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Examining the Brain-Based Learning Model Assisted by an Open-Ended Approach to Understanding Mathematical Concepts

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Abstract: The implementation of this research is due to indications of learning problems related to students' difficulties in understanding mathematics in division material in third-grade elementary school, which results in students' weakness in understanding mathematical concepts. This needs to be improved through the implementation of a brain-based learning model with an open-ended approach so that it affects students' understanding of mathematical concepts. A quasi-experiment with a pretest-posttest control group design was used as the basis for this research method. The study population comprised 96 grade 3 students from five schools in cluster 5, Klaten. Simple randomization was used as a sampling technique with a sample of 48 students. The research instrument used was a test of 10 questions with essay type. Based on the results of the hypothesis test obtained at 0.018, the brain-based learning model assisted by an open-ended approach influences students' understanding of mathematical concepts, with an average increase of 34.96 seen from the pretest and posttest. This research influences students' mathematical concept understanding ability in a more positive direction through collaboration between the brain-based learning model and an open-ended approach.
Keywords: brain based learning model, division material, mathematics concept understanding, open-ended approach

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Introduction

The development of human civilization is one of the important things that can be built through education (Nasichah, 2023; Shodiyev, 2023). The implementation of education certainly requires competent teachers who can develop the quality of students (Kabariah & Adiyono, 2023; Otaya et al., 2020), especially in learning that is difficult for students to understand, such as mathematics through meaningful learning (Bang et al., 2023; Ye et al., 2023). Mathematics is a branch of science that is always related to all aspects of life (Alim et al., 2021; Oppong-Gyebi et al., 2023) and has an important role in building more advanced science and human mindset (Putri et al., 2022). Mathematics has a role in improving human thinking skills through students' daily real-life activities to achieve superior potential in life (Amrullah & Sujarwo, 2018; Minarni & Napitupulu, 2020). Mathematics learning is said to be the most difficult learning to understand, especially for students in Indonesia (Saleh et al., 2018; Wijaya et al., 2019). This can be seen in research conducted by Abidin et al. (2020) and Winarni and Purwandari (2020) that the acquisition of student math learning outcomes in Indonesia is lower when compared to the average of other learning content and support by the PISA (Program for International Student Assessment) in mathematics 2015, Indonesia ranked 64 from 72 countries, and it is very worrying (Arsyad & Upu, 2021). This problem is caused by students' ability to understand mathematical concepts, which is still often wrong (Kusumadewi et al., 2020). When students misunderstand a mathematical concept, and no improvement is made, it will impact students' difficulty in understanding further mathematical material (Firdaus et al., 2022; Simamora et al., 2018). This is

because mathematics material is always related between one material and another (Selvianiresa & Prabawanto, 2017; Triwahyuningtyas et al., 2020).

Understanding students' concepts in mathematics must be given as well as possible since students are at the lowest level, from elementary school to further education (Ekowati & Suwandayani, 2020; Langdon et al., 2023). A good understanding of mathematical concepts will impact students' mathematics learning outcomes (Firdaus et al., 2022). However, according to Alabdulaziz & Tayfour (2023), elementary school students understand mathematical concepts very little. Based on research from Akina et al. (2023), division material is one of the most difficult math materials teachers teach. This is supported by research by Halim (2023) that division material is too demanding for students to memorize division numbers instead of guiding students to know the process or how to divide correctly. Based on observations as a preliminary study conducted in class III of Keputaran 2 Elementary School on September 18 and 19, 2023, there are the same learning problems on division material. These problems include: (1) the teacher only adheres to the concept of memorization in division material so that students' abilities in the thinking process experience inhibition, (2) the delivery of learning materials that the teacher too dominates does not provide opportunities for students to explore knowledge of mathematics independently, (3) students are less enthusiastic about learning mathematics which is only in the classroom.

Students' characteristics and needs in implementing learning must be considered (Mahsusi et al., 2023; Triwahyuningtyas et al., 2020). The implementation of learning during observation activities emphasizes that students can memorize numbers in division alone, not in the process of finding the answer to the quotient. Therefore, it is necessary to have a learning approach that can accommodate students gradually to find answers integrated into students' experiences, namely through an open-ended approach. Based on research by Fatma (2022) and Rahmatika & Waluya (2023), an open-ended approach can improve students' understanding of mathematics concepts, critical thinking skills, learning achievement, and confidence in mathematics. This is supported by Purwoko et al. (2023), who state that the open-ended approach provides various problem-solving solutions in mathematics.

