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Meta-Analysis: The Influence of Mathematical Digital Literacy on Mathematics Learning

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ABSTRACT

The advancement of technology and information in the industrial revolution era has brought significant changes in education which demands strong digital literacy among students to face the challenges of the 21st century. Digital literacy not only includes the ability to read and understand information, but also integrates technology in the learning process and problem solving. This study uses a meta-analysis method to evaluate and combine the results of various studies on digital literacy in mathematics learning in Indonesia. The purposive sampling technique was used to select 12 relevant scientific articles from the last seven years taken from Google Scholar. Data were collected through documentation and filtered to ensure compliance with the research topic. Effect size analysis was used to measure the effect of digital literacy on mathematics learning. The characteristics of the studies analyzed in this study include the year of research, level of education, and type of publication. Statistically, it was obtained that the application of Digital Literacy to mathematical abilities was influenced by the level of education used. The integration of digital technology in mathematics learning at the high school level has a significant impact on improving student achievement. The results of the study indicate that the integration of digital technology prepares students for future challenges with increasingly advanced technology.

Keywords: digital literacy; mathematical ability; mathematics learning; meta analysis

INTRODUCTION

Along with the emergence of the industrial revolution era, technological and information advances have accelerated to meet the increasing needs of humans (Arryadna & Pratiwi, 2022; Cholily et al., 2021a). The rapid growth in information and communication technology has an impact on various aspects of life, including the education sector (Febriyanti Indri, 2023; Junaedy Abu Huraerah et al., 2023). In facing learning in the 21st century, it is important for every individual to have critical thinking skills, knowledge of digital literacy, information literacy, media literacy, and the ability to master information and communication technology (Sifa & Winarto, 2022). Many Indonesian people still do not have a deep understanding of how the digital world works so that most of them are still classified as digitally illiterate and tend to use digital technology solely as a means of communication or sharing information (Amri et al., 2021). This condition is in accordance with what was conveyed by (Maulana et al., 2023)those who stated that although today's young generation are digital natives, they still do not have an adequate understanding of digital literacy.

The growth of science and technology drives innovation in the use of technological products in the learning process. Education is always closely related to literacy, because literacy is a means for students to understand, recognize and apply the knowledge they learn in school (Hasanah & Sukri, 2023). The application of digital technology in education and learning is one of the important innovations. Given the rapid development of information and communication technology, educators need to innovate to keep up with these rapid changes, one of which is by adopting digital literacy in classroom learning (Arsyad Arrajiv et al., 2021).

Digital literacy is one of the basic components that is part of the new independent curriculum where the implementation of this curriculum must integrate technology into the learning process (Muhammadiyah Mataram Mataram & Wulan Sari, 2023; Nyoman et al., 2023). In the digital era like today, almost all information can be accessed easily. Therefore, digital literacy is very important to be implemented at all levels of education (Fitri et al., 2023; Tutut Arima et al., 2021). Digital literacy is an important skill in today's education that includes various forms of literacy such as information literacy, computer literacy, media literacy, communication literacy, visual literacy, and technology literacy (Aqil Siroj et al., 2022; Naufal, 2021; Nugraha, 2022). With digital literacy, the younger generation can take advantage of information sources that are connected to digital technology and prepare themselves to face existing technological challenges (Giovanni & Komariah, 2019; Sari Muliawanti, 2019).

Digital literacy is an important component in mathematics learning, providing opportunities for students to interact, access interesting reading sources, explore diverse material references, and communicate and solve problems in innovative ways (Lia Tasliah et al., 2024; Widianti Heni, 2021). With digital literacy skills, students can obtain mathematical information and knowledge in a smarter and healthier way while building critical thinking patterns. Digital literacy is not just the ability to read, but also includes a deeper understanding of the meaning and ideas contained in a reading (Cholily et al., 2021; Hidayatulloh et al., 2019; Titis Madyaning Ratri et al., 2023). This encourages students to develop skills in evaluating information and finding relevant sources. The application of digital literacy in mathematics learning supports the transformation of the learning process, where students not only understand mathematical theory, but are also able to integrate technology in analysis and problem solving which ultimately strengthens their ability to face challenges in the digital era (Rochmatika & Yana, 2022; Soraya et al., 2023). Digital literacy includes a variety of skills that enable learners to access, analyze, and use information effectively (Cynthia & Sihotang, 2023; Haya et al., 2023).

