IndoMath Indonesia Mathematics Education
ISSN 2614-5103 (Print)
2614-5111 (online)
https://indomath.org/index.php/indomath
Vol 8, No. 1, February 20123, pp. 44-55

Meta-Analysis Study: Effectiveness of Using GeoGebra on Students' Mathematical Ability

Novita Maharani Anajihah
Department of Mathematics Education, Universitas Sarjanawiyata Tamansiswa,
novitamaharanianajihah@gmail.com

Fitria Sulistyowati
Departement of Mathematics Education, Universitas Sarjanawiyata Tamansiswa,
fitria.sulistyowati@ustjogja.ac.id

Esti Harini
Departement of Mathematics Education, Universitas Sarjanawiyata Tamansiswa,
esti@ustjogja.ac.id

Denik Agustito
Departement of Mathematics Education, Universitas Sarjanawiyata Tamansiswa,
agustito@ustjogja.ac.id

Zahra Nugraheni
Departement of Mathematics Education, Institut Agama Islam Negeri Ponorogo,
nugraheni@iainponorogo.ac.id

ABSTRACT

Traditional mathematics learning is often suboptimal. While technology like GeoGebra offers promise due to its visual representation capabilities, prior research on its impact on student mathematical ability is inconclusive This meta-analysis can clarify the influence of GeoGebra on students' mathematical abilities..This meta-analysis examines its overall effectiveness using 10 studies selected from Google Scholar and Scopus based on inclusion criteria. Data were analyzed using RStudio, revealing an overall effect size of 1.31, indicating a highly positive impact. The study also analyzed variability with four moderator variables: education level, publication type, control class type, and mathematical ability. Results show that GeoGebra significantly enhances mathematical abilities based on publication source and control type but is not influenced by education level. Notably, GeoGebra effectively improves students' conceptual understanding of mathematics, making it a valuable tool for enhancing mathematical skills in education. These findings emphasize the significant role of GeoGebra in fostering students' mathematical comprehension.

Keyword: GeoGebra, Mathematic Ability, Meta-Analysis

ABSTRAK

Pembelajaran matematika tradisional sering kali kurang optimal. Sementara teknologi seperti GeoGebra menjanjikan karena kemampuan representasi visualnya, penelitian sebelumnya tentang dampaknya pada kemampuan matematika siswa tidak meyakinkan. Meta-analisis ini dapat menjelaskan pengaruh GeoGebra pada kemampuan matematika siswa. Meta-analisis ini mengevaluasi efektivitas keseluruhannya dengan menganalisis 10 studi yang dipilih dari Google Scholar dan Scopus berdasarkan kriteria inklusi. Data dianalisis menggunakan RStudio, menunjukkan ukuran efek keseluruhan sebesar 1,31, yang mengindikasikan dampak yang sangat positif. Penelitian ini juga menganalisis

Copyright © Authors. This is an open access article distributed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

variabilitas berdasarkan empat variabel moderator: tingkat pendidikan, jenis publikasi, tipe kelas kontrol, dan kemampuan matematis. Hasil menunjukkan bahwa GeoGebra secara signifikan meningkatkan kemampuan matematis berdasarkan sumber publikasi dan tipe kontrol, tetapi tidak dipengaruhi oleh tingkat pendidikan. Secara khusus, GeoGebra terbukti efektif dalam meningkatkan pemahaman konseptual siswa terhadap matematika, sehingga menjadi alat yang bernilai untuk meningkatkan keterampilan matematis dalam pendidikan. Temuan ini menekankan peran penting GeoGebra dalam mendukung pemahaman matematis siswa.

Kata Kunci: GeoGebra, Kemampuan Matematis, Meta-Analisis

INTRODUCTION

Mathematical ability is the capacity to solve problems, both those related to mathematics and those encountered in everyday life situations. According to the National Council of Teachers of Mathematics (NCTM), there are five standards of mathematical proficiency: problem-solving, reasoning, communication, connection, and representation (NCTM, 2000). Mathematical ability plays a crucial role for students, as it equips them with knowledge and helps shape the attitudes and mindsets necessary to preserve and further develop the role of mathematics itself (Darwanto, 2019). Therefore, it is important to focus on strategies that can enhance students' mathematical abilities, one of which is the use of technology in mathematics education.

The integration of technology in learning environments can enhance understanding and improve the quality of educational systems (Attard & Holmes, 2020; Maritsa et al., 2021; Savec et al., 2018). The application of technology in innovative and assertive mathematics learning processes facilitates the development of essential skills and knowledge required to address the educational and societal demands of the 21st century (Adelabu et al., 2019; Chen et al., 2020; Maritsa et al., 2021; Tamur et al., 2018). Incorporating technology into learning provides additional opportunities for students to practice, explore their problems, and present their findings through various alternative solutions (Juandi & Priatna, 2018; Latif et al., 2020; Sung et al., 2016).

