JPPIPA 10(5) (2024)

Jurnal Penelitian Pendidikan IPA

*Journal of Research in Science Education*

http://jppipa.unram.ac.id/index.php/jppipa/index

# How Multimedia Learning Enhances Students' Mathematical Creativity in Science Education: A Meta-Analysis Study

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Received: September 11, 2023
Revised: February 22, 2024
Accepted: May 25, 2024
Published: May 31, 2024

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DOI: 10.29303/jppipa.v10i5.5273



**Abstract:** Many studies have examined the impact of multimedia learning on students' mathematical creativity, but the results are mixed. As multimedia learning has been researched for decades in various subjects and schools, this meta-analysis study aims to synthesize the latest findings on the impact of multimedia learning, particularly on students' mathematical creativity in science learning. Data were obtained from relevant primary research published in national and international journals or proceedings during 2016-2023. This research design uses a meta-analysis approach by analyzing 33 effect size studies that meet the inclusion criteria using systematic review and meta-analysis. The role of science in this context is to ensure that an understanding of students' mathematical creativity is accompanied by a deep understanding of the underlying scientific principles. JASP software was used to measure the Hedges g formula to determine the effect size. The results showed that multimedia learning influences students' mathematical creativity (gRE = 0.768; 95% CI [0.654; 0.882]; $p < 0.001$) when compared to traditional learning. The results of this study provide important information for further meta-analysis studies and the application of multimedia learning to improve students' mathematical creativity in science learning.

**Keywords:** Mathematical creativity; Meta-analysis; Multimedia learning

## Introduction

Creativity has meaning in a sociocultural context that defines certain innovations as novel and creative (Glăveanu et al., 2019). Ambiguity reduction in ethnic leadership can be minimized by managing the scope that supports students' mathematical creativity (Chen & Hou, 2016). An appropriate leader can shape three different aspects of creativity in a group: increasing the creativity of the group, increasing the average creativity of members, and reducing the spread of creativity among group members (Tu et al., 2019). A school of thought that adopts an individualized approach to creativity that focuses on the psychological aspects that influence the creative process (Ilha Villanova & Pina e Cunha, 2021). This highlights that the outcomes of everyday creativity can be personally meaningful creative experiences; that is, they can only be new and important to their creators, regardless of social recognition.

Creativity has been shown to significantly improve student outcomes, employability, productivity, and career advancement prospects (Dickens, 2020; Jahnke et al., 2017). Improved creative thinking skills are strongly correlated with higher student performance, better learning practices, and more opportunities for innovation (Hughes et al., 2018; Rambe et al., 2016). Creativity connects students' imagination to the context of the problem and connects the pre-existing knowledge needed to solve the mathematical modeling problem through questions or statements that indirectly lead to an answer (Nuryadi & Hartono, 2021). In line with Papadakis (2016), he concluded that the experience of teachers as creative individuals in their field is related to the extent to which innovation is introduced into the classroom.

**How to Cite:**
Al-Amin, Y., & Hartono. (2024). How Multimedia Learning Enhances Students’ Mathematical Creativity in Science Education: A Meta-Analysis Study . *Jurnal Penelitian Pendidikan IPA*, *10*(5), 234–241. https://doi.org/10.29303/jppipa.v10i5.5273

Creativity in general has been shown to be an important prerequisite for creative activity as it facilitates the incorporation of original ideas and consideration of other approaches (Pitta-Pantazi et al., 2018). Mathematical creativity showed positive relationships with intelligence, math fluency and overall creativity, but only general creativity and arithmetic intelligence could best explain the differences in mathematical creativity (Meier et al., 2021). Therefore, it is important not to suppress irrelevant information but to continuously update information in working memory to create new combinations, which are essential for creativity (Stolte et al., 2020). In this manner, it is vital to investigate better approaches to upgrade students' mathematical creativity.

Multi means a number or plural, and media means the medium that conveys a message or information such as text, images, audio or video; as such, in language, the term multimedia is a combination of several or more mediums, such as text, images, audio or video, that are used to convey a message or information (Herman et al., 2022). Interactive learning media, or Multimedia, is one way to facilitate math learning that is more interactive and fun for students (G. Li & Liu, 2023). In an interactive learning environment, students can be more actively involved in learning and can develop mathematical creativity through interactive and immersive hands-on experiences (Chipangura & Aldridge, 2017). Stages of successful multimedia learning model implementation include the use of computers in learning activities, use of audio-visual devices, selection of learning materials, selection of software and interactivity and technology selection (Hakim & Solechan, 2018).

