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Meta-Analysis The Effectiveness of Digital Learning Media on Literacy Numeracy: Implications for Education Based Technology

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Abstract
This study evaluates the effectiveness of digital learning media in improving numeracy literacy using a meta-analytic approach. A total of 21 relevant studies were analyzed to determine the effect sizes of various digital media, including augmented reality, website -based learning, and gamification, across different educational levels. The findings indicate that digital learning media significantly enhance students' numeracy skills, with an average effect size of 0.845. Factors such as instructional methods, material complexity, intervention duration, and types of digital media influence the level of effectiveness. Website -based media exhibited the highest effectiveness (d = 1.48), while audiovisual and gamified media contributed positively to non-cognitive learning outcomes. This study underscores the importance of integrating digital media to advance students' numeracy literacy in the era of technology.

Keywords: Digital Learning Media, Numeracy Literacy, Meta-Analysis, Technology-Based Education, Learning Effectiveness

INTRODUCTION

Digital transformation in the 21st century has influence various sector life, including education. Development rapid technology provide various source information and communication that makes learning more effective and efficient (Fajriyah, 2022). In this era, technology No only become tool help, but also an integral part of the learning process in schools. Learning media based on technology play role strategic in increase results Study student with give experience learn more interactive and interesting (Dita, 2022).

In context education, learning media originate from the Latin term *medius,* meaning" connector" or" intermediary ". Learning media functioning as tool For convey message from source to recipient, which can stimulate thoughts, feelings and attention students, so that increase involvement they in the learning process (Hamid et al, 2020). Selection of appropriate media is very important Because can influence effectiveness learning, especially in help student understand material in a way more deep.

Mathematics be one of eye very important lesson in education Because its relevance with development skills 21st century, known as as 4C: thinking critical thinking, communication, collaboration, and creativity (Prayogi, 2020*)*. As part from literacy mathematics, literacy numeracy is ability the basics that must be owned student For face challenge 21st century. Literacy numeracy, according to Han et al. (2017), is skills use numbers and symbols mathematics For solve problem practice, analyze data, and take decision. While that, Murnane et al. (2012) added that literacy Numeracy also includes ability acquire, interpret, apply, and communicate information numeric presented in various formats, such as graphs, tables, or narrative.

The use of digital learning media is one of them solution potential For increase ability numeracy students. Digital media offers various feature interactive that can help student understand concepts numeracy in a way more fun and effective. Some study has show the success of digital media in increase literacy students. As For example, Jannah & Oktaviani (2022) found that use application learning

based on gamification can increase skills numeracy student in a way significant. Findings similar was also reported by Winarni et al. (2021) and Maulidya et al. (2023), which shows that digital media can increase involvement and understanding student in learning numeracy .

However, even though various study has to study the effectiveness of digital learning media, still there is limitations in integrate results existing research For answer challenge education in Indonesia. As example, some studies only focus on improvement motivation Study without evaluate impact direct to literacy numeracy. In addition, it has not There is study comprehensive which is special analyze effectiveness of digital media based on media type, level education, and complexity material in context education national. Therefore that, study This aiming For bridge gap the with meta- analysis approach

With background behind this, research This aiming For conduct a meta- analysis use to study the effectiveness of digital learning media on improvement literacy numeracy. This research given title "Meta- Analysis : The Effectiveness of Digital Learning Media on Improvement Literacy Numeracy" .

METHOD

This research use meta- analysis design, namely method systematic and purposeful For merge results from various relevant research use produce more conclusions strong and more generalization area. Meta- analysis allow identification patterns and trends general through quantitative data integration from various source (Borenstein et al., 2009). In the study this, meta- analysis used For evaluate the effectiveness of digital learning media on literacy numeracy student .

Search Literature

Search literature done using *Google Scholar* database with help application *Publish or* Perish. Keywords used in search are :" Digital learning media" AND" Literacy" numeracy ". Search yielded 994 relevant articles with keywords. Search process focused on published articles between 2019 to 2024 and written in Indonesian or English. Search This designed For ensure comprehensive coverage to relevant research with Topic This .