Implementing GeoGebra software is an effective way to integrate technology into mathematics learning. GeoGebra is a mathematical software that combines dynamic geometry tools in both 2D and 3D dimensions, a Computer Algebra System (CAS), and spreadsheet capabilities (Weinhandl et al., 2020). Utilizing GeoGebra enables students to visually represent geometric concepts more effectively, which is particularly beneficial for students with below-average levels of understanding (Mthethwa et al., 2020). This insight underscores the importance of integrating GeoGebra into geometry learning. Moreover, one of GeoGebra's advantages is its compatibility with all operating systems and its accessibility via the internet. Thus, it can be concluded that GeoGebra can enhance students' mathematical abilities. This statement is supported by several previous studies that demonstrate the positive impact of using GeoGebra in mathematics instruction on students' mathematical skills (Juandi & Priatna, 2018; Kusumah et al., 2020; Supriadi et al., 2014).

Several studies have been conducted previously to test the assumption regarding the use of GeoGebra in improving students' mathematical abilities. However, the findings from these studies show varying results. For example, Kustiawati found that the use of GeoGebra can enhance students' conceptual understanding of mathematics, especially in geometry topics (Kustiawati, 2016).

Similarly, Kusumah et al. reported that GeoGebra is effective in improving students' critical thinking and problem-solving skills in algebra (Kusumah et al., 2020). Septian & Prabawanto also demonstrated that the use of GeoGebra helps students better understand the connections between mathematical concepts and real-life situations (Septian & Prabawanto, 2020).

On the other hand, research by Priyono & Hermanto found that despite using GeoGebra, there were no significant differences in students' problem-solving abilities in mathematics compared to traditional teaching methods (Priyono & Hermanto, 2015). Similarly, Ramadhani reported that GeoGebra did not lead to significant improvements in students' mathematical representation skills (Ramadhani, 2017). Setyani & Lestarialso found that while using GeoGebra in learning was engaging for students, its impact on improving mathematical learning outcomes was not substantial (Setyani & Lestari, 2016). These varied findings indicate inconsistencies in the research results, suggesting the need for a deeper analysis to understand the factors that influence the success of using GeoGebra in mathematics education.

Based on the aforementioned gaps, efforts are needed to integrate the findings of primary studies to provide useful information for policy-making processes (Siddaway et al., 2019). Therefore, a meta-analysis is necessary to encompass all primary studies on the topic, aiming to produce more generalized findings compared to individual studies (Demirel & Dağyar, 2016). In the literature, several meta-analyses have been conducted to assess the effectiveness of mathematics learning assisted by GeoGebra software on students' mathematical abilities in general, as reported by (Juandi et al., 2021; Tamur, Juandi, & Kusumah, 2020). However, to date, meta-analyses evaluating the effectiveness of mathematics learning using GeoGebra software on students' mathematical abilities remain scarce and limited. On the other hand, the use of GeoGebra has become a growing trend among most teachers today (Kusumah et al., 2020). Hence, there is a need for educators to obtain compelling information to determine the circumstances under which mathematics learning supported by GeoGebra software can enhance the effectiveness of students' mathematical abilities.

Based on these reasons, this meta-analysis study was conducted to answer the research question: "How effective is the use of GeoGebra in improving students' mathematical ability compared to not using GeoGebra based on previous studies?". The findings of this study will contribute to the literature by providing valuable information for the future development and implementation of GeoGebra in mathematics education.

METHOD

This study employs a meta-analysis method by examining several articles published in national journals. The primary studies analyzed focus on the effects of using GeoGebra software in mathematics learning on students' mathematical abilities. In general, (Borenstein et al., 2021a) describe the stages of meta-analysis as follows: first, defining inclusion criteria for the studies to be analyzed; second, outlining procedures for collecting empirical data and coding study variables; and third, applying statistical techniques.

Inclusion Criteria

In this study, articles were filtered using the Publish and Perish (PoP) application and then selected based on the following criteria. All studies identified in the initial search were reviewed and assessed for inclusion in the meta-analysis using the following criteria:

1. The publication year range is between 2015 and 2024. This ensures that the studies are recent and reflect the current trends in educational technology, particularly the use of GeoGebra in mathematics education.
2. Studies were conducted in Indonesia and published in international or national journals or proceedings indexed in SINTA. This selection was made to focus on the geographical context of the research, ensuring the findings are relevant to the Indonesian educational setting, which may differ from other regions in terms of curriculum and educational practices.
3. The studies included at least one experimental class using GeoGebra-assisted learning and a control class without GeoGebra assistance. This criterion is essential for directly comparing the effects of GeoGebra on students' mathematical abilities to traditional teaching methods.
4. The articles reported statistical data, including the sample size, mean values, and standard deviations. This is necessary for performing quantitative meta-analysis, which relies on statistical measures to calculate effect sizes and draw conclusions about the effectiveness of GeoGebra in enhancing mathematical abilities.