In fact, there are still many schools that are not equipped with multimedia tools, and although there are tools, the problem is that there are still teachers who have not mastered the operation of multimedia (gaptek) so it will hinder virtual teaching. online), which also has an impact on students' delays in developing their creativity (Simanungkalit et al., 2022). Not all learning spaces where multimedia is used can be considered beneficial for learning, especially those that are not under teacher supervision (Krieglstein et al., 2022). In addition, Mayer (2001), The understanding gained in multimedia learning can be referred to in two categories: storage and transfer.

Media search has also made great progress in image or video content analysis, media search and recommendation, media streaming, media content distribution, and more (B. Li et al., 2013). Multimedia document discovery methods help extract meaningful patterns from documents and provide useful knowledge for various applications (Pushpalatha & Ananthanarayana, 2020). The multimodal nature of media data drives machine learning to develop various emerging techniques to be able to capture and model heterogeneous characteristics of media data (Zhu et al., 2020). Similarity search has always been a very fundamental research topic in multimedia information retrieval. A good similarity search strategy requires not only accuracy but also efficiency (Gionis et al., 1999). The evolution of educational technology has allowed instructional designers to provide more and more images, diagrams, and screens in the learning environment.

The rapid development of digital and online resources is accompanied by a rapid increase in information stimulation, thus driving the trend towards designing complementary multimedia learning environments (Mayer, 2017). Multimedia learning is one of the theories that has grown rapidly with the widespread use of technology in education and the increasing ability to design learning environments that stimulate more than one channel (Park et al., 2019). Therefore, instructional designers should consider how learners process new information when designing visual displays and how certain design techniques can aid learning (Renkl & Scheiter, 2017; Schroeder & Cenkci, 2018).

According to the results of previous research the increase in student learning outcomes using lectora-assisted multimedia is due to the learning system using lectora-assisted multimedia making the material presented more interesting (Nurdiansah et al., 2017). Many students use multimedia as a learning resource, especially encyclopedias that can be accessed online, as the information contained in German literature is not widely available in libraries (Dewi, 2019). For students who are taught with a multimedia-based inquiry learning strategy, the level of creativity affects learning outcomes, which is shown to be a significant difference between groups of students with high levels of creativity and groups of students with low levels of creativity (Sormin, 2016). Therefore, research on the use of multimedia to improve students' mathematical creativity can provide valuable insights for the development of more effective and efficient mathematics learning methods.

This study aims to determine whether there is a significant relationship between multimedia learning and students' mathematical creativity in science learning. This study contributes to development research that develops learning multimedia and aims to improve students' mathematical creativity. These results can be useful for developers who are determining how their products compare to national trends and for researchers who want to gain an understanding of the correlation between multimedia and mathematical creativity. Although this study understands that multimedia is tailored to meet the needs of everyone, we can still gain insight by looking at the overview of previous research on multimedia devoted to improving students' mathematical creativity in science learning.

## Method

*Research Design*

This meta-analysis aims to determine whether there is a correlation between learning science using multimedia and students' mathematical creativity. There are three main steps in (Borenstein et al., 2015), as described in the following sections.

*Inclusion Criteria*

The databases used were SCOPUS, Education Resources Information Center (ERIC), JSTOR, ProQuest, IOP Science, and SAGE. The inclusion criteria used to screen the research publications were: Search keywords: "Multimedia", "interactive", "science learning", "mathematics instruction", "Creative", "creative thinking", "creative in school", "elements of creativity", "school's creativity", "sources of creativity", "students of creativity", "teacher's creativity", "creative education". The year of publication ranges from 2016 to 2023. Quantitative research between multimedia and students' mathematical creativity. Mathematical creativity variables that use instruments in the form of math test questions in science learning. Each article has a minimum sample of 25 participants. The article must report effect size data that shows the magnitude of the influence of multimedia in promoting students' mathematical creativity in science learning.

*Data Collection Technique*

A total of 33 articles were reviewed for the meta-analysis. The appropriate sample size for this study ranged from N=30 to N=60. The study subjects were students who participated in learning science with multimedia.