Research studies state that a person's low ability to understand concepts can be caused by less optimization of brain function (Mekwan & Poonputta, 2023). In processing information, there needs to be a balance between the left and right brains so that it is easier to receive the information provided (Lima et al., 2023). The Brain-Based Learning (BBL) learning model makes it easy for students to learn scientifically by maximizing how the brain works so that they can master mathematical concepts well. This will make it easier for students to understand the content of learning, give a special impression to students, and improve students' skills in maximizing brain performance through concepts that students make (Thonsakul & Poonputta, 2023). Research by Alakayleh (2023) supports that brain-based learning can influence the way a person thinks and achieves good learning outcomes. The Brain-Based Learning model can increase student activeness through the reconstruction of knowledge based on the cognitive abilities that students have previously had in understanding mathematical concepts (Net et al., 2023). This brain-based learning model development innovation is in the form of learning media that optimizes the work of the right and left brain, which functions almost the same as how the mind-mapping model works. The brain-based learning model is implemented with mind mapping adapted to how students learn so that brain function or performance can increase (Jensen, 2014).

This study contributes to proving previous research that the implementation of brain-based learning models is successful in improving understanding of mathematical concepts. In addition to improving students' understanding of mathematical concepts, learning becomes more enjoyable so that students can process their thoughts in understanding a concept to implement the brain-based learning model with an open-ended approach.

Methods

This research was a quasi-experiment with a pretest-posttest control group design. The brain-based learning model assisted by an open-ended approach was given as the treatment applied in the experimental class. In contrast, the control class used the teacher's model. This research was implemented from September 25 to October 6, 2023, in class 3 division material. The population of this study consisted of 5 elementary schools with a total of 96 students who entered Klaten cluster 5. The

sample of this study amounted to 48 obtained from a simple random technique with Keputaran 2 Elementary School as the experimental class and Keputaran 1 Elementary School as the control class.

The test comprised 10 essay-type questions and was used as a research instrument. Before the test was given, the research instrument went through a validity test and sample reliability test, which was tested on students at Keputaran 2 Elementary School as a research sample trial with 30 students (t table = 0.361). From the test results, all test items tested were valid because the t value was less than 0.361 with a reliability significance value of 0.802 with high-reliability criteria.

The data analysis technique in this study uses two types, namely descriptive analysis, and inferential analysis. Descriptive statistical analysis was used to interpret the data obtained from the pretest and posttest of the experimental and control classes by reviewing the mean data, standard deviation, and data variance results. Inferential data analysis was conducted to answer the research hypothesis by assuming parametric statistical tests. The first prerequisite test carried out is the normality and homogeneity test of the data. Data can be declared normal with homogeneous data variance; if the significance value of the data derived from the t count is more than 0.05, then hypothesis testing is carried out through parametric assumptions. The hypothesis test used is through the independent test. The condition is that if the significance value of the calculation results is less than 0.05, then it is stated that the brain-based learning model with an open-ended approach influences students' understanding of mathematical concepts of division material. From beginning to end, this test process uses software called SPSS 26.

Results and Discussion

Results

The first data analysis was carried out descriptively to interpret the calculation results. The results are described in Table 1.

Table 1. Descriptive Analysis of Mathematics Concept Understanding

Data	Means	Deviation Standard	Variants
PrEC	48.18	10.404	108.251
PoEC	83.14	11,038	121.838
PrCC	52.45	13.215	174.641
PoCC	75.36	9.897	97.957

Based on Table 1, the average difference between the experimental and control classes is very much different. The pretest in the experimental (PrCE) class obtained an average of 48.18, and when the posttest (PoCE) averaged 83.14 with an increase of 34.96. In the control class, the pretest (PrCC) obtained was 52.45, while the posttest (PoCC) was 75.36, with an increase of 22.91. The standard deviation and variance results show a relatively high range difference between the experimental and control classes, so the data coverage is wide. The conclusion obtained in Table 1 is that there is an increase in students' understanding of mathematical concepts in both the experimental and control classes. However, the highest increase was obtained in the control class that used a brain-based learning model assisted by an open-ended approach. Continued with the data normality test as a prerequisite test of parametric statistical assumptions before conducting hypothesis testing. The results can be seen in Table 2.

