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Effectiveness of Higher Order Thinking Skills-based Test Instruments in Science Learning in Indonesia: A Meta-analysis

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Abstract: This research is motivated by the many applications of Higher Order Thinking Skills-based test instruments in science learning. However, it has not been found how effective the instrument is in science learning. The purpose of this study was to determine the effectiveness of Higher Order Thinking Skills-based test instruments in science learning. This type of research is a meta-analysis. Data sources come from the databases of Google Scholar, Hindawi, ScienceDirect, Wiley, Taylor of Francis, Sage Journal, Springer, ProQuest and ERIC. Search keywords are test instruments, test instruments based on Higher Order Thinking Skills in science learning, and higher order thinking skills. This study analyzed 20 articles published in 2020-2023 used in the meta-analysis. Data analysis techniques with the help of JSAP software. The results concluded that the summary effect size value was 1.24 (very high effect size). This finding shows that the use of test instruments based on Higher Order Thinking Skills is effectively applied in science learning. Furthermore, the research provides higher order tinking skills-based test instruments in science learning in Indonesia and provides important information for the application of higher order thinking skills-based test instruments in the future

Keywords: Effect size; Higher order thinking skills; Science learning; Test instrument

Introduction

Natural Science is a branch of science that studies natural phenomena (Uluçinar, 2023; He et al., 2020). Science learning trains students to develop logical and scientific thinking skills in learning (Suendarti & Virgana, 2022; Angganing et al., 2022; Aydede, 2022). In addition, in the science learning process students not only understand a concept but pressure students to have critical, careful and meticulous thinking skills (Sumiantari et al., 2019; Baysal et al., 2023; Kim & Alghamdi, 2023). Not only that, science learning helps students learn to find out about the universe through scientific observations and procedures (Puspita et al., 2023; Bantaokul & Polyiem, 2022; Wang & Tsai, 2019; Shapiro, 2015).

But in fact, science learning in schools is not in accordance with the current independent curriculum (Azzahra et al., 2023; Nuryani et al., 2023). Science learning is still teacher-centered so that students find it difficult to understand the subject matter (Fahrezi et al., 2020). In addition, the quality of science learning in Indonesia is classified as low (Yakob et al., 2021). This can be seen from the results of research by the 2018 *Programme for International Student Assessment* (PISA) conducted by the OECD showing the ability of Indonesian students in science literacy to obtain a score of 396 ranked 71 out of 78 countries (Hariyadi et al., 2023;

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Rahman et al., 2023; Utomo et al., 2023; Zulyusri et al, 2023; Ichsan et al., 2023). Teachers use assessment sheets that are not in accordance with the curriculum so that learning objectives are not achieved (Puspita et al., 2023). In addition, in science learning, students have low problem-solving, critical and creative thinking skills (Alomery, 2022; Yustiana et al., 2022; Dwi et al., 2022). Teacher-developed instruments are not suitable for measuring students' higher-order thinking skills in science learning.

For one of the efforts to develop students' abilities in science learning, develop appropriate numeracy test instruments to measure student learning ability. Instrumen numeracy is a tool used to measure students' learning ability (Divayana et al., 2021; Ramadhan & Sumiharsono, 2020). Effective numeracy test instruments are developed in science learning (Qisthi et al., 2023). Numeracy instruments based on higher order thinking skills are widely developed in science learning. Previous research on the application of numeracy instruments effectively develops students' mathematical skills and problem-solving abilities in learning (Purnomo et al., 2022). Development of effective numeracy instruments to improve students' science literacy skills (Sa'dijah et al., 2023).

Furthermore, higher order thinking skill-based test instruments can measure students' higher-order thinking skills in learning. Higher order thinking skills-based test instruments are very important for teachers to develop in science learning so that students have higher-order thinking skills in learning (Rahayu et al., 2023). Quality test instruments can provide the right results in measuring students' cognitive abilities in learning. Research by Apriani et al. (2023) test instruments based on higher order thinking skills are effective and valid developed in science learning. However, research by Zulfiana et al. (2023) states that higher order thinking skill-based test interventions are less effective for measuring students' science literacy. The existence of Kesenja gan in this study needs to be seen comprehensivelyve test intervention based on higher order thinking skills in science teaching. In addition, there are no research findings that measure the effect of interumen test sizes based on higher order thinking skills. Based on this, this study aims to determine the effectiveness of Higher Order Thinking Skills-based test instruments in science learning.