Research on digital literacy and its impact on mathematics learning has been conducted on various populations, educational levels, and materials, producing diverse findings and characteristics in each study in journals and theses. This study uses a meta-analysis method to summarize and review a lot of data from journals objectively, effectively, and efficiently into one integrated study. Various studies on the same subject often produce conflicting or different findings. Therefore, it is very important to integrate quantitative findings in order to produce informative and useful recommendations. Thus, meta-analysis research is needed to unite objectives and reveal facts in order to reach comprehensive and

interesting conclusions. The findings of the meta-analysis determine the effect size and integrate them, thereby increasing the likelihood of reaching the same conclusion.

RESEARCH METHODS

This study uses a meta-analysis design. Meta-analysis is a research method that utilizes secondary quantitative studies obtained from primary studies to reject or accept existing hypotheses. This method comprehensively combines, reviews, and analyzes data from studies with similar themes (Djidu & Kartianom, 2018). The research instrument is data coding to investigate a specific population or sample. The purpose of this study is to statistically and systematically combine, analyze, and synthesize the findings of two or more studies that examine the effect of implementing Mathematical Digital Literacy on mathematics learning. The sampling technique used is purposive sampling, with samples selected based on the following criteria: quantitative research conducted in Indonesia and published in the last seven years. Articles are selected based on their relevance to mathematical digital literacy and mathematics learning, sourced from Google Scholar. The article search process uses the keyword mathematical digital literacy with a focus on the Y variable related to mathematics learning. The subjects of this study were 12 scientific articles published nationally from various journals and proceedings. The data collection technique used is documentation. The collected articles were then filtered to ensure that the content was aligned with the problem to be analyzed. This filtering stage was carried out to ensure that every component required in the effect size calculation could be met. Effect size is a quantitative index used to summarize the results of studies in meta-analysis. This means that effect size reflects the magnitude of the relationship between variables in each study. The choice of effect size index depends on the type of data used in the study (Djidu & Kartianom, 2018). The data analysis technique in this study used the metafor package in the RStudio application, developed by Wolfgang Viechtbauer and explained in his article entitled "*Conducting Meta-Analyses in R with the metafor Package"* (Viechtbauer, 2010). This package is used to analyze the correlation between mathematical digital literacy and mathematics learning through a meta-analysis approach that allows the combination of results from various studies to provide a more comprehensive understanding of the relationship between the two variables. This method is designed to control for variation from various sources, so that the distribution of correlations from the studies analyzed can be used to estimate the actual correlation. By observing the correlation between several variables in various studies, researchers can integrate these results to develop a stronger theory. In addition, meta-correction is carried out to identify and correct biases such as publication bias or research methods, so that the analysis results are more valid and accurate.

RESULTS AND DISCUSSION

Overall Analysis

Based on the results of data processing using RStudio, the Overall Analysis results were obtained as follows:

```
   No           Studi     r   n Level.Akademik Tipe.Publikasi
1   1      Heza, 2022 0.795  35             SD         Jurnal
2   2      Reza, 2022 0.513 334      Mahasiswa      Prosiding
3   3    Johana, 2022 0.081 240      Mahasiswa         Jurnal
4   4     Della, 2022 0.783  72        SMA/SMK         Jurnal
5   5  Septiani, 2023 0.750  78        SMA/SMK         Jurnal
6   6       Sri, 2023 0.294  84      Mahasiswa         Jurnal
7   7     Indri, 2022 0.700  71        SMA/SMK         Jurnal
8   8     Mendi, 2021 0.080  30             SD         Jurnal
9   9 Farleynia, 2019 0.478 666        SMA/SMK         Jurnal
10 10      Redi, 2022 0.722  80             SD         Jurnal
11 11     Santy, 2023 0.491  40      Mahasiswa         Jurnal
12 12      Dedy, 2023 0.696  90      Mahasiswa         Jurnal

Number of studies: k = 12
Number of observations: o = 1820

                         COR           95%-CI     z  p-value
Common effect model   0.5012 [0.4656; 0.5351] 23.27 < 0.0001
Random effects model  0.5725 [0.4238; 0.6911]  6.42 < 0.0001

Quantifying heterogeneity:
 tau^2 = 0.1092 [0.0481; 0.3537]; tau = 0.3305 [0.2193; 0.5947]
 I^2 = 91.5% [87.0%; 94.4%]; H = 3.42 [2.78; 4.22]

Test of heterogeneity:
     Q d.f.  p-value
 128.97   11 < 0.0001
```