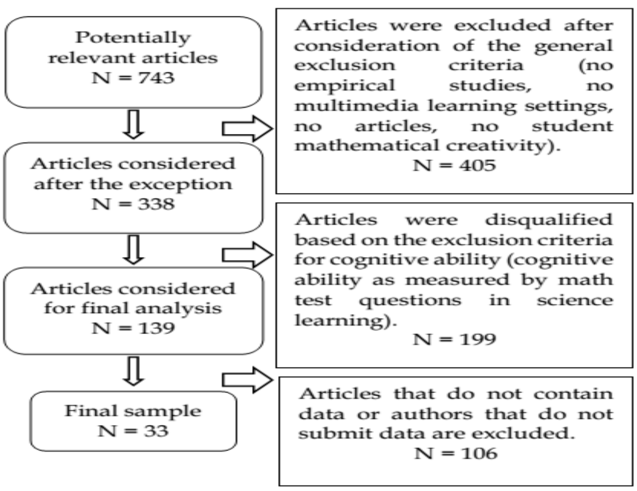


**Figure 1.** Data collection technique

*Data Analysis Technique*

To get the magnitude of the effect of the application of multimedia learning on students' mathematical creativity, the analysis was carried out using the Hedges equation 1:

$$\text{Hedges's } g = \frac{X_1 - X_2}{S_{within}} \tag{1}$$

The **g** values obtained can be categorized into five categories presented in Table 1.

**Table 1.** Effect Size Category

| Interval Effect Size (ES) | Category |
|---|---|
| $-0.15 \le ES < 0.15$ | Neglected effect |
| $0.15 \le ES < 0.40$ | Low effect |
| $0.40 \le ES < 0.75$ | Medium effect |
| $0.75 \le ES < 1.10$ | High effect |
| $1.10 \le ES < 1.45$ | Very high effect |
| $ES \ge 1.45$ | Very good effect |

The data analysis of this study was carried out with the help of the Comprehensive Meta-Analysis (CMA) application.

## Result and Discussion

The aim of this meta-analysis was to investigate the significant correlation between multimedia learning and students' mathematical creativity in science learning. Students' mathematical creativity in science learning refers to students' ability to use mathematical concepts and skills to solve problems related to natural science. It involves applying mathematical concepts such as calculation, measurement, statistics, and modeling to analyze, interpret, and conclude in the context of natural science.

The following will discuss the results of the analysis whether they are in accordance with the assumptions. Regarding the correlation of multimedia learning and mathematical creativity, the analysis showed satisfactory results. Answering questions about the effectiveness of learning multimedia in enhancing creativity, 60% (n=24) rated it very effective, 35% (n=14) rated it average, 3% (n=1) rating is not high effective, while 3% (n=1) is said to be ineffective. These results reflect students' growing awareness about the importance of using multimedia-based technology in the learning process to enhance students' understanding of creativity. Most students (70%, n=28) agreed that multimedia-based learning can help them to get more creative ideas in a shorter time. In addition, 80% (n=32) of students believe that multimedia tools can enhance their creativity. These results indicate that students have a positive attitude towards using multimedia tools to enhance their creativity.