Method

Research Design

This research is a type of meta-analysis research. Meta-analysis research is a type of research that collects and analyzes primary research that can be analyzed quantitatively (Martin & Carolina, 2022; Tamur et al., 2020; Razak et al., 2021; Çevik & Bakioğlu, 2022; Aybirdi et al., 2023; Setiawan et al., 2022). Meta-analysis was conducted to determine the effectiveness of higher order thinking skill-based test instruments in science learning. According to Borenstein et al. (2009) The procedure in meta-analysis research consists of 1) establishing research inclusion criteria; 2) Collection of primary data and coding of data to be analyzed; 3) Perform statistical data tests to analyze data can be seen in figure 1.

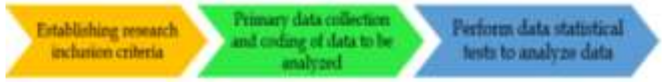

Figure 1. Procedures in meta-analysis

Eligibility Criteria

In the search for data sources, articles included in the meta-analysis must meet the inclusion criteria, namely research must be published in 2020-2023; research comes from reputable international journals or proceedings indexed by SINTA and Scopus; Research must have an experimental class applying test instruments based on higher order thinking skills while conventional control classes; And research data must be complete to calculate the value of the effect size. So, from the process of searching for data sources, 20 articles that meet the inclusion criteria can be seen (Table 3). The data selection process using the Preferred *Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) method can be seen in figure 1.

Data Collection

Data collected in this meta-analysis was based on the databases of Google Scholar, Hindawi, ScienceDirect, Wiley, Taylor of Francis, Sage Journal, Springer, ProQuest and ERIC. Search keywords are test instruments, test instruments based on higher order thinking skills in science learning, and higher order thinking skills. The results of data collection from journal databases can be seen in Table 1.

Table 1. Meta-Analysis Data Collection Results

Description	Sum	Percentage (%)
		Education level
Elementary School	4	20
Junior School	5	25
High School	10	50
University	1	5
		Year of Publication
2020	5	25
2021	4	20
2022	4	20
2023	7	35

Statistical Analysis

Data analysis in meta-analysis research is calculating the effect size value of each study (Riopel et al., 2020; Hillmayr et al., 2020). The effect size in this study is an index that describes the influence of higher order thinking skills-based test instruments in science learning. According to Borenstein et al. (2009) the steps for statistical analysis in meta-analysis are calculating the effect size value of the primary study, conducting heterogeneity tests and determining estimation models, checking publication bias and calculating p-value values for hypothesis testing. Statistical analysis in this meta-analysis with the help of JSAP software. Furthermore, the criteria for effect size values in this meta-analysis can be seen in Table 2.

Table 2. Effect Size Value Category (Cohen et al., 2007)

Effect Size	Category
0.00 ≤ ES≤ 0.20	Small
0.20 ≤ ES≤ 0.80	Medium
ES ≥ 0.80	Large

Furthermore, an important thing to note in conducting meta-analyses is checking publication bias (Smith et al., 2023; Schmid et al., 2023). In a study to check publicity bias using funnel plots and Rosenthal Fail Safe N test (Juandi et al., 2022; Puspita et al., 2022).

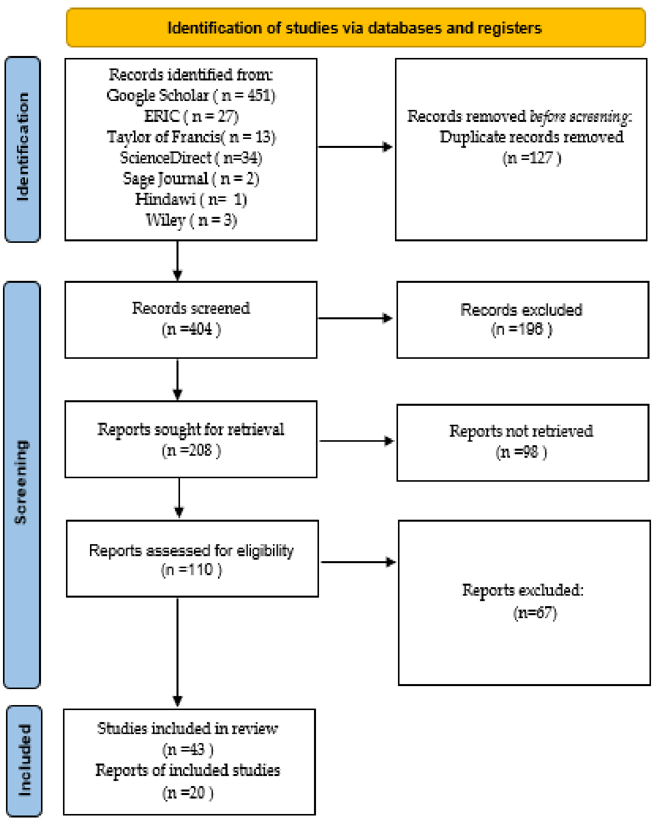

Figure 2. Data selection with preferred reporting items for systematic reviews and meta-analyses (PRISMA) method

Result and Discussion

Based on the analysis of 20 articles that meet the inclusion criteria, effect size values and error standards are calculated which can be seen in Table 3.