Criteria Inclusion and Exclusion

Collected articles selected based on criteria inclusion and exclusion For ensure only relevant and quality research included in meta- analysis. Criteria the is as following :

Criteria	Inclusion	Exclusion
Article Type	Empirical articles published in peer-reviewed journals .	Proceedings, unpublished articles published, article without peer-review, and informal discussions .
Contents	Discussing at least one digital learning media and its relation to student literacy and numeracy at elementary, middle or high school levels in Indonesia.	(1) Only discusses digital learning media, (2) only discusses literacy or numeracy, (3) subject is student education tall or child age early .
Language	Indonesian or English .	Articles that are not written in Indonesian or English .
Year	Published between 2019 and 2024.	Articles published before 2019.

Data Extraction Strategy

Data extraction is step important in review systematic, which includes aggregation information from various included studies. Implementation methodology robust data extraction is essential For ensure reliability and validity of the data found For used in accordance with objective research, in study This data extraction started with determine type article use Zotero app, 128 books, 593 items contain the word literacy Numeracy, 11 Proceedings, 3 Seminar Items, 9 *review items,* 209 items not there is the word media, and 20 items are not using digital media, so results extraction leaving 21 titles remaining articles. Next article read One one by one, selected articles only that shows standard deviation and *effect size* For Can meta- analysis was conducted to article the .

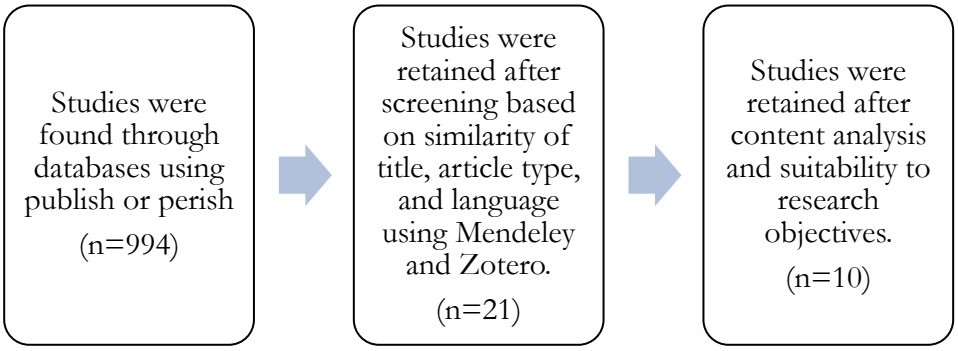

Figure 1. Stages Study Screening in Meta- Analysis Research

Flowchart filtering studies started with identification of 994 articles through keyword search in the database. After the stage filtering beginning based on conformity title and abstract, number remaining articles reduce become 128 articles remaining. Next, the article selected based on criteria inclusion, such as *peer-review* and relevance with use of digital media in literacy numeracy, so that 21 articles remaining. Of the total mentioned, 10 articles chosen For meta analysis based on completeness of the required statistical data .

Data analysis

Data collected organized and analyzed use device soft such as Excel, *Review Manager (*RevMan), and *Comprehensive Meta-Analysis* (CMA). The analysis process involving steps following:

1. **Calculation Size Effect** : Using size effect standard like Cohen's *d* For measure the magnitude influence or difference between group. One of the size effect frequently used standards used is Cohen's d, which evaluates the average difference between two group with consider data variability .

   Formula main For Calculating Cohen's d is :

$$d = (X_1 - X_2) / s_p$$

   Where:

   $X\bar{}_1$ and $X\bar{}_2$: Average of two group (group) experiments and controls).

   s_p: Standard deviation pooled *standard* deviation, calculated with formula :

$$s_p = \sqrt{[((n_1 - 1)s_1{}^2 + (n_2 - 1)s_2{}^2) / (n_1 + n_2 - 2)]}$$

   Where:

   s_1 and s_2: Standard deviation from each group .

   n_1 and n_2: Size sample from each group .