Figure 1. Overall Analysis Results

Based on Figure 1, the results of the meta-analysis show that there is a significant correlation ($p < 0.001$) between digital literacy and mathematical ability, where the strength of the relationship between the two variables is included in the strong category ($r_{RE} = 0{,}5725$).The results of the heterogeneity test showed that the effect size used in the meta-analysis was heterogeneous ($Q = 128.97$; $p < 0{,}001$)with a variation level reaching 91,5%. This indicates that the random effects model is more appropriate to explain the relationship between digital literacy and mathematical ability. In addition, the high variation in effect size in the meta-analysis needs to be investigated for its causes, so that analysis of potential moderator variables is carried out to reveal the causes of the high variation.

Fores Plot

Based on the results of data processing using RStudio, the following Fores Plot results were obtained*:*

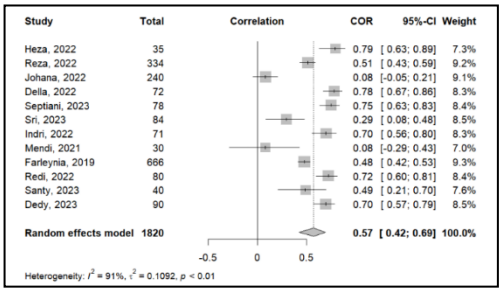

Figure 2. Fores Plot

Moderator Variable Analysis

Based on the results of data processing using RStudio, the results of the moderator variable analysis were obtained as follows:

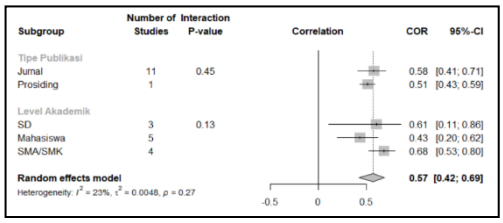

Figure 3. The Moderator Variable Analysis

In this study, the moderator variable of study type consists of two categories. The relationship between Digital Literacy and Mathematical Ability was found to be strongest in studies published in the journal($r_{RE} = 0{,}58$).

In this study, the moderator variable of academic level consists of three categories. The relationship between digital literacy and mathematical ability was found to be strongest in studies involving samples at the high school/vocational school level ($r_{RE} = 0{,}68$), while the weakest occurred in studies involving samples at the college level ($r_{RE} = 0{,}43$).

Publication Bias Evaluation

Based on the results of data processing using RStudio, the following publication bias evaluation results were obtained:

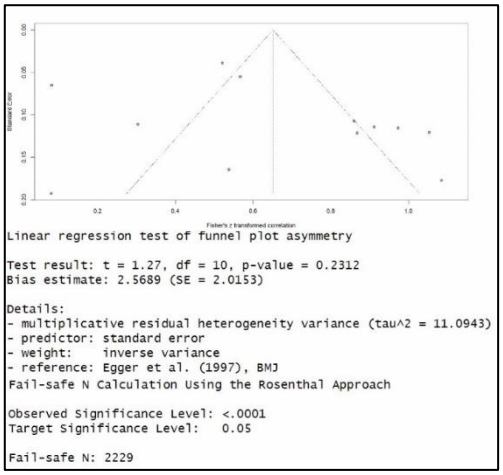

Figure 4. Publication Bias Evaluation

Based on Figure 4, the funnel plot shows that the effect sizes of the studies have varying magnitudes. The standard errors of the studies also have varying values. However, in general, the distribution of the effect size plot tends to be balanced on the right and left sides. This indicates that the distribution of the effect size plot is relatively symmetrical. This is reinforced by the results of Egger's test which shows that the funnel plot is confirmed to be symmetrical ($t = 1{,}27$; $p = 0{,}2312$). This indicates that there is no publication bias problem in this meta-analysis. In addition, the results of the fail-safe N analysis obtained a value of 2229. In this study, the value of $5K + 10$ yaitu $5(10) + 10 = 60$. Because the fail-safe N value is more than 70, this result further confirms that there is no publication bias problem in this meta-analysis.