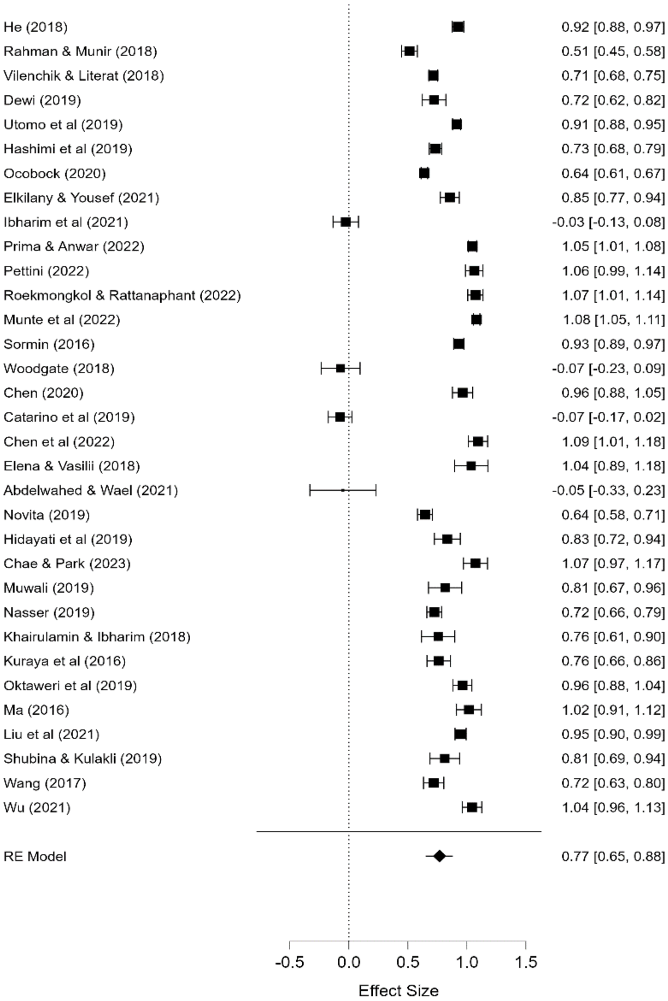


**Figure 2.** Forest plot for effect sizes

**Table 2.** Coefficient Effect Size

| Coefficients | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval | |
| | Estimate | Standard Error | z | p | Lower | Upper |
| intercept | 0.768 | 0.058 | 13.218 | < .001 | 0.654 | 0.882 |

*Note.* Wald test.

In the 33 meta-analysis effect sizes ranged from 0.654 to 0.882. This explains that the study reported the effect of multimedia on students' mathematical creativity better than the control group. Learning media can clarify the presentation of messages and information so that it can facilitate and improve the learning outcome process. In addition, procedural mathematical creativity will be successful if students try to understand the problem, connect, and represent between related mathematical concepts, and generalize the problem. Results show a positive correlation between multimedia learning and students' mathematical creativity. As in Chai et al. (2018), the study discussed the correlation between multimedia usability and creativity, and they showed a positive correlation in relation to the usefulness and use of multimedia in lesson planning.

The results of the analysis showed that 29 out of 33 studies had a positive effect size, indicating the influence of multimedia on creativity. The sample size in the meta-analysis ranged from 46 to 98 students (experimental and control class samples combined). Figure 2 shows the effect size of all studies. The results of the primary analysis showed that there was a significant effect of multimedia application on students' mathematical creativity (gRE = 0.768; 95% CI [0.654; 0.882]; $p < 0.001$). Summary effect is 0.297; when compared with Cohen's classification (Table 1) the value is in the High category. Therefore, it can be concluded that there is an effect of multimedia application on students' mathematical creativity. These results suggest that multimedia can be effective in enhancing creativity in learning. Therefore, teachers or educators should be encouraged to use this multimedia application in learning (Al Hashimi et al., 2019).

To test the structural validity of the correlation between multimedia learning and mathematical creativity, widely accepted definitions were followed to provide an ideal and high degree of consistency between measurement results and the theoretical assumptions on which they are based. Multimedia used in the learning process will improve students' mathematical thought process to be more creative (Chen et al., 2022). In this case, the application of multimedia can be implemented in the learning process at school and multimedia can be used as a means of increasing students' mathematical creativity in science learning.

**Table 3.** Fixed and Random Effects

| | Q | df | p |
|---|---|---|---|
| Omnibus test of Model Coefficients | 58.896 | 1 | < .001 |
| Test of Residual Heterogeneity | 524.890 | 32 | < .001 |

*Note.* *p* -values are approximate.
*Note.* The model was estimated using Restricted ML method.

In 33 studies confirmed that the heterogeneity test showed there was a significant difference in variance of effect sizes (Q = 524.890; $p < 0.001$). This suggests the potential for analyzing moderator variables to uncover the source of variance between effect sizes. Following is the analysis of moderator variables in this meta-analysis study.

**Table 4.** Egger's Test

| Regression test for Funnel plot asymmetry ("Egger's test") | | |
|---|---|---|
| | z | p |
| sei | -3.105 | 0.002 |

To check for publication bias, we used several methods, namely Funnel plot and Egger test. Figure 2 shows the overall effect size study from the Funnel plot analysis. Whether or not the effect size distribution is within the symmetry of the Funnel plot is checked using the Egger test. The Egger test result is z = -3.105 and p = 0.002, which confirms that the effect size distribution is symmetrical. These results indicate that there was no publication bias in this meta-analysis study. Multimedia-based teaching methods can be recognized as one of the most effective parts of educational tools to create a learning environment that makes students directly involved and provides situations and opportunities to enhance students' creativity and academic subjects (Mishra & Koehler, 2006). As Livingston (2010) suggests, by utilizing new technologies and linking the use of the Internet into the learning process can create space for increased creativity in education.