Table 3. Effect Size and Standard Error 20 Articles

Code	Year	Country	Journal Index	Effect Size	Standard Error
Study 1	2022	Indonesian	Sinta	0.67	0.21
Study 2	2020	Indonesian	Sinta	1.22	0.34
Study 3	2020	Indonesian	Scopus	0.96	0.27
Study 4	2022	Indonesian	Scopus	1.45	0.22
Study 5	2023	Indonesian	SINTA	0.80	0.35
Study 6	2021	Indonesian	Sinta	0.79	0.20
Study 7	2022	Indonesian	Sinta	0.53	0.23
Study 8	2023	Indonesian	Sinta	0.82	0.31
Study 9	2022	Indonesian	Scopus	2.51	0.45
Study 10	2023	Indonesian	Scopus	1.34	0.31
Study 11	2021	Indonesian	Scopus	0.95	0.35
Study 12	2021	Indonesian	Sinta	0.81	0.20
Study 13	2021	Indonesian	Scopus	0.88	0.22
Study 14	2022	Indonesian	Sinta	1.04	0.35
Study 15	2021	Indonesian	Scopus	2.07	0.40
Study 16	2023	Indonesian	Sinta	1.30	0.28
Study 17	2022	Indonesian	Sinta	0.75	0.20
Study 18	2022	Indonesian	Scopus	1.70	0.36
Study 19	2023	Indonesian	Scopus	1.19	0.40
Study 20	2023	Indonesian	Sinta	0.77	0.17

Table 3, the effect size values of the 20 articles analyzed ranged from 0.53 to 2.51. According to the effect size category Cohen et al., (2007) there are five articles with a medium effect size value (25%) and fifteen articles with a high effect size value (75%). Next, conduct heterogeneity tests and determine the estimation model used in calculating the average effect size of 20 articles. The results of the heterogeneity test and determination of the estimation model with random and fixed models can be seen in Table 4.

Table 4. Heterogeneity Test Results with Random and Fixed Models

	Q	Df	P
Omnibus test of Coefficients Mode	78.169	1	< 0.001
Test of Residual Heterogeneity	214.086	19	< 0.001

Table 4, explaining the results of the heterogeneity test, obtained a Q value of 214,086 greater than the value of 78,169 and a p value of < 0.001. This finding concludes that the effect size analyzed is heterogeneously distributed. The random effect model is effective for analyzing the mean effect size 20 articles included in the meta-analysis. The next step is to check the publication bias of the 20 articles included in the meta-analysis. Publication bias checking in meta-analyses with funnel plots and Rosenthal Fail Safe N (Bernard et al., 2014;

Suryono et al., 2023; Li & Wang, 2023; Juandi et al., 2021). The results of the publication bias test can be seen in Figure 3.

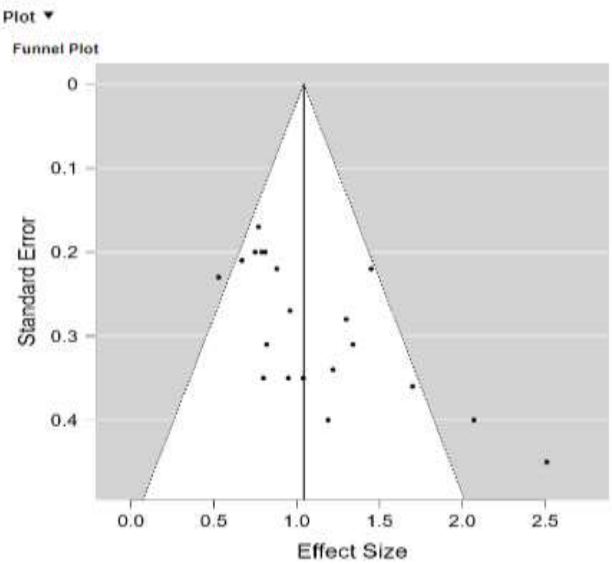

Figure 3. Funnel Plot Standard Error

Based on figure 3, the results of the analysis of 20 effect sizes with funnel plots cannot be concluded whether the form of funnel plot analysis is symmetric or asymmetric. Furthermore, it is necessary to do the Rosenthal Fail Safe N test. The results of the Rosenthal Fail Safe test can be seen in Table 5.