Data Collection

The data for this meta-analysis were gathered from various credible sources, primarily academic databases such as Google Scholar and Scopus. The data collection process involved a systematic search using relevant keywords, such as "GeoGebra" and "mathematical abilities," as well as their equivalents in English, to ensure the accurate identification of all relevant publications related to the use of GeoGebra in mathematics learning. Based on the previously established inclusion criteria, a total of 10 articles were selected for analysis in this study.

Statistical Analysis

The calculations involved compiling the number of individuals in each class (n), the post-test mean scores, and the standard deviations of the control and experimental classes from all 10 selected articles. The collected data were tabulated using Microsoft Excel. Effect size calculations were performed using the Standardized Mean Difference (SMD) method to account for differences in the scoring scales of the data obtained.

The analysis was conducted using RStudio, utilizing syntax developed by Sara Balduzzi, Gerta Rucker, Guido Schwarzer (Balduzzi et al., 2019), and Wolfgang Viechtbauer (Viechtbauer, 2010). After calculating the effect size, a homogeneity test was performed to determine the appropriate analysis model by examining the Q-statistic and p-value. If $p < 0.05$, the distribution of effect sizes from the primary studies is considered heterogeneous, and the random-effects model is applied (Tamur, Juandi, & Adem, 2020).

Once the random-effects model was selected, an analysis of study variation through moderator variables was conducted. Published studies are generally more likely to be included in meta-analyses compared to unpublished studies, raising concerns that meta-analyses might overestimate the true effect size (Borenstein et al., 2021a).The study is considered resistant to bias if the distribution of effect sizes demonstrates symmetry around a vertical line (Bernard et al., 2014).

RESULT AND DISCUSSION

Result

The unit of analysis in meta-analysis is the effect size (Borenstein et al., 2021b; Israel & Richter, 2011; Kelley & Preacher, 2012). The purpose of this meta-analysis study is to determine the overall effect of using GeoGebra in mathematics learning on students' mathematical abilities. The first step of the analysis is calculating the SMD (Standardized Mean Difference) effect size for each primary study. Based on the calculations, the effect sizes of each study are presented in the summary effect analysis in Figure 1.

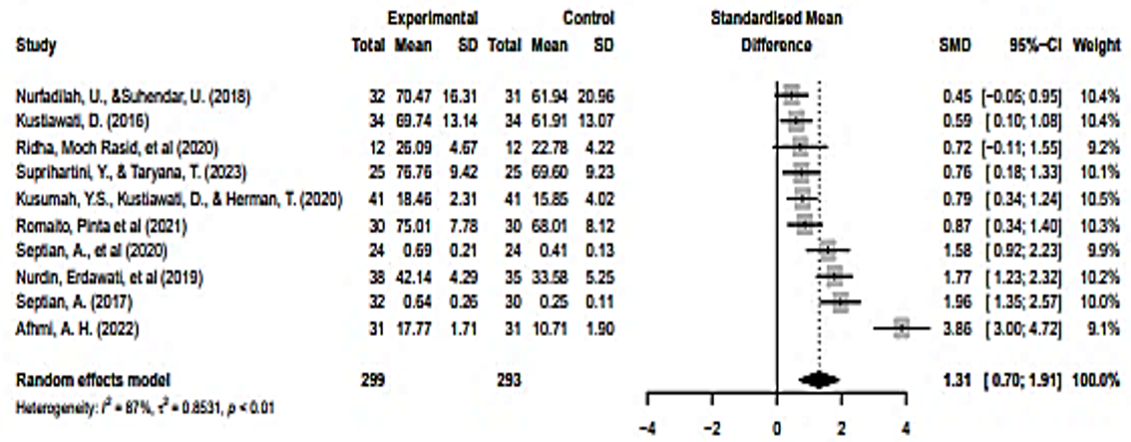


Figure 1. Analysis of Summary Effect

As shown in Figure 1, the data analysis results indicate that the effect sizes from the 10 studies range from 0.45 to 3.86. All studies (100%) report positive effect sizes, suggesting that students' mathematical abilities in the experimental group (using GeoGebra) were higher than in the control group (without GeoGebra). No studies showed a negative effect size, meaning that the use of GeoGebra consistently enhanced students' mathematical abilities compared to those in the control group. Overall, the effect sizes from the 10 studies suggest that the use of GeoGebra in mathematics learning has a significant and positive effect on students' mathematical abilities.