Digital literacy is a basic skill that must be possessed by students in using the latest technological devices to facilitate understanding of learning materials. The development of information and communication technology has led to an abundance of digital information sources in society. Digital technology and digital literacy are important factors in the transformation of digital-based education and learning services.

Based on the discussed article Jaya & Sucipto (2023), it is explained that the role of digital technology in mathematics education at the high school level is studied in depth, showing that technology integration in high school classes is carried out in a more consistent and structured way compared to college. Interactive digital tools such as math apps, smart

boards, and online resources are used extensively to help students understand mathematical concepts visually and practically, increasing engagement and learning effectiveness (Mulyadi & Afriansyah, 2022).

In line with these findings, an article by UNICEF revealed that the integration of digital technology in the high school mathematics curriculum significantly improves student achievement (Manubey et al., 2022; UNICEF, 2021). The use of educational software, math apps and online resources not only helps students understand concepts visually and practically, but also increases their motivation and engagement (Mustari, 2023a). In addition, access to a variety of additional resources and personalized learning approaches allow students to learn at their own pace and learning style, resulting in deeper understanding and better academic achievement. The combination of a structured approach and the use of sophisticated technology makes learning mathematics at the high school level more effective and engaging.

The implementation of digital technology in mathematics learning at the high school level has shown significant positive impacts. For example, case studies in several schools highlight the use of interactive mathematics applications and educational software that have significantly improved student exam results. Digital literacy also helps students develop critical thinking, problem-solving, and collaboration skills, all of which are highly sought after in today's workplace. The use of technology in education significantly improves students' digital skills and prepares them for future challenges. In addition, strong digital literacy skills are positively associated with academic achievement and career readiness in the technology sector (Endrawati Subroto et al., 2023; Mustari, 2023b).

Mathematical digital literacy at the college level is often lower than that of high school students due to the different demands of higher education, such as independence in learning and the need for more advanced technology skills (An IEEE Futere Networks Program, n.d.). College students are faced with more complex academic tasks, such as research and task management, but many still lack basic technology skills (Aswan, 2023). In addition, technological innovations such as algorithms and AI are increasingly being used, but students often feel unprepared for them (Mulyati, 2023; Setiawati & Coesamin, 2023). Differences in access to technology between students also create gaps, with some students being more advanced due to previous experience, while others are left behind (Haldawari et al., 2024; Lingga et al., 2022). At the high school level, students receive more structured guidance in the use of technology, while in college independence is emphasized without adequate support.

The importance of research on digital literacy on students' mathematical abilities involves the development of critical thinking, problem-solving, and collaboration skills. In an ever-evolving workforce, these skills are becoming increasingly important for students to succeed in their careers. Therefore, further research on how digital literacy affects students' mathematical abilities will help us better understand the relationship between digital literacy, academic achievement, and career readiness in the digital age. In doing so, this research will not only provide new insights into education but also help prepare students for an increasingly technology-dependent future.

CONCLUSION

Based on the discussion that has been presented, it can be concluded that the integration of digital technology in mathematics learning, especially at the high school level, has a significant impact on improving student achievement. Through the use of interactive digital tools and mathematical applications, as well as the implementation of a structured and personalized learning approach, students can gain a deeper understanding of mathematical concepts. In addition, digital literacy also plays an important role in developing critical thinking, problem-solving, and collaboration skills, which are skills that are very much needed in the world of work. Research shows that the integration of digital technology in education not only improves students' digital skills but also prepares them for future challenges. However, at the college level, mathematical digital literacy tends to be lower than that of high school students. This is due to the difference in demands, where students are required to be more independent in learning and require more advanced technological skills. Although faced with more complex tasks such as research and task management, many students still lack basic skills in technology. Therefore, the importance of further research on digital literacy on mathematical abilities at the student level, because it can provide new insights into education and help prepare students for the increasingly developing digital era. Thus, the integration of digital technologies and the enhancement of digital literacy in mathematics education not only helps to improve students' academic achievement, but also prepares them for success in a future that is increasingly dependent on technology.

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