Table 5. Rosenthal Fail Safe N

File Drawer Analysis			
	Fail Safe N	Target Significance	Observed Significance
Rosenthal	2203	0.050	< 0.001

Table 5, shows the Rosenthal fail safe N test result of 2203 with sig value 0.50 and p < 0.00. The Rosenthal fail Safer value compared to the value of k = 20 or k = 5k + 10 = 110, then the Rosenthal fail safe value of N > 5k + 10 means that in the analysis of 20 articles included in the meta-analysis data no publication bias was found. Next, calculate the average value of the effect size to test the hypothesis. The results of the mean effect size test can be seen in Table 6.

Table 6. Mean Effect Size

Coefficients	ICE	Standard Error	Z	P	95% Coenfidence Lower	Upper
Intercept	1.04	0.090	11.595	< 0.001	0.868	1.221

Based on Table 6, explaining the mean effect size value with random effect model is obtained ($r_{RE} = 1.04$; SE = 0.090; z = 11.59 ; p < 0.001). This finding shows that the use of higher order thinking skill-based test instruments has a significant effect on science learning in Indonesia. The effect size in this is included in the high category. With a confidence level of 95% with a lower limit of 0.868 and an upper limit of 1.221. Therefore, the application of higher order thinking skills-based test instruments is effective and influential in science learning.

This research is in line with Ahmad et al. (2017) stated that higher order thinking skills-based test instruments are effectively used in science learning. This result is supported by Ramadan et al. (2019) a valid higher order thinking skills-based test instrument that can measure students' higher-order thinking skills in learning. The use of higher order thinking skills-based test instruments is very necessary in science learning because it can develop students' critical thinking and analytical skills (Walid et al., 2019; Arafat et al., 2021). Furthermore, higher order thinking skills-based test instruments help students solve higher-order thinking problems (Damaianti et al., 2020).

The use of test instruments based on students' higher order thinking skills helps teachers be more creative in developing assessments in science learning (Suprapto et al., 2020). In addition, in science learning students must have higher-order thinking skills in order to be able to solve problems in learning (Utama et al., 2020; Wilson & Narasuman, 2020). Not only that, test instruments based on higher order thinking skills students learn more creatively (Samritin & Suryanto, 2016). According to Tanujaya (2016), higher order thinking skills-based test instruments are an effective evaluation tool to measure cognitive abilities in science learning. Test instruments are a tool to determine student success in learning science. Higher order thinking skills-based test instruments are an important solution in evaluating the quality of science learning in Indonesia.

Conclusion

From this meta-analysis, it can be concluded that the summary effect size value is 1.04 (very high effect size). This finding shows that the use of test instruments based on Higher Order Thinking Skills is effectively applied in science learning. Furthermore, the research provides higher order thinking skills-based test instruments in science learning in Indonesia and provides important information for the application of higher order thinking skills-based test instruments in the future. The use of higher order thinking skills-based test instruments is an important solution for teachers to evaluate science learning in Indonesia. Higher order thinking skills based test instruments encourage students to have higher-order thinking skills in science learning.

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In the research, all researchers contributed Tomi Apra Santosa, Siska Angreni and Rona Taula Sari collecting, selecting and analyzing data statistically and Festiyed, Yerimadesi, Yuhi Ahda, Heffi Alberida and Fitri Arsih provided guidance, input and checked this article.

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Conflicts of Interest
The authors declare no conflict of interest.

References

Ahmad, S., Prahmana, R. C. I., Kenedi, A. K., Helsa, Y., Arianil, Y., & Zainil, M. (2017). The instruments of higher order thinking skills. In *Journal of Physics: Conference Series* (Vol. 943, No. 1, p. 012053). IOP Publishing. https://doi.org/10.1088/1742-6596/943/1/012053

Alomery, H. (2022). The Effectiveness of Visual Mind Mapping Strategy for Improving English Language Learners' Critical Thinking Skills and Reading Ability. *European Journal of Educational Research*, *11*(3), 1245–1257. Retrieved from http://files.eric.ed.gov/fulltext/EJ1329573.pdf

