding of the overall effects and their interdependencies" (Google, 2023). An example of a multivariate meta-analysis conceptual framework is captured in Figure 3 below to help the audience of this paper see a multivariable meta-analysis in a visual form. Figure 3 draws upon the work of Aloe et al. (2013). Their paper, however, does not provide an example of a multivariate meta-analysis conceptual framework. Based on Figure 3, there is only one intervention called classroom management self-efficacy (CMSE) and three outcomes (pooled effect sizes), namely, emotional exhaustion (EE), depersonalization (DP), and personal accomplishment (PA). In short, multivariate meta-analysis focuses on one intervention but multiple outcomes (pooled effect sizes). The R packages recommended for multivariate meta-analysis are the metaSEM package (Cheung, 2015) and metafor package (Viechtbauer, 2010). The recommended packages need to be used in combination. Based on Figure 3, a hypothesis is that CMSE has a significant effect on EE, DP, and PA.

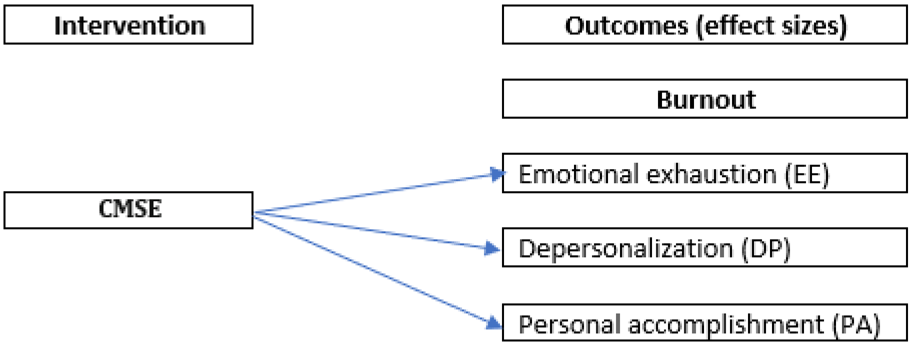

Figure 3. Multivariate meta-analysis conceptual framework

2.2.3. Multilevel Meta-Analysis

When prompted with "multilevel meta-analysis", the Bard-generated text stated that "Multilevel meta-analysis, also known as hierarchical meta-analysis, takes the analysis of combined research findings a step further. It delves into situations where studies themselves are nested within broader contexts or groups" (Google, 2023). In short, the idea of multilevel meta-analysis focuses on the cluster effects on a single outcome (effect size). Here, users need to know the concepts of meta-analysis, multilevel modeling, and R to learn multilevel meta-analysis. Thus, it makes it quite challenging to learn multilevel meta-analysis. An example of a multilevel meta-analysis is captured in Figure 4 below to help the audience of this paper see a multilevel meta-analysis in a visual form. Figure 4 draws upon the work of Bornmann et al. (2007). Their paper, however, does not provide an example of a multilevel meta-analysis conceptual framework. Based on Figure 4, the levels of IVs are classified into three levels: one micro and two macro levels. The two macro levels are viewed as cluster (contextual) effects. The three IV levels affect only one outcome (pooled effect size). In short, multilevel meta-analysis focuses on the effects of cluster levels on a single outcome (pooled effect size). The R package recommended is the metaSEM package (Cheung, 2015). Based on Figure 4, we can propose a hypothesis that all IVs (from different levels) have significant effects on DV (pooled effect size).