**Table 5.** File Drawer Analysis

File Drawer Analysis

| | Fail-safe N | Target Significance | Observed Significance |
|---|---|---|---|
| Rosenthal | 10358.000 | 0.050 | < .001 |

Furthermore, in this study the fail-safe N is 10358 (= 0.05; p < 0.001). The number of studies (k) is 33 so the value of 5k + 10 = 5(33) + 10 is 175. Since the fail-safe N is 10358 and higher than the value of 5k + 10, it can be concluded that there is no publication bias in this meta-analysis study. Research on creativity in education has shown a strong relationship between the learning strategies used in the classroom and students' levels of creative thinking (Elkilany & Yousef, 2021). Support to continue to improve student creativity must continue to be carried out either through related institutions or in the field of research.

Creativity is the most asset a person has for continuous evolution (Brand et al., 2015). Creativity is something that can be highly valued or not valued at all because there is no general-purpose agreement on its meaning, although it has a broad meaning. The characteristics of a creative person range from the ability to think divergently, to be imaginative, to enjoy challenges to persevere in doing things (Amrullah et al., 2018). Encouraging students' mathematical creativity in science learning requires a student-centered learning approach, emphasis on problem solving, use of relevant technology, and facilitating collaboration between students to exchange ideas and solutions. Thus, students can better develop mathematical skills and understand their application in the context of natural science.

The educational context must represent the conditions and availability of resources in which creative learning is encouraged, assessed, monitored, and managed. These studies only came from reviews and overviews, so the number of studies analyzed was relatively small compared to meta-analysis studies. Therefore, further meta-analysis studies of recent research findings are needed and are not limited to research published in journals and proceedings, but also supplemented by other sources (e.g., theses and bachelor theses).

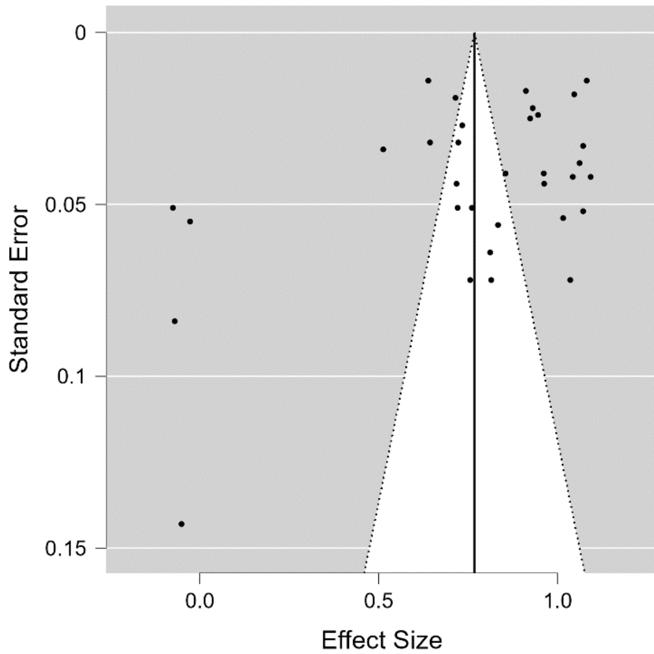

**Figure 3.** Funnel plot and effect sizes

Hopefully, this will strengthen the findings of this meta-analysis study and allow for broader generalization. Further research could reveal the impact of other moderator variables, such as the type of instrument to test creativity and the country where the study was conducted. Analyzing the impact of country on the effect of multimedia on creativity is interesting, allowing us to explore whether the effect of multimedia is the same across countries. However, the challenge is that such a study should involve many studies spread across different countries.

## Conclusion

This meta-analysis synthesized 33 studies on the effectiveness of multimedia on students' mathematical creativity in science learning. The results of this meta-analysis provide empirical evidence that multimedia implementation has High effect on students' mathematical creativity compared with traditional learning models. The results confirm that multimedia may be used as an alternative learning model that can be applied at various school levels to improve students' mathematical creativity in science learning. In addition, this meta-analysis study also revealed that the effectiveness of multimedia on mathematical creativity can also be influenced by the time of research implementation and sampling techniques. This needs to be considered and considered by researchers when using multimedia as an intervention in the learning process. For further meta-analysis studies, it is recommended to synthesize research on how learning media can facilitate students in increasing their interest in learning so that it has an impact on trained creativity. Furthermore, future research should investigate whether problem-based learning materials can explain the relationship between multimedia and students' mathematical creativity in science learning. Therefore, future research should involve more primary studies so that the findings obtained are more comprehensive.