2. **Statistical Model** : Analysis done with effect model fixed (*Fixed-Effect Model*) or effect random (*Random-Effect Model*), depending on the level of Data heterogeneity. *Fixed-Effect Model* used Because the studies analyzed own similar and purposeful variables For generalization to the population certain. However, *the Random-Effect Model* applied For consider variation addition between studies that are not explained by error random merely, like difference design study or characteristics sample

   Average *effect size* formula For *Fixed-Effect* Mode:

$$\boldsymbol{\bar{d}} = (\boldsymbol{\Sigma w_i d_i}) / (\boldsymbol{\Sigma w_i})$$

Where: d_i = *effect size* of the i-th study

$w_i = 1 / v_i$ (weight based on variance from each study)

   Average *effect size* formula For *Random-Effect Model* :

$$\boldsymbol{\bar{d}} = (\boldsymbol{\Sigma w_i} * \boldsymbol{d_i}) / (\boldsymbol{\Sigma w_i} *)$$

Where:

$w_i{}^* = 1 / (v_i + \tau^2)$ (weights that account for variance between studies)

3. **Heterogeneity :** Heterogeneity tests (χ^2 and I^2) were performed. For determine variation between included research .

4. Formula For measure level heterogeneity (I^2 and Q):

$$I^2 = ((Q - df) / Q) \times 100\%$$

$$Q = \Sigma w_i(d_i - \bar{d})^2$$

   Where:

Q = heterogeneity statistic df = degrees of freedom (number of studies - 1)

RESULTS AND DISCUSSION

Meta-analysis This explore ten dimensions main, including method learning, complexity material, duration intervention, design research, existence group control, results non-cognitive learning, characteristics participant education, technology used, type instrument assessment, and level completeness learn. Every dimensions analyzed For give a comprehensive overview related factors that influence the success of digital learning media.

Table 1 presents information about title article, year publication, design research, as well as digital learning media used in articles that will be analyzed use meta- analysis method.

Table 1. Main Research Information

Study Title	Year	Research Design
Effectiveness of Learning Media Digital Based" Numeracy Mathematics (NUMET)" Integer Material Against Mathematical Comprehension Ability Students at the Studio Ampang Malaysia Guidance	2023	Quasi-experiment
Effectiveness of Learning Media Based on Website In Exploration Ability Numeracy Mathematical Based on Behaviorism Learners	2024	Pretest-Posttest One Group
Effectiveness of Learning Models Discovery Learning to Ability Literacy Fraction Material Numeracy Students of Class V of Jenggrik 03 Elementary School, Sragen Year Academic Year 2022/2023	2023	One Group Pretest-Posttest
Effectiveness of Learning Modules Mathematics Based on Electronics In Enhancement Ability Literacy Numeracy Student	2024	Quasi-experiment
Influence Game Morning Finger Mathematics To Ability Numeracy Grade V Elementary School Students	2024	Pre- experiment
The Influence of Audiovisual Media to Ability Measurement in Early Childhood	2023	Pretest-Posttest One Group
The Influence of Learning Media Digital Quizizz Based on Learning Outcomes Mathematics Students in Elementary School	2024	Pretest-Posttest Control Group
Influence Use of Augmented Reality Media To Ability Literacy Digital Numeracy in Learning Mathematics Data Presentation Material Class V MI At-Taufiq	2022	Quasi-experiment
Influence Problem Based Learning Assisted by Youtube Media To Ability Literacy Numeracy Student	2021	True Experiment
Use Google Sites Fraction Material For Increase Activities and Abilities Numeracy Student Elementary school	2022	Research and Development

Table 2. Analysis Results Effectiveness

Digital Learning Media	Educational level	Number of Samples	Effect size	Category Effectiveness
NuMet	Elementary school	60	0.85	Tall
Website -based Learning	Junior High School	30	1.48	Very high
Discovery Learning	Elementary school	31	0.85	Tall