Angganing, P., Budiningsih, C. A., & Haryanto. (2022). The Profile of Students' Communication Skills on Science Learning in Elementary Schools. *Pegem Egitim ve Ogretim Dergisi*, *13*(1), 117–124. https://doi.org/10.47750/pegegog.13.01.14

Apriani, S. P., Zuhro, M. V., Siregar, N., Ristanto, R. H., & Isfaeni, H. (2023). Diferensiasi Pembelajaran Virus Sebuah Pengembangan Instrumen Higher Order Thinking Skill (HOTS). *Diklabio: Jurnal Pendidikan dan Pembelajaran Biologi, 7*(2), 197-211. https://doi.org/10.33369/diklabio.7.2.197-211

Arafah, K., Amin, B. D., Sari, S. S., & Hakim, A. (2021, May). The development of higher order-thinking skills (HOTS) instrument assessment in physics study. In *Journal of Physics: Conference Series* (Vol. 1899, No. 1, p. 012140). IOP Publishing. https://doi.org/10.1088/1742-6596/1899/1/012140

Aybirdi, N. (2023). The Impact of Flipped Learning on L2 Learners' Achievements : A Meta- Analysis. *International Journal of Education*, *11*(1), 41–60. Retrieved from https://files.eric.ed.gov/fulltext/EJ1373405.pdf

Aydede, M. N. (2022). Examining the Primary School Teacher Candidates' Science Learning Skills in Terms of Their Attitudes towards Science and Their Science Teaching Self-Efficacy Beliefs. *International Journal of Educational Methodology*, *8*(4), 853–864. https://doi.org/10.12973/ijem.8.4.853

Azzahra, I., Nurhasanah, A., & Hermawati, E. (2023). Implementasi Kurikulum Merdeka pada Pembelajaran IPAS di SDN 4 Purwawinangun. *Didaktik: Jurnal Ilmiah PGSD STKIP Subang, 9*(2), 6230-6238. https://doi.org/10.36989/didaktik.v9i2.1270

Bantaokul, P., & Polyiem, T. (2022). The Use of Integrated 5Es of Inquiring-Based Learning and Gamification to Improve Grade 8 Student Science Learning Achievement. *Journal of Educational Issues*, *8*(1), 459. https://doi.org/10.5296/jei.v8i1.19802

Baysal et al. (2023). The Effect Of Gender On Motivation Towards Science Learning: A Meta-Analysis Study. *Research in Pedagogy*, *13*(1), 1–18. https://doi.org/10.5937/IstrPed2301001B

Bernard, R. M., Borokhovski, E., Schmid, R. F., & Tamim, R. (2014). A meta-analysis of blended learning and technology use in higher education : From the general to the applied. *J Comput High Educ*, 1–37. https://doi.org/10.1007/s12528-013-9077-3

Borenstein, M., & Hedges, L. V. (2009). *Introduction to Meta-Analysis*. John Wiley & Sons

Çevik, M., & Bakioğlu, B. (2022). The Effect of STEM Education Integrated into Teaching-Learning Approaches (SEITLA) on Learning Outcomes: A Meta-Analysis Study. *International Journal of Progressive Education*, *18*(2), 119–135. https://doi.org/10.29329/ijpe.2022.431.8

Cohen, L., Manion, L., Lecturer, P., Morrison, K., & Lecturer, S. (2007). *Research Methods in Education*. Routledge.

Damaianti, V. S., Abidin, Y., & Rahma, R. (2020). Higher order thinking skills-based reading literacy assessment instrument : An Indonesian context. *Indonesian Journal of Applied Linguistics*, *10*(2), 513–525. https://doi.org/10.17509/ijal.v10i2.28600

Divayana, D. G. H., Sudirtha, I. G., & Suartama, I. K. (2021). Digital Test Instruments Based on" Wondershare-Superitem" for Supporting Distance Learning Implementation of Assessment Course. *International Journal of Instruction, 14*(4), 945-964. https://doi.org/10.29333/iji.2021.14454a

Ernawati, M. D. W., Rusdi, M., Asrial, A., Muhaimin, M., Wulandari, M., & Maryani, S. (2022). Analysis of

Problem Based Learning in the Scaffolding Design: Students' Creative-Thinking Skills. *Cypriot Journal of Educational Sciences, 17*(7), 2333-2348. Retrieved from http://files.eric.ed.gov/fulltext/EJ1350312.pdf