Table 2. Normality Test

No.	Data	Significance
1.	PrCE	0,505
2.	PoCE	0.508
3.	PrCC	0.509
4.	PoCC	0.481

Based on the normality test of pretest and posttest data in both experimental and control classes, it has a significance value of more than 5%, so it is stated that the overall data is normally distributed.

The next step is to go through the data homogeneity test to see whether the resulting data variance is homogeneous or not. The results are shown in Table 3.

Table 3. Homogeneity Test Result

Data	Sig. value
Based On Trimmed Mean	0.481

The result of the significance calculation in Table 3 is 0.431. Thus, stating that the variance of the resulting data is homogeneous. Because the prerequisite test carried out gets the results of normally distributed data and homogeneous data variance, it can use parametric statistical tests. In testing the hypothesis using an independent test. The condition is that if the 2-tailed significance value obtained is more than 5%, then H_0 is accepted, and Ha is rejected. This indicates that there is no effect of a brain-based learning model with an open-ended approach on the understanding of mathematical concepts of grade 3 students on division material. However, if the significance calculation result is less than 5%, then Ha is accepted, and H_0 is rejected. The calculation results are as follows in table 4:

Table 4. Independent Test Results in

t_{count}	df	Sig. 2-tailed
2.459	42	0.018

Based on the 2-tailed significance value in Table 4 obtained of 0.018, it is stated that the brain-based learning model with an open-ended approach affects students' understanding of mathematical concepts in class 3 division material of Keputaran 2 Elementary School. This also answers the hypothesis that Ha is accepted and H_0 is rejected.

Discussion

The understanding of mathematical concepts in division material has changed significantly. This is evidenced in the results of the data analysis above, especially in the descriptive analysis. Changes in a positive direction toward students' understanding of mathematical concepts are based on the application of the brain-based learning model with an open-ended approach. In addition to changes in students' understanding of mathematical concepts, implementing the brain-based learning model with an open-ended approach can activate students' thinking power so that they are active in building knowledge captured by the brain through the stimulus provided by the teacher. According to the theory of Eladl & Saad (2019), the brain-based learning model not only makes the brain work optimally but also increases students' motivation in learning, especially in terms of classroom activities. Relevant to this theory, Araghi et al. (2023) state that the participation of students in active learning activities will positively impact the achievement of students' concept understanding.

The brain-based learning model must optimize learning through challenges in the thinking process that are integrated with the student learning environment, the learning process that occurs pleasantly, and active and meaningful learning (Sucilestari, 2023). In addition, low-grade students who are in the concrete operational stage need to be given fun learning, such as games in learning and music. This is in line with Tisza & Markopoulos (2023), who states that the brain can work well if there is an element of fun, not pressure, on students. In addition, it is necessary to pay attention to students' learning styles so that information processing based on the material delivered by the teacher can be well achieved to students (Opoku et al., 2023). The learning process also needs to be done in detail and order. Therefore, the implementation of the open-ended approach can present students with the learning process in detail (Rahmatika & Waluya, 2023). The more detailed the process of explanation, the more information students will receive, which will make students think more openly about various possibilities for solving problems (Inganah et al., 2023). The diversity of students in thinking will determine the way students solve problems according to the characteristics of the students themselves. This will stimulate students to have a learning style that they like, affecting how their brains work (Amsil et al., 2023).

The initial implementation of the brain-based learning model is the pre-exposure stage. This stage provides a stimulus to students so that they can think and review the learning that will be carried out before it is taught to them. This activity can be done by focusing students' attention through brain

gymnastics actions and paying attention to the concept map of the material to be learned. During brain gymnastics activities, teachers can pay attention to students who are less interested in participating in brain gymnastics and motivate students by saying that brain gymnastics is very useful in training student concentration (Anggraini et al., 2023). According to Ramos-Galarza et al. (2023), brain exercises carried out by stimulating brain waves through light movements by the body accompanied by games can improve students' ability and attention in learning. In addition, at this stage, the teacher also provides a concept map of the material to be learned, which must be done in detail and clearly. According to Ma et al. (2023), learning will be effective by making creative notes through concept maps so that each main concept to be learned is identified, which is then narrated according to the learning style of students in the classroom.