E-Module Jarimatika	Junior High School	20	0.4	Currently
Morning Game	Elementary school	20	0.7	Currently
Audiovisual Media	Early Childhood Education	18	0.9	Tall
Quizizz	Elementary school	24	0.75	Currently
Augmented Reality	Elementary school	49	0.91	Tall
YouTube based PBL	Junior High School	60	0.71	Currently
Google Sites	Elementary school	40	0.81	Tall

Table 2, informs *Effect size* that is level the effectiveness of digital learning media in increase ability numeracy students, including amount total participants in every research, Category effectiveness classify size effect become category such as "High," "Medium," or "Very High" based on meta - analysis standards used, providing interpretation direct about the success of each learning media .

Table 2 shows that media is based *website* give size effect highest (d = 1.48), which can associated with level interactivity high that supports the learning process numeracy. In contrast, e- module based media only show effectiveness moderate (d = 0.40), probable Because lack of element gamification or visualization interactive.

Analysis Based on Meta-Analysis Dimensions

Analysis in meta- analysis This done with consider various dimensions that influence the effectiveness of digital learning media on literacy numeracy. Dimensions the covers method teaching, complexity material, duration intervention, design research, existence group control, characteristics participant education, technology used, type instrument assessment, up to level completeness learning. Approach This aiming For dig patterns main thing that appears in results research, providing description comprehensive about supporting factors the success of digital learning media in increase literacy numeracy.

Every dimensions the analyzed in a way deep For identify his contribution to effectiveness of digital learning media. Analysis This No only evaluate the impact of each factor in a way separate, but also highlights interaction inter-dimensional which can influence results learning. Here this is description more details related every dimensions studied in meta- analysis.

Learning Methods

Various method learning applied in study this, including *Discovery Learning, Problem-Based Learning (PBL), and* learning models based on gamification. The study by Agustin et al. (2023) show effectiveness tall from *Discovery Learning (effect size* 0.85) in increase understanding fractions. Devinra et al. (2024) reported effectiveness currently from Quizizz (*effect size* 0.75) in evaluation formative. While that, media based gamification like Morning Jarimatika give motivation Study student with category effectiveness moderate (0.70).

Other studies, such as by Nurhaliza et al. (2024), highlighting advantages of media based *website* that reaches category very high effectiveness (*effect size* 1.48) through presentation interactive materials. Approach This show that method integrated learning element interactive and gamification tend give more results significant.

Complexity of Learning Materials

The effectiveness of digital learning media is also influenced by complexity. material. Topic numeracy simple like number round show results more Good compared to material complex like data presentation. The study by Jannah et al. (2022) underlines effectiveness *augmented reality* with category high (effect size 0.91) for material data presentation.

Based media (Devya et al., 2022) used For teach fractions also show level involvement high students, with level completion 81.25%. This result confirm importance election appropriate material with ability student For maximize effectiveness of learning media.

Duration Intervention

Duration intervention contribute significant to effectiveness of digital learning media. Study with duration more long, like *Discovery Learning* for 10 weeks (Agustin et al., 2023), resulting in category effectiveness high (0.85). On the other hand, the study with duration short, like use of the E-Module for five weeks (Huda et al., 2024), only show effectiveness moderate (0.40). Findings This show that longer duration long give enough time For student understand and internalize material.

Research Design

Design Types research also influences validity Results. Research with *true experiment design,* such as by Ambarwati et al. (2021), resulted in more valid results than quasi - experiments or pre-experiment. *True experiment* in learning YouTube based generates category effectiveness moderate (0.71), while augmented reality in quasi- experimental design show category high (0.91).

Existence group control in design research, as applied by Devinra et al. (2024) on the Quizizz media, provides clear and improving comparison reliability results.

Non- Cognitive Learning Outcomes

Apart from the ability numeracy, results non- cognitive learning like motivation, participation, and involvement students were also analyzed. A study by Yohanah et al. (2024) showed improvement enthusiasm student through gamification jarimatika, while audiovisual media (Satriana et al., 2023) was reported increase ability social child age early.