Using the random effects model, the analysis shows a Random Effect number of 299 with a prediction interval. The heterogeneity is indicated by I^2 = 87%, t^2 = 0.8531, and $p < 0.01$, with a Standardized Mean Difference (SMD) of 1.31. Therefore, this study reveals a significant effect of using GeoGebra on students' mathematical abilities. The aggregate effect size falls within the "moderate" category.

```
Test of heterogeneity:
     Q d.f.  p-value
 70.44    9 < 0.0001
```

Figure 2. Heterogeneity Test

The second stage is to conduct a heterogeneity test and estimation model. Based on the calculations, the results of the heterogeneity test are presented in Figure 2. In Figure 2, the Q-value is 70.44 with df = 9 and a p-value < 0.0001. Therefore, the distribution of effect sizes is found to be heterogeneous at $p < 0.05$ (indicating that the actual effect sizes vary from one study to another). Since the p-value < 0.05, it can be concluded that, overall, the use of GeoGebra in mathematics learning has a more significant impact on students' mathematical abilities compared to learning without GeoGebra. The level of variation in effect sizes across studies is reflected in the I^2 value of 87.2, which indicates that 87.2% of the observed variation in effect sizes is attributable to true heterogeneity (not due to sampling errors). Therefore, this study has high heterogeneity, as the I^2 value is ≥ 75%. Since the homogeneity test was rejected, the estimation model used is the random-effects model. The third stage involves checking for publication bias. The funnel plot of the study is presented in Figure 3.

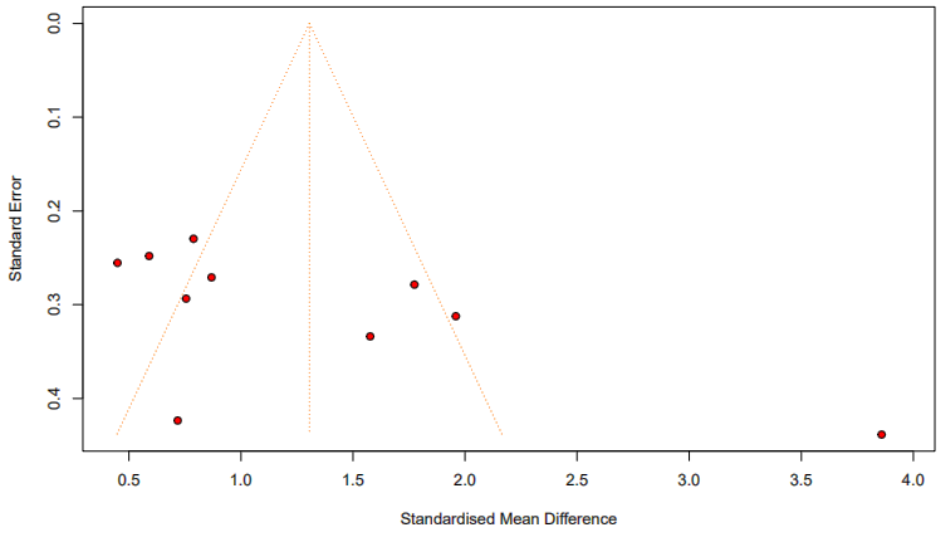


Figure 3. Funnel Plot

Based on Figure 3, it appears that the distribution of effect sizes is not fully symmetrical around the vertical line. Meanwhile, Figure 4 shows a bias estimate of 9.0898 > 1, meaning that the studies included in this analysis are resistant to publication bias. Therefore, no studies are missing or need to be added to the analysis due to publication bias.

```
Linear regression test of funnel plot asymmetry

Test result: t = 2.40, df = 8, p-value = 0.0434
Bias estimate: 9.0898 (SE = 3.7922)
```

Figure 4. Results of Funnel Plot Asymmetry Analysis

```
Fail-safe N Calculation Using the Rosenthal Approach

Observed Significance Level: <.0001
Target Significance Level:   0.05

Fail-safe N: 618
```

Figure 5. Results of Fail-safe N

The final stage involves analyzing the moderator variables to determine the contribution of each moderator variable to the variance differences among the effect sizes. The analysis of study characteristics is conducted by examining the influence of moderator variables on the 10 effect sizes from the 10 primary studies, including: education level, type of publication, type of control, and the type of mathematical ability measured. The results of the moderator variable analysis are presented in Figure 6.