The second stage is the preparation. At this stage, the teacher can integrate the open-ended approach by giving students problems related to the learning material. Questions and answers can be given to the problems posed by the teacher so that student's readiness to learn can be formed. Based on research by Rahman et al. (2023), starting learning by posing problems to students will create student curiosity and student participation in class for diverse answers from students. However, at this stage, there were still a few students who responded to the teacher's questions. This is natural because maybe students still feel shy in giving answers. The teacher's task is to provide stimulus to students in the form of awards that can be given in the form of stars, thumbs up, or words of wisdom so that they can raise students' confidence to express their opinions or thoughts (Bernadi, 2017; Pandita & Kiran, 2023). Positive stimulus continues to be given until students understand the problem as a learning topic that they want to learn based on the diversity of opinions that students have given. Note that at this stage, you should not blame students' answers because it will hinder students' confidence in the next stage of learning.

Initiation and acquisition are the next stage, where the teacher helps students form groups and conduct group activities to obtain information or knowledge through experimental discussions. The teacher carries out the experimental activity by bringing marbles to each group in different amounts. Each group was allowed to come forward. Then, the teacher began to conduct experiments by explaining the concept of division to students. The learning that was done was like this: Group A was given 12 marbles. One of the students in the group distributed the marbles to 4 students in the group until there were no marbles left. Then, the group counted how many marbles the students had obtained. For example, from 12 marbles with four students in the group, it means 12:4, which is 3. So, each student gets three marbles. This continues to be done by the teacher to the next few groups until the students understand the simple concept of division material. At this stage, the open-ended approach is indirectly implemented, where students can solve problems through the experiment. After students begin to understand the concept of division, the teacher gives the teaching module to students to answer the questions in the teaching module. In group activities, the teacher continues to provide full guidance to students until all students understand the concept of division. Guided learning activities will avoid misconceptions, and initially, confused students become more active during learning activities (Lin & Sumardani, 2023). This reveals that the learning taught by the teacher has been meaningful for students. Learning can be said to be meaningful if students can understand concepts through various ways of developing learning so that students understand and are more active (Prihatiningtyas & Husna, 2023).

Followed by the elaboration stage, the stage of managing learning materials. The elaboration stage aims to straighten out students' understanding of learning materials that were initially wrong to deepen their understanding through investigating and analyzing activities (Budiharti & Jailani, 2014; Gustian et al., 2023). At this stage, the integration of the open-ended approach is through activities to discuss things that are declared difficult to solve by students in answering questions in the teaching module and correcting mistakes in groups when answering questions. Each group exchanges the teaching module that has been filled in with other groups to be able to review the work that has been completed by their friends. If there is an error in answering in a group, the teacher will ask the students, "Is there a group that is correct in answering?". In the field, there was one group that answered correctly, and the teacher asked the group to explain to their friends how to get the correct answer by coming forward. After that, the teacher's job is to straighten out the answers that have been written on the board. Then, the teacher can give the same impromptu question and invite students to answer the question directly. This must be done because if left unchecked, it will cause misconceptions that will continue to the next math lesson (Stohlmann, M., & Yang, 2023). Therefore, at the elaboration stage, students learn to review and

evaluate their work, which can be constructively obtained from constructive feedback (Fatmawati et al., 2022; Setiawan et al., 2019). Relevant to research by Sappaile et al. (2023), the elaboration stage can expand ideas so that they are clearer and more detailed.

The fifth stage is incubation and memory encoding. This stage is given the opportunity to take a short break, and the teacher plays music. Through the music, it is hoped that students can relax for a moment so that students are not stressed. If students are stressed, it will hinder learning (Si et al., 2023). Therefore, music can be useful in relaxing the mind and reducing stress (Genisa et al., 2023). During the relaxation process, the teacher can ask questions that lead to the learning that has been carried out. This is so that learning can stick in students' memory. After seeing students relax enough, proceed to the verification and confidence checking stages. The purpose of this stage is so that students can reflect on learning by confirming the understanding that students have learned. The teacher can provide evaluation questions for students to do independently. After students have finished answering the questions, the teacher can provide opportunities for students regarding the learning that has been carried out, both in things that students like in learning and things that students are less interested in. With reflections from students, it will help improve further learning (Mamede & Schmidt, 2023). The final stage of the implementation of the brain-based learning model is the celebration and integration stage. This stage aims to secure students' love of learning. The implementation that can be done is to provide positive implications for all activities that students have done, such as giving appreciation both in the form of words and class stars. The appreciation will make students proud of what they have gone through and eager to learn harder at the next meeting (Frank, 2023). In addition, the teacher can invite students to sing class yells if anything reinforces to students that learning is important. Teachers can make the learning environment as fun as possible so that students become interested in learning (Rusticus et al., 2023).