Characteristics Learners

The effectiveness of digital media varies based on level education. Junior high school students show results best, like in study by Nurhaliza et al. (2024) which reached very high category (1.48). On the other hand, effectiveness in PAUD tends to be more low Because limitations cognitive. Pretest data also showed that student with skills beginning low to obtain benefit more big from interactive media like *augmented reality* (Jannah et al., 2022).

Media and Technology Used

The effectiveness of digital media is greatly influenced by the technology used. *Website* -based learning (Nurhaliza et al., 2024) and augmented reality (Jannah et al., 2022) show effectiveness highest Because integrate element supporting visualization and interactivity learning numeracy.

Instrument Type Evaluation

Instrument like *pretest-posttest* support measurement effectiveness in a way consistent. Devinra et al. (2024) used 20 questions choice double For evaluate ability numeracy student in a way formative, producing significant results.

Level of Completion Study

Level of completion Study student varies from 75% to 88%. Google Sites (Devya et al., 2022) shows completion 81.25%, while *augmented reality* (Jannah et al., 2022) reached 88%. The level of completion This reflect media success in facilitate learning numeracy.

Analysis Results

For interpret data in a comprehensive, meta- analysis results This analyzed use two approach main, namely *Fixed-Effect Model* and *Random-Effect Model.* Approach This chosen For ensure results analysis capable reflect variation between research, both originating from from heterogeneity and also homogeneity of data. Here is results analysis based on both models.

Meta- analysis This done use two approach main, namely *Fixed-Effect Model* and *Random-Effect Model,* for interpret data in a comprehensive. *Fixed-Effect Model* assume that all studies own the same effect *size* in the population and provides weight more big on studies with variance more small. In contrast, *the Random-Effect Model* takes into account variation addition between studies that are not explained by error random solely. Both of these models used For describe the effectiveness of digital learning media on literacy numeracy in a way more comprehensive.

Analysis results *Fixed-Effect* Model shows the average *effect size* of 0.845, with a confidence interval of narrow (95% CI: 0.741 - 0.950), which indicates consistency results between study. The moderate level of heterogeneity, with Q of 18.10 and I^2 of 50.28%, indicates existence variations that can be explained by factors contextual like design research, media types, and characteristics participants. While that, *Random-Effect Model* produced the same average effect *size* (0.845),

however with confidence interval more width (95% CI: 0.692 - 0.997), reflecting more uncertainty big consequence heterogeneity. Variation addition between The study represented by the Tau² value (0.029) also shows relative difference small until moderate.

From the results analysis second approach mentioned, digital learning media has proven to be very effective in increase ability literacy numeracy students, good through a *fixed-effect* model and also *random-effect*. Although the result consistent, existence heterogeneity moderate (I^2 around 50%) indicates the need analysis subgroup For explore factors that influence variation between research, such as types of learning media or level education. This is give more insight Details For guide optimal implementation of digital learning media.

For give visualization meta- analysis results, Figure 2 presents a *Forest plot* diagram depicting distribution *effect size* from every research analyzed. This diagram display estimate *effect size* individuals, their confidence intervals, and the average combined *effect size*. based on *Fixed-Effect Model* and *Random-Effect Model*. *Forest plots* This make it easier interpretation heterogeneity between study and help identify pattern the effectiveness of digital learning media on literacy numeracy .