Fahrezi, I., Taufiq, M., Akhwani, A., & Nafia'ah, N. (2020). Meta-Analisis Pengaruh Model Pembelajaran Project Based Learning Terhadap Hasil Belajar Siswa Pada Mata Pelajaran IPA Sekolah Dasar. *Jurnal Ilmiah Pendidikan Profesi Guru*, *3*(3), 408. https://doi.org/10.23887/jippg.v3i3.28081

Hariyadi, S., Santosa, T. A., & Sakti, B. P. (2023). Effectiveness of STEM-Based Mind Mapping Learning Model to Improve Students' Science Literacy in the Era of Revolution. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 791–799. https://doi.org/10.29303/jppipa.v9i10.5125

He, X. X., Deng, Y. P., Liu, J. H., Sun, G. Y., Xiong, J. W., & Xiao, Y. (2023). The Chain Mediating Role of Perceived Family Support for Formal and Informal Science Learning in the Association between Family Socioeconomic Status and Informal Science Learning Experiences. *Journal of Baltic Science Education, 22*(2), 232-253. https://doi.org/10.33225/jbse/23.22.232

Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I., & Reiss, K. M. (2020). Computers & Education The potential of digital tools to enhance mathematics and science learning in secondary schools : A context-specific meta-analysis. *Computers & Education*, *153*(April), 103897. https://doi.org/10.1016/j.compedu.2020.103897

Ichsan, Suharyat, Y., Santosa, T. A., & Satria, E. (2023). The Effectiveness of STEM-Based Learning in Teaching 21 st Century Skills in Generation Z Student in Science Learning : A. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 150–166. https://doi.org/10.29303/jppipa.v9i1.2517

Juandi, D., Kusumah, Y. S., & Tamur, M. (2022). A Meta-Analysis of the last two decades of realistic mathematics education approaches. *International Journal of Instruction*, *15*(1), 381–400. https://doi.org/10.29333/iji.2022.15122a

Juandi, D., Kusumah, Y. S., Tamur, M., Perbowo, K. S., & Tanu, T. (2021). Heliyon A meta-analysis of Geogebra software decade of assisted mathematics learning : what to learn and where to go ? *Heliyon*, *7*(October), e06953. https://doi.org/10.1016/j.heliyon.2021.e06953

Kim, S. Y., & Hamdan Alghamdi, A. K. (2023). Secondary School Students' Perceptions of Science Learning Environment and Self-Efficacy in South Korea: Gender Differences. *Journal of Baltic Science Education*, *22*(2), 269–281. https://doi.org/10.33225/jbse/23.22.269

Li, S., & Wang, W. (2023). Effect of blended learning on student performance in K-12 settings : A meta-analysis. *J Comput Assist Learn*, 1–19. https://doi.org/10.1111/jcal.12696

Martin, F., & Carolina, N. (2022). A Meta-Analysis on the Community of Inquiry Presences and Learning Outcomes in Online and Blended Learning Environments. *Online Learning Journal*, *26*(1), 325–359. https://doi.org/10.24059/olj.v26i1.2604

Purnomo, H., Sa'dijah, C., Hidayanto, E., Permadi, H., & Anwar, L. (2022). Development of Instrument Numeracy Skills Test of Minimum Competency Assessment (MCA) in Indonesia. *International Journal of Instruction, 15*(3), 635-648. https://doi.org/10.29333/iji.2022.15335a

Puspita, S., & Irfandi, I. (2022). Meta-Analysis of Focusky Learning Media on Student Learning Outcomes. *Jurnal Ilmu Pendidikan Muhammadiyah Kramat Jati, 3*(2), 20-22. https://doi.org/10.55943/jipmukjt.v3i2.34

Puspita, A. D., Maryani, I., & Sukma, H. H. (2023). Problem-based science learning in elementary schools: A bibliometric analysis. *Journal of Education and Learning*, *17*(2), 285–293. https://doi.org/10.11591/edulearn.v17i2.20856

Qisthi, C. U., Abidin, Z., & Sulistyono, S. (2023). Pengembangan Instrumen Literasi Numerasi Biologi Pada Pembelajaran IPA Dalam Materi Sistem Pernapasan Pada Manusia. *Jurnal Ilmiah Wahana Pendidikan, 9*(22), 191-202. https://doi.org/10.5281/zenodo.10096812

Rahayu, N. K. L. A., Widiartini, N. K., & Divayana, D. G. H. (2023). Pengembangan Instrumen Higher Order Thinking Skill (HOTS) Matematika Program Studi Penelitian dan Evaluasi Pendidikan. *Jurnal Penelitian Dan Evaluasi Pendidikan Indonesia*, *13*(1), 17–26. https://doi.org/10.23887/jpepi.v13i1.1761