The results of the research that has been conducted state that the brain-based learning model can have a positive influence on students' understanding of mathematical concepts and ways of thinking in processing information. With the integration of the open-ended approach, learning can be done in detail and clearly to create good collaboration and meaningful learning for students. The integration between the brain-based learning model and the open-ended approach needs to be done again on different materials to provide greater insight into improving learning because the integration of this model and approach is very rarely used.

Conclusion

The implementation of the brain-based learning model assisted by an open-ended approach not only affects students' understanding of mathematical concepts but can increase class activeness seen during the research process. However, this needs to be researched again to get empirical evidence. Based on the conclusions, implications, and limitations in this study, it is necessary to pay attention to several things, namely: (1) when implemented in elementary schools, it is necessary to pay attention in detail to each syntax in the BBL model followed by an open-ended approach so that students become more capable of developing their concept understanding abilities, (2) for future researchers, it can be used in terms of developing other abilities, such as mathematical literacy skills, critical thinking skills, and others to get varied results, and (3) in carrying out research, it is necessary to have an observer so that he can provide input on the implementation of better learning and also need observation guidelines so that students' understanding abilities can be seen to have changed or not based on student behavior in the classroom.

References

Abidin, Z., Utomo, A. C., Pratiwi, V., & Farokhah, L. (2020). Project-based learning-literacy in improving students' mathematical reasoning abilities in elementary schools. *JMIE (Journal of Madrasah Ibtidaiyah Education)*, *4*(1), 39. https://doi.org/10.32934/jmie.v4i1.170

Akina, A., Mufidah, M., Sani, N. K., & Astuti, G. A. M. N. (2023). Application of the guided discovery learning model to improve student learning outcomes in fractions division material. *Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram*, *11*(2), 527. https://doi.org/10.33394/j-ps.v11i2.7266

Alabdulaziz, M. S., & Tayfour, E. A. (2023). A comparative study of the effects of distance learning and face-to-face learning during the covid-19 pandemic on learning mathematical concepts in primary students of the Kingdom of Bahrain. *Education Sciences*, *13*(2), 133. https://doi.org/https://doi.org/10.3390/educsci13020133

Alakayleh, S. S. (2023). The effectiveness of a program based on brain-based learning in acquiring mathematical skills among students with learning difficulties in math. *Resmilitaris*, *13*(3), 3076–3082. https://resmilitaris.net/menu-script/index.php/resmilitaris/article/view/3947

Alim, J. A., Hermita, N., Alim, M. L., Wijaya, T. T., & Pereira, J. (2021). Developing a math textbook using realistic mathematics education approach to increase elementary students' learning motivation. *Jurnal Prima Edukasia*, *9*(2), 193–201. https://doi.org/10.21831/jpe.v9i2.39393

Amrullah, K., & Sujarwo, S. (2018). The effectiveness of the cooperative problem-based learning in improving the elementary school students' critical thinking skills and interpersonal intelligence. *Jurnal Prima Edukasia*, *6*(1), 66–77. https://doi.org/10.2991/icei-17.2018.66

Amsil, A., Maksum, H., Nasir, M., & Andrizal, A. (2023). Contribution of learning styles to learning outcomes during the covid-19 pandemic for students at SMKN 1 West Sumatra. *JTPVI: Jurnal Teknologi dan Pendidikan Vokasi Indonesia*, *1*(2), 209–216. https://doi.org/10.24036/jtpvi.v1i2.60

Araghi, T., Busch, C. A., & Cooper, K. M. (2023). The aspects of active-learning science courses that exacerbate and alleviate depression in undergraduates. *CBE Life Sciences Education*, *22*(2), 1–15. https://doi.org/10.1187/cbe.22-10-0199

Arsyad, N., & Upu, H. (2021). The analysis of higher order thinking skills in solving PISA (programme for international student assessment) questions for 10th grade students. *In 4th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2019)*, *611*(ICoESM), 246–251.