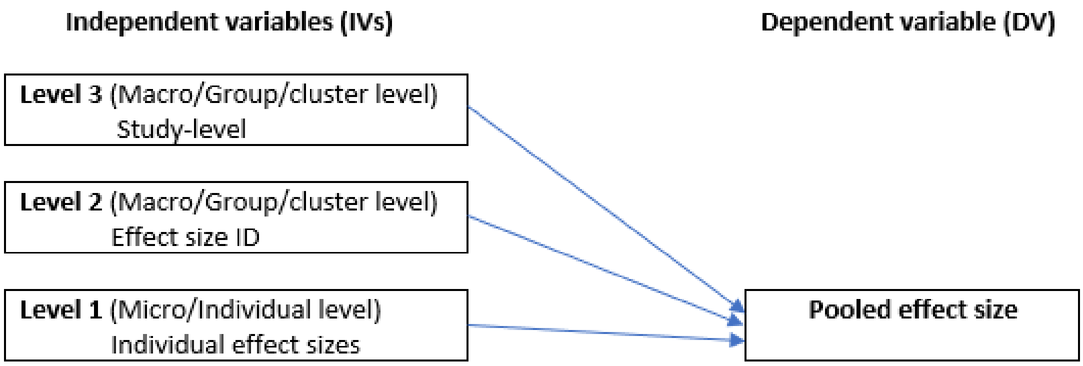

Figure 4. Multilevel meta-analysis conceptual framework

2.2.4. Network Meta-analysis

When prompted with "Network meta-analysis (NMA)", the ChatGPT-generated text stated that "Network meta-analysis (NMA) is a powerful statistical technique that goes beyond traditional pairwise comparisons in research. It takes you on a journey through a web of interconnected studies, allowing you to analyze the effectiveness of multiple interventions indirectly compared to each other, even if they haven't been directly compared in single studies" (OpenAI, 2023). When prompted with "Network meta-analysis", the Bard-generated text stated that "Network meta-analysis (NMA), also known as multiple treatment comparison meta-analysis or mixed treatment comparison, is a statistical technique used to compare and integrate evidence from multiple studies that directly or indirectly compare different interventions. This method is particularly useful when there are multiple treatments for a particular condition and head-to-head comparisons are limited or absent" (Google, 2023). An example of a network meta-analysis is captured in Figure 5 below to help the audience of this paper see a network meta-analysis in a visual form. Figure 5 draws upon the work of Chayaban et al. (2021). Their paper, however, does not provide an example of a network meta-analysis conceptual framework. Based on Figure 5, there are three different models: traditional teaching model (A), interaction teaching model (B), and coaching teaching model (C). Thus, there are three outcomes (pooled effect sizes). These outcomes can be compared directly (A and B, and A and C) and indirectly (B and C). In short, the idea of network meta-analysis focuses on measuring multiple outcomes of multiple treatments/interventions. Unlike multivariate meta-analysis (which only shows one treatment/intervention), network meta-analysis shows multiple treatments/interventions and their respective outcomes (effect sizes). For network meta-analysis, the netmeta package for network meta-analysis (Balduzzi et al., 2023) is recommended. Based on Figure 5, a hypothesis is that the pooled effect size between A and B is significant. In addition, a hypothesis is that the pooled effect size between A and C is significant. Furthermore, the pooled effect size between B and C can be indirectly compared by comparing the weights of the effect sizes between A and B, and A and C. Based on Figure 5, a hypothesis is that the pooled effect size (between A and B) is significant. In addition, the pooled effect size (between A and C) is significant.