Rahman, A. A., Santosa, T. A., Nurtamam, M. E., & Widoyo, H. (2023). Meta-Analysis : The Effect of Ethnoscience-Based Project Based Learning Model on Students ' Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 611–620. https://doi.org/10.29303/jppipa.v9i9.4871

Ramadhan, S., Mardapi, D., Prasetyo, Z. K., & Utomo, H. B. (2019). The Development of an Instrument to Measure the Higher Order Thinking Skill in Physics. *European Journal of Educational Research*, *8*(3), 743–751. https://doi.org/10.12973/eu-jer.8.3.743

Ramadhan, S., & Sumiharsono, R. (2020). The Quality of Test Instruments Constructed by Teachers in Bima Regency, Indonesia : Document Analysis.

International Journal of Instruction, *13*(2), 507–518. https://doi.org/10.29333/iji.2020.13235a

Razak, A., Santosa, T. A., Lufri, & Zulyusri. (2021). Meta-Analisis: Pengaruh HOTS (Higher Order Thinking Skill) terhadap Kemampuan Literasi Sains dan Lesson Study Siswa pada Materi Ekologi dan Lingkungan pada Masa Pandemi Covid-19. *Bioedusiana: Jurnal Pendidikan Biologi*, *6*(1), 79–87. https://doi.org/10.37058/bioed.v6i1.2930

Riopel, M., Nenciovici, L., Potvin, P., Chastenay, P., Charland, P., Sarrasin, J. B., & Masson, S. (2019). Impact of serious games on science learning achievement compared with more conventional instruction: an overview and a meta-analysis. *Studies in Science Education, 55*(2), 169-214. https://doi.org/10.1080/03057267.2019.1722420

Sa'dijah, C., Purnomo, H., Abdullah, A. H., Permadi, H., Anwar, L., Cahyowati, E. T. D., & Sa'diyah, M. (2023). Students' numeracy skills in solving numeracy tasks: Analysis of students of junior high schools. In *AIP Conference Proceedings* (Vol. 2569, No. 1). AIP Publishing. https://doi.org/10.1063/5.0113664

Schmid, R. F., Borokhovski, E., Bernard, R. M., Pickup, D. I., & Abrami, P. C. (2023). A meta-analysis of online learning, blended learning, the flipped classroom and classroom instruction for pre-service and in-service teachers. *Computers and Education Open*, *5*(January), 100142. https://doi.org/10.1016/j.caeo.2023.100142

Setiawan, A. A., Muhtadi, A., & Hukom, J. (2022). Blended Learning and Student Mathematics Ability in Indonesia: A Meta-Analysis Study. *International Journal of Instruction, 15*(2), 905-916. https://doi.org/10.29333/iji.2022.15249a

Shapiro, B. (2015). Studying lifeworlds of science learning: A longitudinal study of changing ideas, contexts, and personal orientations in science learning. *Canadian Journal of Science, Mathematics and Technology Education*, *4*(1), 127–147. https://doi.org/10.1080/14926150409556601

Smith, L. A., Oakden-rayner, L., Bird, A., Zeng, M., To, M., Mukherjee, S., & Palmer, L. J. (2023). Articles Machine learning and deep learning predictive models for long-term prognosis in patients with chronic obstructive pulmonary disease : a systematic review and meta-analysis. *The Lancet Digital Health*, *5*(12), e872–e881. https://doi.org/10.1016/S2589-7500(23)00177-2

Suendarti, M., & Virgana, V. (2022). Elevating natural science learning achievement: Cooperative learning and learning interest. *Journal of Education and Learning (EduLearn)*, *16*(1), 114–120. https://doi.org/10.11591/edulearn.v16i1.20419

Sugih, S. N., Maula, L. H., & Nurmeta, I. K. (2023). Implementasi kurikulum merdeka dalam pembelajaran IPAS di sekolah dasar. *Jurnal Pendidikan Dasar Flobamorata, 4*(2), 599-603. https://doi.org/10.51494/jpdf.v4i2.952

Sumiantari, N. L. E., Suardana, I. N., & Selamet, K. (2019). Pengaruh Model Problem Based Learning Terhadap Kemampuan Pemecahan Masalah Ipa Siswa Kelas VIII SMP Universitas Pendidikan Ganesha. *JPPSI: Jurnal Pendidikan Dan Pembelajaran Sains Indonesia*, *2*(April), 12–22. https://doi.org/10.23887/jppsi.v2i1.17219