Bang, H. J., Li, L., & Flynn, K. (2023). Efficacy of an adaptive game-based math learning app to support personalized learning and improve early elementary school students' learning. *Early Childhood Education Journal*, *51*(4), 717–732. https://doi.org/10.1007/s10643-022-01332-3

Bernadi, R. M. A. (2017). Increasing the creativity of fourth grade elementary school students through integrative thematic learning with an open-ended approach. *Jurnal Prima Edukasia*, *5*(1), 91–101. https://doi.org/10.21831/jpe.v5i1.7783

Budiharti, B., & Jailani, J. (2014). The effectiveness of the realistic mathematics learning model judging from the learning achievement and creativity of elementary school students. *Jurnal Prima Edukasia*, *2*(1), 27. https://doi.org/10.21831/jpe.v2i1.2642

Ekowati, D. W., & Suwandayani, B. I. (2020). Understanding the concept of π numbers for elementary school pre-service teachers on circle materials. *Jurnal Prima Edukasia*, *8*(1), 12–19. https://doi.org/10.21831/jpe.v8i1.30103

Eladl, A. M., & Saad, M. A. E. (2019). Effect of a brain-based learning program on working memory and academic motivation among tenth grade omanis students. *International Journal of Psycho-Educational Science*, *8*(1), 42–50. https://www.journals.lapub.co.uk/index.php/IJPES

Fatma, R. (2022). Development of student-based work sheet open ended problem in fraction materials class iii elementary school. *Journal of General Education Science*, *1*(2), 109–117. https://journal.berpusi.co.id/index.php/JoGEs/article/view/169

Fatmawati, A., Zubaidah, S., Mahanal, S., & Sutopo, S. (2022). Representation skills of students with different ability levels when learning using the LCMR model. *Pegem Egitim ve Ogretim Dergisi*, *13*(1), 177–192. https://doi.org/10.47750/pegegog.13.01.20

Firdaus, F. M., Afianti, D., Cahya, R., & Septianingtias, A. (2022). The use of macromedia flash application in improving the mathematical understanding of elementary school students. *Jurnal Prima Edukasia*, *10*(2), 114–122. https://doi.org/10.21831/jpe.v10i2.47427

Frank, J. (2023). Rethinking the purposes of schooling in a global pandemic: From learning loss to a renewed appreciation for mourning and human excellence. *Studies in Philosophy and Education*, *42*(1), 5–16. https://doi.org/10.1007/s11217-022-09850-8

Genisa, G., Yuliza, E., & Gunardi, S. (2023). The effect of classical music therapy and deep breathing relaxation therapy on lowering blood pressure in hypertension sufferers in RW 001 Samba Danum Village, Katingan Tengah District, Central Kalimantan year 2022. *Journal of Complementary Nursing*, *2*(2), 172–179. https://doi.org/https://doi.org/10.53801/jcn.v2i2.111

Gustian, K., Rusmawaty, D., Mulawarman, U., Kuaro, J., Kelua, G., Samarinda Ulu, K., Samarinda, K., & Timur, K. (2023). The benefits of flipped classroom model for EFL learners. *Journal on Education*, *05*(04), 13918–13935. https://doi.org/https://doi.org/10.31004/joe.v5i4.2411

Halim, A. (2023). Application of a realistic learning model to improve student learning outcomes with division and multiplication material in class IV MIN 19 Bireuen application of a realistic learning model to improve student learning outcomes with division and multiplica. *Intelektium*, *4*(2), 55–64. https://doi.org/https://doi.org/10.37010/int.v4i2.1314

Inganah, S., Darmayanti, R., & Rizki, N. (2023). Problems, solutions, and expectations: 6c integration of 21st century education into learning mathematics. *JEMS (Journal of Mathematics and Science Education)*, *11*(1), 220–238. http://e-journal.unipma.ac.id/index.php/JEMS/article/view/14646/4772

Jensen, E. (2014). *Brain based learning: New teaching paradigm*. Indeks.