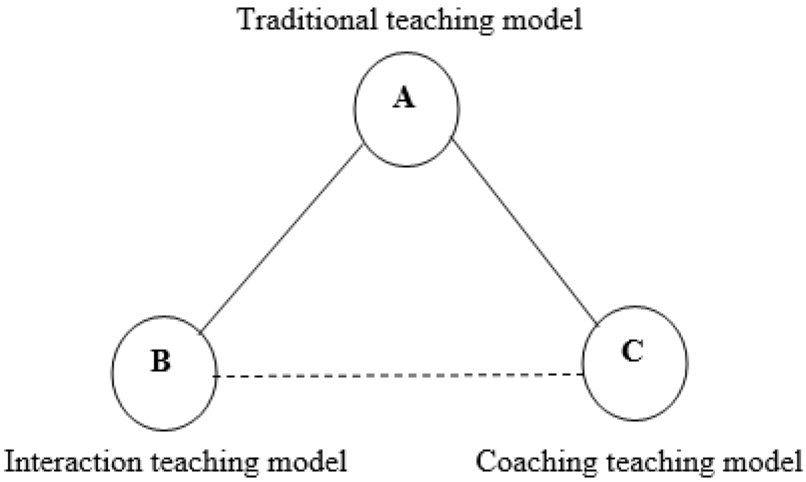

Figure 5. Network meta-analysis conceptual framework

2.2.5. Structural Equation Meta-analysis

When prompted with "structural equation meta-analysis (MASEM)", the ChatGPT-generated text stated that "Structural Equation Modeling Meta-Analysis (MASEM) is an advanced statistical approach that combines structural equation modeling (SEM) with meta-analysis techniques. MASEM allows researchers to examine relationships among variables within each study using SEM while also synthesizing these relationships across multiple studies through meta-analysis. This approach is particularly useful when dealing with complex models and investigating the generalizability of relationships [in the model]" (OpenAI, 2023). This category of meta-analysis is also called meta-analysis structural equation modeling (MASEM). This is probably the most complex category of meta-analysis presented in this paper in terms of complexities and analysis using R. The idea of MASEM is to conduct a structural equation model using the meta-analysis data. Figure 6 is an example of a conceptual framework for MASEM. The R software package that can conduct MASEM is called metaSEM. We hope that there will be more R packages available to run MASEM soon. To conduct MASEM, users need to understand R and SEM. The learning curves for both R and SEM are quite steep. Now, let's try to develop a MASEM conceptual framework. MASEM shares the conceptual framework with a traditional SEM but requires a different data input. In addition, the calculations between MASEM and SEM are not quite the same. One essential capability is that the metaSEM package can compute heterogeneity for MASEM. This is a necessary statistic for MASEM. Based on the metaSEM package, two types of MASEM can be analyzed by the package. The first one is the one-stage SEM (OSSEM), which does not compute the heterogeneity. Whereas the two-stage SEM (TSSEM) does compute heterogeneity. Some authors, for example, Jaroentaku & Kao-iean (2020), reported the heterogeneity value in their work. On the other hand, many authors do not report the heterogeneity values in their papers, for example, the work of Than et al. (2021), Thanapad et al. (2023), and Wangsin (2017). These authors may have to mention which approach they are using, OSSEM or TSSEM. An example of a MASEM conceptual framework is captured in Figure 6 below to help the audience of this paper see a meta-analysis structural equation modeling in a visual form. Figure 6 draws upon the work of Becker & Schram (1994). Their paper, however, does not provide an example of a MASEM conceptual framework. Based on Figure 6, the effects of IVs (Spatial and Verbal) on Math are computed using the meta-analysis structural equation modeling approach. For MASEM, we recommend the metaSEM package (Cheung, 2015). Based on Figure 6, a hypothesis is that the spatial and verbal exam scores significantly affect the math score.

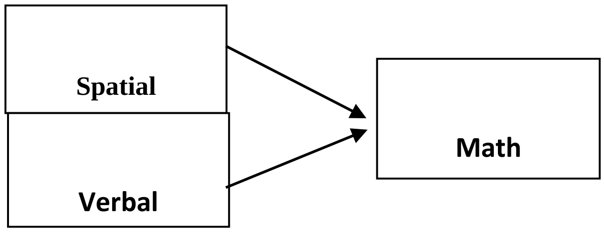

Figure 6: Structural equation modeling meta-analysis conceptual framework

3. Key Steps in Conducting a Meta-Analysis

3.1. Defining the Research Question

A meta-analysis study begins with a clear and focused question. Let's use a univariate meta-analysis to illustrate this point (see Figure 2). Is the outcome (pooled effect size) of emotional exhaustion (EE) of the included studies based on a systematic review statistically significant? This research question is a base for the development of Figure 2. In addition, the research question becomes the navigator of the meta-analysis study.

3.2. A Systematic Review

A systematic review is required before a meta-analysis. The purpose is to look for relevant studies to address the research question. A systematic review is a scientific investigation that uses explicit and reproducible methods to identify, select, and critically appraise all relevant research evidence on a specific question.