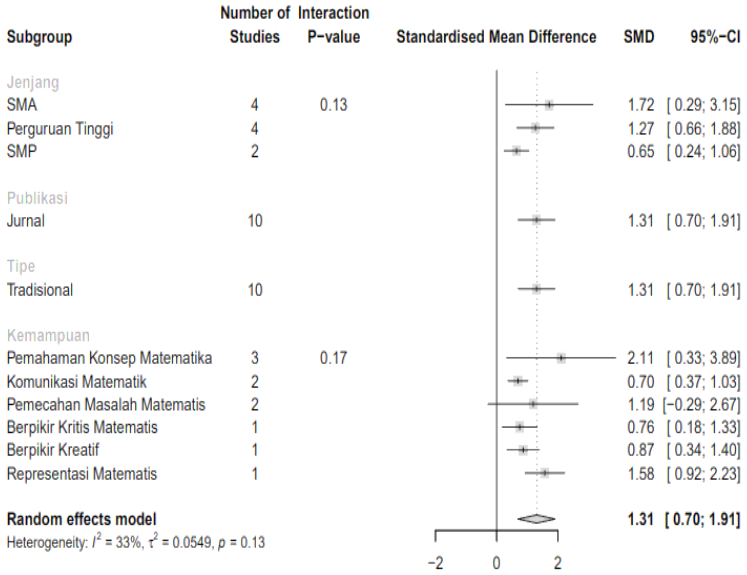


Figure 6. Results of Moderator Variable Analysis

Based on Figure 6, the analysis of the moderator variable for educational level reveals that the effect size at the high school level is 1.72, which is in the same category as the effect size at the college level, which is 1.27, while the effect size at the junior high school level is 0.65. The analysis shows that GeoGebra is effective in improving students' mathematical abilities at all education levels, with the largest effect observed at the high school level, followed by college and junior high school. The p-value was found to be 0.13 > 0.05. Since the p-value > 0.05, the effect size distribution for the three education level categories is homogeneous. Thus, no significant differences were found between education levels in the impact of GeoGebra on students' mathematical abilities.

Regarding the publication source, it was found that all studies analyzed were journal publications, so there were no differences in effect based on publication type. For the control group type, all studies analyzed used control classes with traditional teaching methods (without any technology), so there were no differences in effect based on the type of control class.

For the characteristic of mathematical abilities, the lowest effect size was found to be 0.70 in studies examining students' mathematical communication abilities. This is similar to the effect sizes for critical thinking abilities (0.76) and creative thinking abilities (0.87). The effect size for mathematical problem-solving ability was 1.19, which is not far from the effect size for mathematical representation ability, which was 1.58. The highest effect size was found in studies examining conceptual understanding of mathematics, with an effect size of 2.11. The p-value was found to be 0.17 > 0.05. Since the p-value > 0.05, the effect size distribution for the categories within the ability characteristics is homogeneous. Therefore, no significant differences were found in the effect of GeoGebra on various types of mathematical abilities.

Discussion

The analysis results show that the overall effect size of the studies, which is 1.31, indicates that mathematics learning using GeoGebra software has a large positive effect on students' mathematical abilities compared to learning without GeoGebra. This effect size suggests that, on average, students who received learning with GeoGebra outperformed 87.2% of students in the class without GeoGebra, who initially had equivalent mathematical abilities. The results of this meta-analysis of empirical studies revealed an overall effect size of 1.31, which is statistically significant and indicates a positive impact on the mathematical abilities of students who use GeoGebra compared to students who do not. This effect size implies that students who learn with GeoGebra outperform students in conventional learning conditions by 87.2%. This provides strong evidence for the effectiveness of GeoGebra technology-based learning.

Another finding in this study that deserves attention is the effect size by educational level. Based on the education level, it was found that the studies at the high school (SMA) level had a relatively larger effect size compared to those at the junior high school (SMP) and university levels. This finding is supported by a previous meta-analysis (Tamur, Juandi, & Kusumah, 2020), which investigated the variation in the results of primary studies based on education level. This indicates that the intervention has different impacts on students' mathematics ability in different education level groups. The finding that learning using GeoGebra at the Senior High School (SMA) level has a larger effect size compared to the Junior High School (SMP) level indicates that the intervention or learning method applied in SMA has a more significant impact on student learning outcomes. However, the large effect size of high school students compared to college students indicates that the use of GeoGebra at the college level needs to be reviewed. This is consistent with Dale’s Cone of Experience shown in Figure 7.