Kabariah, S., & Adiyono, A. (2023). Efforts to use technology effectively in supporting the implementation of educational supervision. *Indonesian Journal of Education (Injoe)*, *3*(1), 63–78. http://injoe.org/index.php/INJOE/article/view/49/49

Kusumadewi, R. F., Neolaka, A., & Yasin, M. (2020). Improving the ability of understanding mathematical concepts through digital-based comics for elementary school students. *Al Ibtida: Jurnal Pendidikan Guru MI*, *7*(2), 280. https://doi.org/10.24235/al.ibtida.snj.v7i2.7024

Langdon, C., Kurz, C., & Coppola, M. (2023). The importance of early number concepts for learning mathematics in deaf and hard of hearing children. *Perspectives on Early Childhood Psychology and Education*, *5*(2), 126–155. https://doi.org/10.58948/2834-8257.1061

Lima, C., Lopes, J. A., Souza, V., Barros, S., Winkler, I., & Senna, V. (2023). Analysis of brain activation and wave frequencies during a sentence completion task: A paradigm used with EEG in aphasic participants. *PeerJ*, *11*, 1–21. https://doi.org/10.7717/peerj.15518

Lin, C. H., & Sumardani, D. (2023). Transitioning to virtual reality learning in 5E learning model: Pedagogical practices for science learning. *Interactive Learning Environments*, *12*(3), 1–15. https://doi.org/https://doi.org/10.1080/10494820.2022.2160468

Ma, N., Du, L., Zhang, Y. L., Cui, Z. J., & Ma, R. (2023). The effect of interaction between knowledge map and collaborative learning strategies on teachers' learning performance and self-efficacy of group learning. *Interactive Learning Environments*, *31*(3), 1592–1606. https://doi.org/https://doi.org/10.1080/10494820.2020.1855204

Mahsusi, Hudaa, S., Nuryani, Bahtiar, A., & Subuki, M. (2023). Integrated application-based digital learning technology in successful learning activities during the pandemic. *Journal of Applied Engineering and Technological Science*, *4*(2), 633–643. https://doi.org/10.37385/jaets.v4i2.1449

Mamede, S., & Schmidt, H. G. (2023). Deliberate reflection and clinical reasoning: Founding ideas and empirical findings. *Medical Education*, *57*(1), 76–85. https://doi.org/10.1111/medu.14863

Mekwan, J., & Poonputta, A. (2023). The effects of integrated brain-based learning and skills training in linear and quadratic functions among grade 11 students. *Journal of Education and Learning*, *12*(3), 78–85. https://doi.org/10.5539/jel.v12n3p78

Minarni, A., & Napitupulu, E. E. (2020). The role of constructivism-based learning in improving mathematical high order thinking skills of Indonesian students. *Infinity Journal*, *9*(1), 111–132. https://doi.org/10.22460/infinity.v9i1.p111-132

Nasichah, A. H. (2023). The role of taman pendidikan Alquran in instilling the students' principles of the importance of seek Islamic education at pondok pesantren. *In Proceeding International Conference on Religion, Science and Education*, 231–237. http://sunankalijaga.org/prosiding/index.php/icrse/article/view/916%0Ahttps://sunankalijaga.org/prosiding/index.php/icrse/article/download/916/856

Net, W. W. W. P., Education, B., Training, T., Bengkulu, U., & Supratman, J. W. R. (2023). Retention achievement in brain-based whole learning is supported by students' scientific literacy and concept mastery. *Pegem Journal of Education and Instruction*, *13*(3), 294–303. https://doi.org/10.47750/pegegog.13.03.30

Opoku, O. G., Adamu, A., & Daniel, O. (2023). Relation between students' personality traits and their preferred teaching methods: Students at the University of Ghana and the Huzhou Normal University. *Heliyon*, *9*(1), e13011. https://doi.org/10.1016/j.heliyon.2023.e13011

Oppong-Gyebi, E., Dissou, Y. A., Brantuo, W. A., Maanu, V., Boateng, F. O., & Adu-Obeng, B. (2023). Improving STEM mathematics achievement through self-efficacy, student perception, and mathematics connection: The mediating role of student interest. *Journal of Pedagogical Research*, *7*(4), 186–202. https://doi.org/10.33902/jpr.202321085

Otaya, L. G., Kartowagiran, B., & Retnawati, H. (2020). The construct validity and reliability of the lesson plan assessment instrument in primary schools. *Jurnal Prima Edukasia*, *8*(2), 126–134. https://doi.org/10.21831/jpe.v8i2.33275