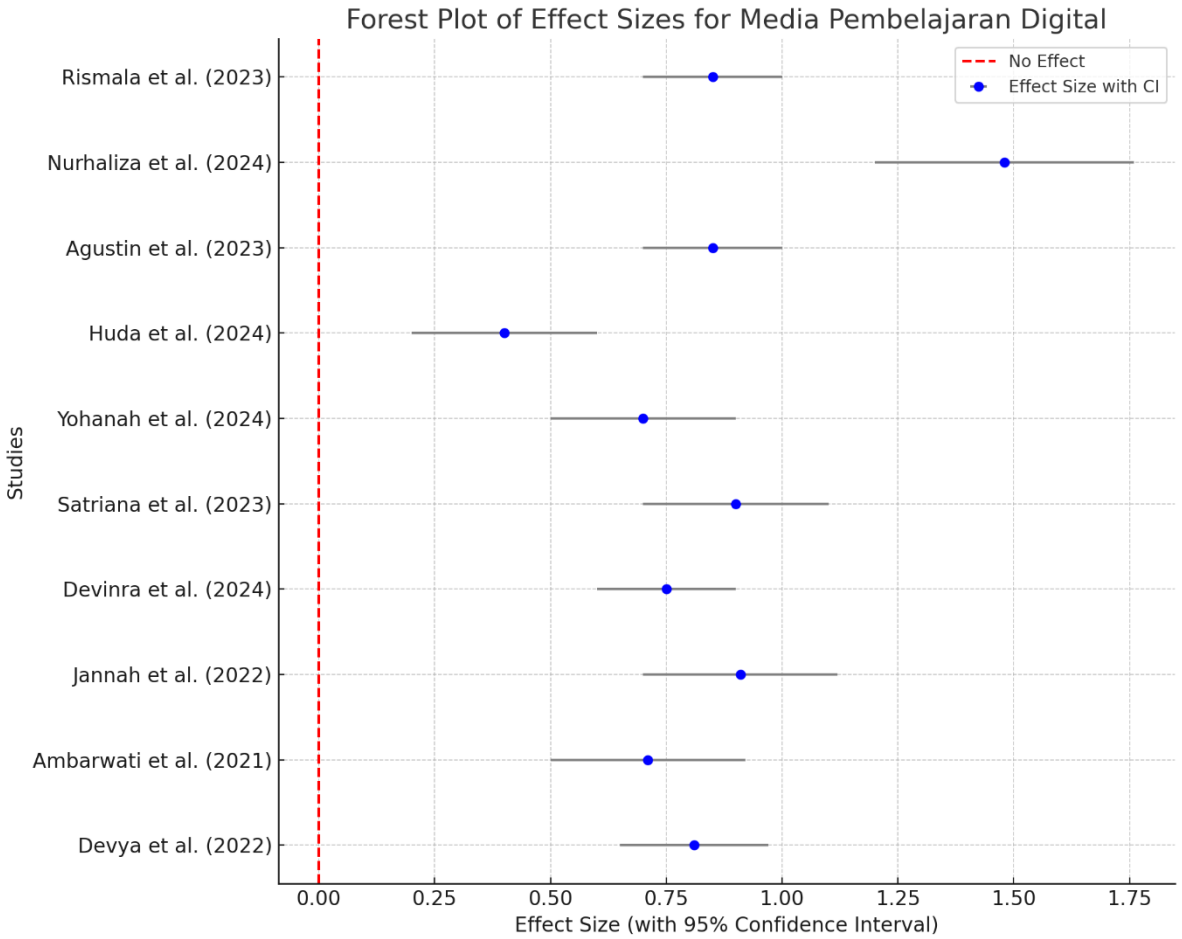

Figure 2. Forest plot diagram

In general Overall, this diagram show that part big studies show significant and positive effect *size,* strengthening findings that digital learning media is very effective For increase numeracy students. *Forest plot* give visualization the effectiveness of each study in meta- analysis.

Study with more samples large, such as by Nurhaliza et al. (2024), has a larger CI line. short, showing more results sure. Effectiveness Highest namely the study by Nurhaliza et al. (2024) shows *effect size* highest 1.48) with no confidence interval overlap overlap with studies other, signifies advantages of media based *website* in increase numeracy.

The degree of *heterogeneity of effect sizes* between study presented in Figure 3. This diagram give description about the variations that exist between the studies analyzed, as well as contribution variance between studies to the total variance. Information This important For evaluate how far the

results study own uniformity or influenced by factors specific, such as design research, characteristics participants, or type of digital learning media used.