**Acknowledgments**
The author thanks everyone who participated in helping to conduct the research.

**Funding**
This work received no specific grant from any public, commercial, or not-for-profit funding agency.

**Conflicts of Interest**
The authors declare no conflict of interest.

## References

Al Hashimi, S., Al Muwali, A., Zaki, Y., & Mahdi, N. (2019). The effectiveness of social media and multimedia-based pedagogy in enhancing creativity among art, design, and digital media students. *International Journal of Emerging Technologies in Learning*, *14*(21), 176–190. https://doi.org/10.3991/ijet.v14i21.10596

Amrullah, S., Tae, L. F., Irawan, F. I., Ramdani, Z., & Prakoso, B. H. (2018). Studi Sistematik Aspek Kreativitas dalam Konteks Pendidikan. *Psympathic : Jurnal Ilmiah Psikologi*, *5*(2), 187–200. https://doi.org/10.15575/psy.v5i2.3533

Borenstein, M., Hedges, L. V., & Rothstein, H. R. (2015). Introduction to meta-analysis. In *Leadership and Organizational Outcomes: Meta-Analysis of Empirical Studies*. https://doi.org/10.1007/978-3-319-14908-0_2

Brand, G., Hendy, L., & Harrison, R. (2015). Mining the Gap! Fostering Creativity and Innovative Thinking. *Procedia Technology*, *20*(July), 79–84. https://doi.org/10.1016/j.protcy.2015.07.014

Chai, J. X., & Fan, K. K. (2018). Constructing creativity: Social media and creative expression in design education. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(1), 33–43. https://doi.org/10.12973/ejmste/79321

Chen, A. S. Y., & Hou, Y. H. (2016). The effects of ethical leadership, voice behavior and climates for innovation on creativity: A moderated mediation examination. *Leadership Quarterly*, *27*(1), 1–13. https://doi.org/10.1016/j.leaqua.2015.10.007

Chen, Y. C., Tsui, P. L., Lee, C. S., Chiang, M. C., & Lan, B. K. (2022). Incorporating Multimedia Teaching Methods and Computational Thinking into the Baking Dessert Course. *Electronics (Switzerland)*, *11*(22). https://doi.org/10.3390/electronics11223772

Chipangura, A., & Aldridge, J. (2017). Impact of multimedia on students' perceptions of the learning environment in mathematics classrooms. *Learning Environments Research*, *20*(1), 121–138. https://doi.org/10.1007/s10984-016-9224-7

Dewi, N. (2019). Cognition, conscience, and creativity: Multimedia-based literature teaching for pre-service teachers in Indonesia. *3L: Language, Linguistics, Literature*, *25*(2), 86–98. https://doi.org/10.17576/3L-2019-2502-07

Dickens, A. J. (2020). Educating for Creativity within Higher Education: Integration of Research into Media Practice. In *The Wabash Center Journal on Teaching*, *1*(1). https://doi.org/10.31046/wabashjournal.v1i1.1600

Elkilany, E. A., & Yousef, W. (2021). Cultivating Creativity of Graphic Design and Multimedia Students: The Perceptions of Arab Faculty and Experts. *SAGE Open*, *11*(4). https://doi.org/10.1177/21582440211058198

Gionis, A., Indyk, P., & Motwani, R. (1999). Similarity Search in High Dimensions via Hashing. In *Proceedings of the 25th International Conference on Very Large Data Bases* (Vol. 99, No. 6, pp. 518-529). Retrieved from http://dl.acm.org/citation.cfm?id=645925.671516

Glăveanu, V. P., Hanchett Hanson, M., Baer, J., Barbot, B., Clapp, E., Corazza, G., Hennessey, B., Karwowski, M., Kaufman, J., & Lebuda, I. (2019). Advancing Creativity Theory and Research A Socio-cultural Manifesto. *Journal of Creative Behavior*, *54*(3), 741–745. https://doi.org/10.1002/jocb.395

Hadi, S. (2017, May). Efektivitas penggunaan video sebagai media pembelajaran untuk siswa sekolah dasar. In *Seminar Nasional Teknologi Pembelajaran Dan Pendidikan Dasar 2017* (pp. 96-102) Retrieved from https://core.ac.uk/download/pdf/267023793.pdf

Hakim, F. N., & Solechan, A. (2018). Design and implementation multimedia learning success for vocational schools. *International Journal of Electrical and Computer Engineering*, *8*(2), 1067–1073. https://doi.org/10.11591/ijece.v8i2.pp1067-1073