3.3. Study Selection and Quality Assessment

The assumption here is that not all studies hold the same quality. Thus, there is a need to evaluate the primary studies to be included in a meta-analysis study. First, the pre-defined criteria to evaluate the study need to be determined. These criteria can focus on verbal dimensions, for example, selection bias (were participants selected in a way that could influence the results?), performance bias (was there blinding or concealment of allocation to prevent biased intervention delivery or outcome assessment?), detection bias (were the outcome measurements accurate and reliable?), attrition bias (were participants lost to follow-up, and could this introduce bias?), and reporting bias (was the study reported transparently and completely?).

3.4. Data Extraction

This is a process of extracting the data from the primary studies. Data points from each study can include sample size, effect size, and statistical results. The most important data is the effect size, or raw data that can be converted to effect size. These data points serve as the key input for further meta-analysis.

3.5. Choosing an Effect Size Metric

Choosing the right effect size in meta-analysis is crucial for accurately summarizing and interpreting the results of your analysis. Common effect sizes for different data types and research questions for continuous data, mean difference (Cohen's d), measures the difference in means between groups, standardized by the pooled standard deviation. The standardized mean difference (Hedges' g) is similar to Cohen's d but with a small-sample correction. Categorical data, odds ratio (OR), measures the odds of an event occurring in one group compared to another and is suitable for dichotomous outcomes (e.g., presence/absence of disease). The risk ratio is the ratio of the probability of an event occurring in one group compared to another and is preferred for studies with frequent events. Relative risk is similar to risk ratio but expressed as a percentage. Correlations, Pearson's correlation coefficient (r), measures the strength and direction of a linear relationship between two continuous variables and is therefore suitable for investigating associations between variables.

3.6. Statistical Analysis

Two common types of statistical methods are used to pool the effect sizes across the primary studies included in a meta-analysis study: fixed-effects or random-effects models. A fixed-effect model is a statistical approach used to combine the results of multiple studies investigating the same research question. It assumes that there is one true underlying effect size that applies to all the studies included in the analysis. The random-effects model is a statistical approach used in meta-analysis that assumes the true effect size of a treatment can vary across different studies. Here, users need to decide which model to use for their research, fixed-effects or random-effects models.

3.7. Heterogeneity Assessment

If heterogeneity exists in a meta-analysis study, it means that variability exists in that meta-analysis study which can arise from various factors, such as differences in study design, populations, interventions, variation in specific interventions or treatments used in each study, and outcome measures. The way outcomes are measured might differ across studies. To prove that heterogeneity does not exist in a meta-analysis study, subgroup analysis, and meta-regression can be carried out.

3.8. Publication Bias Analysis

Publication bias can be demonstrated visually through a funnel plot asymmetry. However, this involves human judgment to visually assess whether the publication bias exists. We can avoid human judgment by conducting a statistical test, such as Egger's test. Egger's test is used to assess the presence of publication bias in a meta-analysis. Publication bias occurs when research with statistically significant results is more likely to be published than research with non-significant results. This can lead to a skewed distribution of effect sizes in a meta-analysis, making it appear as if there is a stronger effect than there is.

3.9. Results Interpretation and Reporting

Several items need to be reported. First, the summary of effect sizes of the primary studies included along with their respective confidence intervals and the overall (pooled) effect size along with its respective confidence intervals of a meta-study need to be reported. This information is usually captured in a forest plot. Second, the assessment of heterogeneity must be included, meaning differences in effect sizes across the included studies, using statistical tests like Cochran's Q and I^2. If significant heterogeneity exists, explore potential sources through subgroup analyses or meta-regression to provide a more nuanced understanding of the results. Third, publication bias needs to be reported. This can be presented in a graphical form through a funnel plot. In addition, a statistical test (e.g. Egger's test) can also be presented. Fourth, discussion, limitations, and implications need to be included.

4. Conclusions

As mentioned in the introduction, the categorization of meta-analyses is rarely seen, if ever. In addition, explanations of the differences between different categories of meta-analyses are also rarely seen. The application of a conceptual framework is also not typically used in a meta-analysis study. By now, the categories of meta-analyses and their respective conceptual frameworks should become clear to researchers. The R packages suitable for the different categories of meta-analyses are recommended in the paper. Thus, it is recommended that the audience of this paper use the categories of meta-analyses presented in this paper as their road map to learn the concepts of different categories of meta-analyses, develop conceptual frameworks for their meta-analysis studies, and select the right R packages for conducting the meta-analyses of their choices. What needs to be done beyond this paper? It would be very helpful if more learning resources were available for each category of meta-analysis presented in this paper. Therefore, it is recommended that more learning resources (e.g. tutorial papers) be made available. Finally, the categorization of meta-analyses, their respective conceptual framework development, and applicable R packages presented in this paper can be applied to other social science research contexts (e.g. economics, marketing, and business management).