Suprapto, E., Sumiharsono, R., & Ramadhan, S. (2020). The Analysis of Instrument Quality to Measure the Students ' Higher Order Thinking Skill in Physics Learning. *Journal of Turkish Science Education*, *17*(4), 520–527. https://doi.org/10.36681/tused.2020.42

Suryanto, S. (2016). Developing An Assessment Instrument Of Junior High School Students' Higher Order Thinking Skills In MathematicS. *Research and Evaluation in Education*, *2*(1), 92–107. http://dx.doi.org/10.21831/reid.v2i1.8268

Suryono, W., Haryanto, B. B., Santosa, T. A., Suharyat, Y., & Sappaile, B. I. (2023). The Effect of The Blended Learning Model on Student Critical Thinking Skill : Meta-analysis. *Edumaspul - Jurnal Pendidikan*, *7*(1), 1386–1397. https://doi.org/10.33487/edumaspul.v7i1.6087

Tamur, M., Juandi, D., & Kusumah, Y. S. (2020). The Effectiveness of the Application of Mathematical Software in. *International Journal of Instruction*, *13*(4), 867–884. https://doi.org/10.29333/iji.2020.13453a

Tanujaya, B. (2016). Development of an Instrument to Measure Higher Order Thinking Skills in Senior High School Mathematics Instruction. *Journal of Education and Practice*, *7*(21), 144–148. Retrieved from https://files.eric.ed.gov/fulltext/EJ1109390.pdf

Uluçinar, U. (2023). The Effect of Problem-Based Learning in Science Education on Academic Achievement: A Meta-Analytical Study. *Science Education International*, *34*(2), 72–85. https://doi.org/10.33828/sei.v34.i2.1

Utama, C. (2020). The Instrument Development to Measure Higher-Order Thinking Skills for Pre-Service Biology Teacher. *International Journal of Instruction*, *13*(4), 833–848.

Utomo, W., Suryono, W., Santosa, T. A., & Agustina, I. (2023). The Effect of STEAM-Based Hybrid Based Learning Model on Students' Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 742–750. https://doi.org/10.29303/jppipa.v9i9.5147

Walid, A., Sajidan, S., Ramli, M., & Gamal, R. (2019).

Construction of The Assessment Concept to Measure Students' High Order Thinking Skills. *Journal for the Education of Gifted Young*, *7*(June), 237–251. https://doi.org/10.17478/jegys.528180

Wang, Y. L., & Tsai, C. C. (2019). Exploring the structure of science learning self-efficacy: the role of science learning hardiness and perceived responses to capitalization attempts among Taiwanese junior high school students. *Research in Science and Technological Education*, *37*(1), 54–70. https://doi.org/10.1080/02635143.2018.1480476

Wilson, D. M., & Narasuman, S. (2020). Investigating Teachers' Implementation and Strategies on Higher Order Thinking Skills in School Based Assessment Instruments. *Asian Journal of University Education (AJUE)*, *16*(1), 1–15. https://doi.org/10.24191/ajue.v16i1.8991

Yakob, M., Hamdani, H., Sari, R. P., Haji, A. G., & Nahadi, N. (2021). Implementation of performance assessment in stem-based science learning to improve students' habits of mind. *International Journal of Evaluation and Research in Education*, *10*(2), 624–631. https://doi.org/10.11591/ijere.v10i2.21084

Yustiana, Mahadi, I., & Ariska, D. (2022). The Effect of E-Learning Based on the Problem-Based Learning Model on Students' Creative Thinking Skills During the Covid-19 Pandemic. *International Journal of Instruction*, *15*(2), 329–348. https://doi.org/10.29333/iji.2022.15219a

Zulfiana, S., Gunamantha, I. M., & Putrayasa, I. B. (2023). Pengembangan Instrumen Kemampuan Berpikir Tingkat Tinggi Dan Literasi Sains Pada Pembelajaran IPA Kelas V SD. *PENDASI Jurnal Pendidikan Dasar Indonesia, 7*(1), 13-24. https://doi.org/10.23887/jurnal_pendas.v7i1.1384

Zulyusri, Z., Santosa, T. A., Festiyed, F., Yerimadesi, Y., Yohandri, Y., Razak, A., & Sofianora, A. (2023). Effectiveness of STEM Learning Based on Design Thiking in Improving Critical Thinking Skills in Science Learning : A. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 112–119. https://doi.org/10.29303/jppipa.v9i6.3709