Herman, Shara, A. M., Silalahi, T. F., Sherly, & Julyanthry. (2022). Teachers' Attitude towards Minimum Competency Assessment at Sultan Agung Senior High School in Pematangsiantar, Indonesia. *Journal of Curriculum and Teaching*, *11*(1), 1–14. https://doi.org/10.5430/jct.v11n2p1

Howland, J. L., & Moore, J. L. (2002). Student perceptions as distance learners in internet-based courses. *Distance Education*, *23*(2), 183–195. https://doi.org/10.1080/0158791022000009196

Hughes, D. J., Lee, A., Tian, A. W., Newman, A., & Legood, A. (2018). Leadership, creativity, and innovation: A critical review and practical recommendations. *Leadership Quarterly*, *29*(5), 549–569. https://doi.org/10.1016/j.leaqua.2018.03.001

Ilha Villanova, A. L., & Pina e Cunha, M. (2021). Everyday Creativity: A Systematic Literature Review. *Journal of Creative Behavior*, *55*(3), 673–695. https://doi.org/10.1002/jocb.481

Jahnke, I., Haertel, T., & Wildt, J. (2017). Teachers' conceptions of student creativity in higher education. *Innovations in Education and Teaching International*, *54*(1), 87–95. https://doi.org/10.1080/14703297.2015.1088396

Khusniyah, N. L., & Hakim, L. (2019). Efektivitas Pembelajaran Berbasis Daring: Sebuah Bukti Pada Pembelajaran Bahasa Inggris. *Jurnal Tatsqif*, *17*(1), 19–33. https://doi.org/10.20414/jtq.v17i1.667

Krieglstein, F., Beege, M., Rey, G. D., Ginns, P., Krell, M., & Schneider, S. (2022). A Systematic Meta-analysis of the Reliability and Validity of Subjective Cognitive Load Questionnaires in Experimental Multimedia Learning Research. In *Educational Psychology Review* (Vol. 34, Issue 4). Springer US. https://doi.org/10.1007/s10648-022-09683-4

Lee, J. (2018). The effects of knowledge sharing on individual creativity in higher education institutions: Socio-technical view. *Administrative Sciences*, *8*(2). https://doi.org/10.3390/admsci8020021

Li, B., Wang, Z., Liu, J., & Zhu, W. (2013). Two decades of internet video streaming: A retrospective view. *ACM Transactions on Multimedia Computing, Communications and Applications*, *9*(1 SUPPL), 1–20. https://doi.org/10.1145/2505805

Li, G., & Liu, W. (2023). Multimedia data processing technology and application based on deep learning. *Advances in Multimedia*. https://doi.org/10.1155/2023/4184425

Livingston, L. (2010). Teaching creativity in higher education. *Arts Education Policy Review*, *111*(2), 59–62. https://doi.org/10.1080/10632910903455884

Mayer, R. E. (2001). *Multimedia Learning*. Cambridge University Press. https://doi.org/10.1017/CBO9781139164603

Mayer, R. E. (2017). Using multimedia for e-learning. *Journal of Computer Assisted Learning*, *33*(5), 403–423. https://doi.org/10.1111/jcal.12197

Meier, M. A., Burgstaller, J. A., Benedek, M., Vogel, S. E., & Grabner, R. H. (2021). Mathematical creativity in adults: Its measurement and its relation to intelligence, mathematical competence and general creativity. *Journal of Intelligence*, *9*(1), 1–27. https://doi.org/10.3390/jintelligence9010010

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record*, *108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Nurdiansah, E., Hamdani, N. A., & Hernawan, H. (2017). Pengaruh Penggunaan Multimedia Berbantuan Aplikasi Lectora Terhadap Kreativitas dan Hasil Belajar Kognitif Peserta Didik pada Pokok Bahasan Ekosistem. *Jurnal Teknologi Pendidikan Dan Pembelajaran*, *2*(2), 265–277.

Nuryadi, A., & Hartono. (2021). Solution plan as a strategy to support students in modeling mathematics. *Journal of Physics: Conference Series*, *1806*(1). https://doi.org/10.1088/1742-6596/1806/1/012117

Papadakis, S. (2016). Creativity and innovation in European education. 10 years eTwinning. Past, present and the future. *International Journal of Technology Enhanced Learning*, *1*(1), 1. https://doi.org/10.1504/ijtel.2016.10001503

Park, C. W., Kim, D. gook, Cho, S., & Han, H. J. (2019). Adoption of multimedia technology for learning and gender difference. *Computers in Human Behavior*, *92*, 288–296. https://doi.org/10.1016/j.chb.2018.11.029