References

Aloe, A. M., Amo, L., & Shanahan, M. E. (2013). Classroom management self-efficacy and burnout: a multivariate meta-analysis. *Educational Psychology Review*, *26*(1), 101–126. https://doi.org/10.1007/s10648-013-9244-0

Balduzzi, S., Rücker, G., Nikolakopoulou, A., Papakonstantinou, T., Salanti, G., Efthimiou, O., & Schwarzer, G. (2023). netmeta: An R package for network meta-analysis using Frequentist Methods. *Journal of Statistical Software*, *106*(2). https://doi.org/10.18637/jss.v106.i02

Balduzzi, S., Rücker, G., Schwarzer, G. (2019). "How to perform a meta-analysis with R: a practical tutorial." *Evidence-Based Mental Health*, 153–160. DOI: 10.1136/ebmental-2019-300117

Becker, B. J., & Schram, C. M. (1994). Examining explanatory models through research synthesis. In H. Cooper & L. V. Hedges (Eds.), *The Handbook of Research Synthesis*. Russell Sage Foundation.

Bornmann, L., Mutz, R., & Daniel, H. (2007). Gender differences in grant peer review: A meta-analysis. *Journal of Informetrics*, *1*(3), 226–238. https://doi.org/10.1016/j.joi.2007.03.001

Chayaban, W., Tippayakulpairoj, D., Siripila, S., Noklang, S., Anantanasan, N., Chaiboonma, S., & Piromsombat, C. (2021). A Network meta-analysis of teaching method influencing mathematics achievement of students. *Journal of Educational Measurement, Mahasarakham University*, *27*(1). https://so02.tci-thaijo.org/index.php/jemmsu/article/view/240457

Cheung, M. W. (2015). metaSEM: an R package for meta-analysis using structural equation modeling. *Frontiers in Psychology*, 5. https://doi.org/10.3389/fpsyg.2014.01521

Google. (2023). Bard (2023.07.13 version) [Large language model]. https://bard.google.com

Jaroentaku, N., & Kao-iean, S. (2020). Well-being of adolescences: Meta-analytic structural equation modeling. *An Online Journal of Education (OJED)*, *15*(20). https://so01.tci-thaijo.org/index.php/OJED/article/view/240666

OpenAI. (2023). ChatGPT (Mar 14 version) [Large language model]. https://chat.openai.com/chat

Pigott, T. D., & Polanin, J. R. (2019). Methodological guidance paper: High-quality meta-analysis in a systematic review. *Review of Educational Research*, *90*(1), 24–46. https://doi.org/10.3102/0034654319877153

Than, W. W., Kyaw, E. M., & Htoo, H. Z. (2021). A Meta-analytic structural equation modelling on the unified theory of acceptance and use of technology in higher education. *International Journal of Educational Management and Development Studies*, *2*(4), 44–71. https://doi.org/10.53378/352074

Thanapad, M., Ratanaolarn, T., & Kiddee, K. (2023). Meta-analytic structural equation modeling (MASEM) analysis of the elderly's quality of life (Qol) in ASEAN. *Journal of Namibian Studies*, 34. https://namibian-studies.com/index.php/JNS/article/view/2408/1633

Viechtbauer, W. (2010). Conducting meta-analyses In R with the MetaforPackage. *Journal of Statistical Software*, *36*(3). https://doi.org/10.18637/jss.v036.i03

Wangsin, N. (2017). Factors effecting on quality of secondary school learners using meta-analysis structural equation modeling (MASEM). *Ubon Ratchathani Rajabhat University Journal of Humanities and Social Sciences*, *6*(2), 23–46.