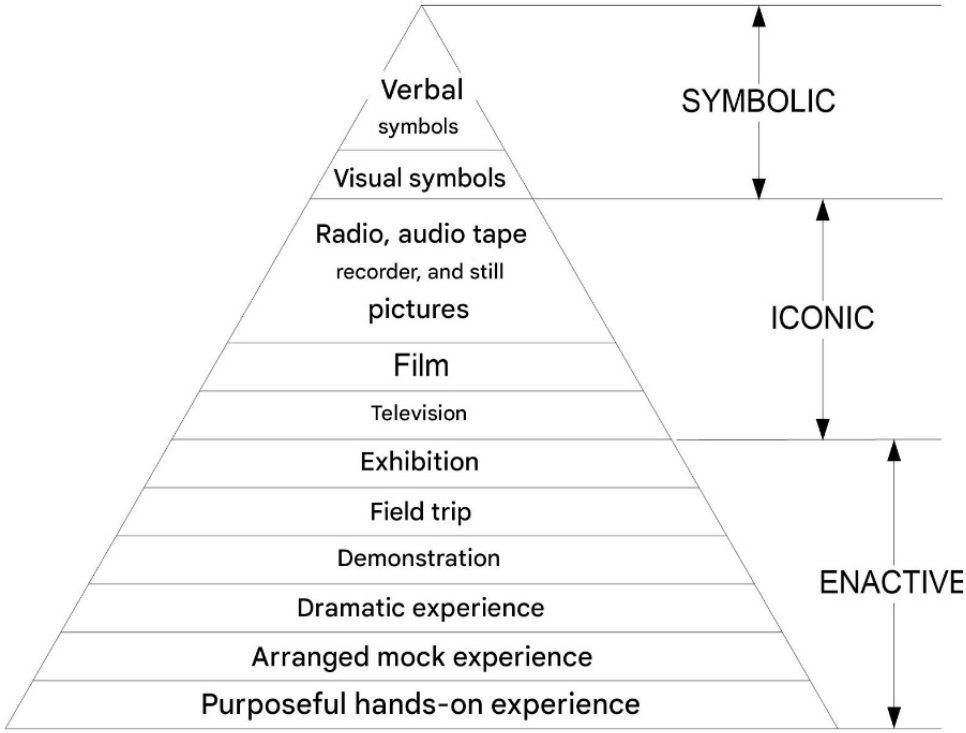


Figure 7. Dale's Cone Experience

Dale's Cone of Experience in Figure 7 depicts the stages of cognitive development adapted from Bruner's cognitive development (Dwyer, 2010; Lee & Reeves, 2017; Molenda, 2003). Cognitive development at the symbolic stage is the stage of learning when students can express concepts in the form of symbols, visuals and language (Çeliköz et al., 2016; Stapleton & Stefaniak, 2019). So that when students encounter a symbol, they will be able to recognize the concept marked by that symbol again (Çeliköz et al., 2016). At the symbolic stage, learning is represented in the form of abstract symbols, be it verbal symbols, for example words, letters, or sentences, mathematical symbols, or other abstract symbols (Williams, 2004). On the other hand, Piaget's cognitive theory at the formal operational stage states that students' cognitive development with abstract and symbolic reasoning occurs at the age of 12 years and above and will be better at a higher age (Ghazi et al., 2014). In other words, students over 12 years old with a higher age have better visual and symbolic abilities than students at a lower age. This is in line with the results of the meta-analysis conducted that high school students have a larger effect size than junior high school students in mathematical abilities because they are better able to visualize GeoGebra objects.

However, this study found that the effect size of college students was smaller than high school students in mathematical abilities. This shows that age differences are not always a benchmark for intervening with students. This result is consistent with the findings of the study by (Cheung & Slavin, 2013), which found that the effect size based on education level did not differ significantly. However, this result contrasts with the findings of (Tamur, Juandi, & Kusumah, 2020), which showed significant differences in effect sizes based on education level. The difference in these findings is a problem that can be explored further in future research. Therefore, it can be concluded that students' mathematical abilities through the use of GeoGebra in mathematics learning are not significantly

influenced by their level of education. However, it gives a larger effect size to high school students than junior high school students.

Based on students' mathematical abilities, the effect size shows that GeoGebra is most effective in enhancing students' conceptual understanding of mathematics compared to other abilities (mathematical representation, critical thinking, creative thinking, mathematical communication, and problem-solving skills). The analysis based on mathematical ability characteristics did not find any significant differences in the effects of using GeoGebra across various types of mathematical abilities. However, this finding has not yet been supported by similar studies. To address this limitation, further research is needed that specifically investigates the impact of GeoGebra on various types of mathematical abilities using a larger and more diverse sample. This additional research will help validate the current findings and provide a more comprehensive understanding of GeoGebra's effectiveness in improving students' mathematical abilities across different learning contexts.

Based on the findings and descriptions above, it can be said that GeoGebra has a significant impact on students' mathematical abilities, and is most effective in improving students' conceptual understanding of mathematics compared to other abilities (mathematical representation, critical thinking, creative thinking, mathematical communication, and problem-solving skills). Meanwhile, based on education level, GeoGebra has a more significant impact on high school students but less significant on college and junior high school students. This finding can be a reference for teachers at the secondary and college levels to better adjust GeoGebra-based learning that adjusts to their level of cognitive development.