Pitta-Pantazi, D., Kattou, M., & Christou, C. (2018). *Mathematical Creativity: Product, Person, Process and Press*. 27–53. https://doi.org/10.1007/978-3-319-73156-8_2

Pushpalatha, K., & Ananthanarayana, V. S. (2020). Multimedia Document Mining using Sequential Multimedia Feature Patterns. In *2020 IEEE Sixth International Conference on Multimedia Big Data (BigMM)* (pp. 231-238). IEEE. https://doi.org/10.1109/BigMM50055.2020.00040

Rambe, P., Ndofirepi, T., & Dzansi, D. (2016). Technological Creativity and its Influence on Entrepreneurship Intentions of Vocational Education Students. In *European Conference on Innovation and Entrepreneurship* (p. 602). Academic Conferences International Limited. Retrieved from https://rb.gy/w27zk7

Renkl, A., & Scheiter, K. (2017). Studying Visual Displays: How to Instructionally Support Learning. *Educational Psychology Review*, *29*(3), 599–621. https://doi.org/10.1007/s10648-015-9340-4

Schoevers, E. M., Kroesbergen, E. H., & Kattou, M. (2018). Mathematical Creativity A Combination of Domain-general Creative and Domain-specific Mathematical Skills. *Journal of Creative Behavior*, *54*(2), 242–252. https://doi.org/10.1002/jocb.361

Schroeder, N. L., & Cenkci, A. T. (2018). Spatial Contiguity and Spatial Split-Attention Effects in Multimedia Learning Environments: a Meta-Analysis. *Educational Psychology Review*, *30*(3), 679–701. https://doi.org/10.1007/s10648-018-9435-9

Shneiderman, B. (2000). Creating Creativity: User Interfaces for Supporting Innovation. *ACM Transactions on Computer-Human Interaction*, *7*(1), 114–138. https://doi.org/10.1145/344949.345077

Simanungkalit, D. U., Harianja, H. M., Hutasoit, L. T., Sipahutar, M. S., Simanjuntak, L., & Munthe, B. (2022). Implementasi Media Pembelajaran terhadap Prestasi Belajar Siswa di SD Negeri 173349 Hutaginjang Kecamatan Muara-Tapanuli Utara. *Jurma: Jurnal Program Mahasiswa Kreatif*, *6*(1), 195–2001. Retrieved from http://pkm.uika-bogor.ac.id/index.php/pkm-p/issue/archive

Sormin, E. (2016). Pengaruh Kreativitas dalam Pembelajaran Inkuiri Berbasis Multimedia terhadap Hasil Belajar Siswa pada Pokok Bahasan Ikatan Kimia. *Jurnal EduMatSains*, *1*(1), 51–60. Retrieved from https://repository.uki.ac.id/id/eprint/620

Stolte, M., García, T., Van Luit, J. E. H., Oranje, B., & Kroesbergen, E. H. (2020). The contribution of executive functions in predicting mathematical creativity in typical elementary school classes: A twofold role for updating. *Journal of Intelligence*, *8*(2), 1–20. https://doi.org/10.3390/jintelligence8020026

Taylor, S. P. (2018). *Innovation in the Public Sector: Dimensions, Processes, Barriers and Developing a Fostering Framework*. *5*(1), 28–37. https://doi.org/10.5281/zenodo.1156261

Tu, Y., Lu, X., Choi, J. N., & Guo, W. (2019). Ethical Leadership and Team-Level Creativity: Mediation of Psychological Safety Climate and Moderation of Supervisor Support for Creativity. *Journal of Business Ethics*, *159*(2), 551–565. https://doi.org/10.1007/s10551-018-3839-9

Willemsen, R. H., Schoevers, E. M., & Kroesbergen, E. H. (2020). The Structure of Creativity in Primary Education: An Empirical Confirmation of the Amusement Park Theory. *Journal of Creative Behavior*, *54*(4), 857–870. https://doi.org/10.1002/jocb.411

Woodgate, D. (2018). *Foresight as a Tool for Increasing Creativity in the Age of Technology-Enhanced Learning* (Vol. 1, Issue September). Springer International Publishing. https://doi.org/10.1007/978-3-030-00825-3

Zhu, W., Wang, X., & Gao, W. (2020). Multimedia Intelligence: When Multimedia Meets Artificial Intelligence. *IEEE Transactions on Multimedia*, *22*(7), 1823–1835. https://doi.org/10.1109/TMM.2020.2969791