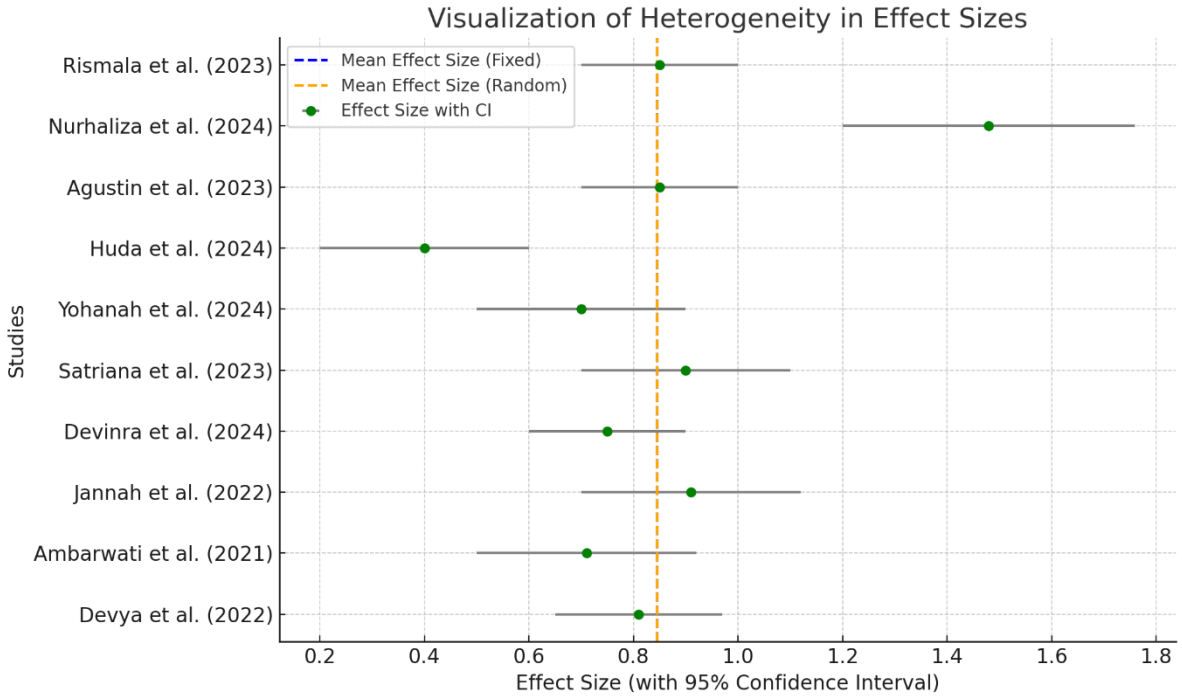

Figure 3. Heterogeneity Diagram Effect size s

Visualization heterogeneity in the diagram form has been made For show difference *effect size* between study and its confidence interval. Heterogeneity diagram describe variation between studies in matter effect size and confidence interval (CI). This diagram show that digital learning media overall effective in increase ability numeracy students and variations between study (heterogeneity) partly big moderate as well as can explained by the differences in design research, types of digital media, or characteristics sample.

Contribution Science

analysis results This give contribution significant in theory learning digital based. Digital media supports constructivism through experience meaningful and interactive learning . Apart from that, theory behaviorism reinforced with element motivating gamification student For Study in a way active.

CONCLUSION

Meta- analysis This show that digital learning media is significant effective in increase literacy numeracy students, with size high effect. Factors like method learning, complexity material, duration interventions, and the types of digital media that play a role role crucial in determine its effectiveness. Media based *website* and *augmented reality* show results best, support understanding concept and motivation Study student optimally. In addition, digital media does not only increase results cognitive, but also contributes to non- cognitive aspects, such as involvement students and motivation learning, especially through gamification. Findings This emphasize the need planning strategic in selecting and implementing appropriate digital media with need students, characteristics materials and objectives learning, for maximize potential learning based on technology in the digital era.

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