CONCLUSION

The results of the meta-analysis indicate that from 10 studies discussing the use of GeoGebra software in mathematics learning, there is a significant positive impact on students' mathematical abilities compared to traditional learning without GeoGebra. The overall effect size of 1.31 suggests that teaching with GeoGebra has a large positive effect on students' mathematical abilities when compared to traditional teaching methods (without GeoGebra). Thus, it can be concluded that, overall, the use of GeoGebra software in mathematics education has a strong and more significant influence on students' mathematical abilities compared to teaching without GeoGebra.

Additionally, when considering various study characteristics, the use of GeoGebra to improve students' mathematical abilities is not influenced by the level of education. Therefore, GeoGebra is suitable for application at all three educational levels: junior high school, senior high school, and higher education. This study also reveals that GeoGebra is effective in enhancing students' conceptual understanding of mathematics. However, the use of GeoGebra does not show significant differences in improving other types of mathematical abilities, such as mathematical representation, critical thinking, creative thinking, mathematical communication, and problem-solving skills.

ACKNOWLEDGEMENT

The authors would like to thank LP2M Universitas Sarjanawiyata Tamansiswa for providing financial assistance in the implementation of research and publication. The authors would also like to thank all parties who have helped in the implementation of the research. Hopefully this research can be a reference for further research related to Geogebra Applet-based mathematics learning.

REFERENCES

Adelabu, F. M., Makgato, M., & Ramaligela, M. S. (2019). The importance of dynamic geometry computer software on learners' performance in geometry. *Electronic Journal of E-Learning*, *17*(1), pp52-63.

Attard, C., & Holmes, K. (2020). "It gives you that sense of hope": An exploration of technology use to mediate student engagement with mathematics. *Heliyon*, *6*(1).

Balduzzi, S., Rücker, G., & Schwarzer, G. (2019). How to perform a meta-analysis with R: a practical tutorial. *BMJ Ment Health*, *22*(4), 153–160.

Bernard, R. M., Borokhovski, E., Schmid, R. F., Tamim, R. M., & Abrami, P. C. (2014). A meta-analysis of blended learning and technology use in higher education: From the general to the applied. *Journal of Computing in Higher Education*, *26*, 87–122.

Borenstein, M., Hedges, L. V, Higgins, J. P. T., & Rothstein, H. R. (2021a). *Introduction to meta-analysis*. John Wiley & Sons.

Borenstein, M., Hedges, L. V, Higgins, J. P. T., & Rothstein, H. R. (2021b). *Introduction to meta-analysis*. John wiley & sons.

Çeliköz, N., Erişen, Y., & Şahin, M. (2016). Cognitive learning theories. *Learning and Teaching: Theories, Approaches and Models*, 31–45.

Chen, C.-H., Shih, C.-C., & Law, V. (2020). The effects of competition in digital game-based learning (DGBL): a meta-analysis. *Educational Technology Research and Development*, *68*(4), 1855–1873.

Cheung, A. C. K., & Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review*, *9*, 88–113.

Darwanto, D. (2019). Hard Skills Matematik Siswa: Pengertian dan Indikatornya. *Eksponen*, *9*(1), 21–27.

Demirel, M., & Dağyar, M. (2016). Effects of problem-based learning on attitude: A meta-analysis study. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(8), 2115–2137.

Dwyer, F. (2010). Edgar Dale's cone of experience: A quasi-experimental analysis. *International Journal of Instructional Media*, *37*(4), 431–438.

Ghazi, S. R., Khan, U. A., Shahzada, G., & Ullah, K. (2014). Formal Operational Stage of Piaget's Cognitive Development Theory: An Implication in Learning Mathematics. *Journal of Educational Research (1027-9776)*, *17*(2).

Israel, H., & Richter, R. R. (2011). A guide to understanding meta-analysis. *Journal of Orthopaedic & Sports Physical Therapy*, *41*(7), 496–504.

Juandi, D., Kusumah, Y., Tamur, M., Perbowo, K., Siagian, M., Sulastri, R., & Negara, H. (2021). *The effectiveness of dynamic geometry software applications in learning mathematics: A meta-analysis study*.

Juandi, D., & Priatna, N. (2018). Discovery learning model with geogebra assisted for improvement mathematical visual thinking ability. *Journal of Physics: Conference Series*, *1013*(1), 012209.

Kelley, K., & Preacher, K. J. (2012). On effect size. *Psychological Methods*, *17*(2), 137.

Kustiawati, D. (2016). Pembelajaran geometri berbantuan software geogebra terhadap kemampuan komunikasi matematik siswa. *JIPMat*, *1*(2).

Kusumah, Y. S., Kustiawati, D., & Herman, T. (2020). The Effect of GeoGebra in Three-Dimensional Geometry Learning on Students' Mathematical Communication Ability. *International Journal of Instruction*, *13*(2), 895–908.

Latif, B., Yuliardi, R., & Tamur, M. (2020). Computer-assisted learning using the Cabri 3D for improving spatial ability and self-regulated learning. *Heliyon*, *6*(11).

Lee, S. J., & Reeves, T. C. (2017). Edgar dale and the cone of experience. *Foundations of Learning and Instructional Design Technology*.

Maritsa, A., Salsabila, U. H., Wafiq, M., Anindya, P. R., & Ma'shum, M. A. (2021). Pengaruh teknologi dalam dunia pendidikan. *Al-Mutharahah: Jurnal Penelitian Dan Kajian Sosial Keagamaan*, *18*(2), 91–100.

Molenda, M. (2003). Cone of experience. *Educational Technology: An Encyclopedia*, 161–165.

Mthethwa, M., Bayaga, A., Bossé, M. J., & Williams, D. (2020). GeoGebra for learning and teaching: A parallel investigation. *South African Journal of Education*, *40*(2).

NCTM. (2000). Principles and Standards for School Mathematics. *Reston, VA: National Council of Teachers of Mathematics*.

Priyono, S., & Hermanto, R. (2015). Peningkatan kemampuan representasi matematik peserta didik dengan menggunakan model problem based learning (PBL) berbantuan media software Geogebra. *JP3M (Jurnal Penelitian Pendidikan Dan Pengajaran Matematika)*, *1*(1), 55–64.

Ramadhani, R. (2017). PERBEDAAN PENINGKATAN SELF EFFICACY MATEMATIS ANTARA SISWA YANG MENDAPAT PEMBELAJARAN PENEMUAN TERBIMBING BERBANTUAN GEOGEBRA DENGAN TANPA BERBANTUAN GEOGEBRA DI SMPN 22 MEDAN. *JURNAL PENELITIAN PENDIDIKAN MIPA*, *2*(1), 159–165.

Savec, V. F., Hrast, Š., Šuligoj, V., & Avsec, S. (2018). The innovative use of ICT in STEM teacher training programmes at the University of Ljubljana. *World Trans. Eng. Tech. Edu*, *16*(4), 421–427.

Septian, A., & Prabawanto, S. (2020). GeoGebra in integral areas to improve mathematical representation ability. *Journal of Physics: Conference Series*, *1613*(1), 012035.

Setyani, N., & Lestari, H. P. (2016). Efektivitas Pembelajaran Matematika Dengan Model CPS (Creative Problem Solving) Berbantuan Geogebra Ditinjau Dari Prestasi Belajar Dan Kreativitas Siswa Kelas VIII SMP PGRI Tegalsari Kabupaten Purworejo. *Jurnal Pedagogi Matematika*, *5*(7).

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: a best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. *Annual Review of Psychology*, *70*, 747–770.

Stapleton, L., & Stefaniak, J. (2019). Cognitive constructivism: Revisiting Jerome Bruner's influence on instructional design practices. *TechTrends*, *63*, 4–5.

Sung, Y.-T., Chang, K.-E., & Liu, T.-C. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Computers & Education*, *94*, 252–275.

Supriadi, N., Kusumah, Y. S., Sabandar, J., & Afgani, J. D. (2014). Developing High-order mathematical thinking competency on high school students' through GeoGebra-assisted blended learning. *Mathematical Theory and Modeling*, *4*(6), 57–66.

Tamur, M., Juandi, D., & Adem, A. M. G. (2020). Realistic mathematics education in Indonesia and recommendations for future implementation: A meta-analysis study. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, *4*(1), 17–27.

Tamur, M., Juandi, D., & Kusumah, Y. S. (2020). The Effectiveness of the Application of Mathematical Software in Indonesia; A Meta-Analysis Study. *International Journal of Instruction*, *13*(4), 867–884.

Tamur, M., Sennen, E., & Men, F. E. (2018). Konsep Dasar Matematika Berbasis CAS dan DGS. *STKIP St. Paulus Ruteng*.

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software*, *36*(3), 1–48.

Weinhandl, R., Lavicza, Z., Hohenwarter, M., & Schallert, S. (2020). Enhancing flipped mathematics education by utilising GeoGebra. *International Journal of Education in Mathematics, Science and Technology*, *8*(1), 1–15.

Williams, R. T. (2004). Social cognitive theories of jean piaget and jerome bruner. 高松大学紀要, *41*, 117–123.