Pandita, A., & Kiran, R. (2023). The technology interface and student engagement are significant stimuli in sustainable student satisfaction. *Sustainability (Switzerland)*, *15*(10). https://doi.org/10.3390/su15107923

Prihatiningtyas, N. C., & Husna, N. (2023). The influence of the meaningful instructional design (mid) learning model on students' mathematical problem solving ability in three variable linear equation systems. *Innovative: Journal of Social Science Research*, *3*(2), 12131–12144. https://doi.org/https://doi.org/10.31004/innovative.v3i2.1378

Purwoko, R. Y., Kusumaningrum, B., Laila, A. N., & Astuti, E. P. (2023). Development of open ended based mathematics e-modules to enhance students' critical thinking ability. *Mathline: Jurnal Matematika dan Pendidikan Matematika*, *8*(1), 194–206. https://doi.org/10.31943/mathline.v8i1.337

Putri, A. P., Hidayat, W., & Harun, L. (2022). A case study of prospective teacher students' views on the position of mathematics on human civilization. *Rangkiang Mathematics Journal*, *1*(2), 49–56. https://doi.org/https://doi.org/10.24036/rmj.v1i2.10

Rahman, A., Abdul, N. B., & Mannong, A. B. M. (2023). An analysis of teachers' questioning strategies to attract students' activeness and curiosity in the classroom interaction. *English Language Teaching Methodology*, *3*(1), 59–68. https://doi.org/10.56983/eltm.v3i1.207

Rahmatika, D., & Waluya, S. B. (2023). Students' mathematical reasoning ability viewed from self-

regulated learning in the missouri mathematics project learning with open-ended approach. *Unnes Journal of Mathematics Education*, *12*(1), 84–92. https://doi.org/10.15294/ujme.v12i1.66188

Ramos-Galarza, C., Aymacaña-Villacreses, C., & Cruz-Cárdenas, J. (2023). The intervention of brain gym in the mathematical abilities of high-school students: A pilot study. *Frontiers in Psychology*, *13*(1), 1–11. https://doi.org/10.3389/fpsyg.2022.1045567

Rizki Anggraini, I., . N. A., Marwah Sofa, S., & Dwi Marta, F. (2023). Differences in the level of learning concentration of grade V elementary school students before and after brain gymnastics (brain gym). *KnE Medicine*, *2023*, 359–370. https://doi.org/10.18502/kme.v3i3.13523

Rusticus, S. A., Pashootan, T., & Mah, A. (2023). What are the key elements of a positive learning environment? Perspectives from students and faculty. *Learning Environments Research*, *26*(1), 161–175. https://doi.org/10.1007/s10984-022-09410-4

Saleh, M., Charitas, R., Prahmana, I., & Isa, M. (2018). Improving the reasoning ability of elementary school student through the Indonesian realistic. *Journal on Mathematics Education*, *9*(1), 41–54. https://ejournal.unsri.ac.id/index.php/jme/article/view/5049

Sappaile, B. I., Palalas, E., Huzaefah, O., Yusuf, N. F. M., Purhanudin, M. V., & Sitopu, J. W. (2023). Development of worksheet based on a scientific approach with the help of the GeoGebra application for class VIII middle school students. *Jurnal Pendidikan Tambusai*, *7*(2), 9872–9878. https://doi.org/https://doi.org/10.31004/jptam.v7i2.7902

Selvianiresa, D., & Prabawanto, S. (2017). Contextual teaching and learning approach of mathematics in primary schools. *Journal of Physics: Conference Series*, *895*(1). https://doi.org/10.1088/1742-6596/895/1/012171

Setiawan, A., Fajaruddin, S., & Andini, D. W. (2019). Development an honesty and discipline assessment instrument in the integrated thematic learning at elementary school. *Jurnal Prima Edukasia*, *7*(1), 9–19. https://doi.org/10.21831/jpe.v7i1.23117

Shodiyev, J. J. (2023). The role of scientific thinking and mental development in improving human development and value. *Innovative Development in Educational Activities*, *2*(9), 251–261. https://openidea.uz/index.php/idea/article/view/1292

Si, W., Khan, N. A., Ali, M., Amin, M. W., & Pan, Q. (2023). Excessive enterprise social media usage and employee creativity: An application of the transactional theory of stress and coping. *Acta Psychologica*, *232*. https://doi.org/10.1016/j.actpsy.2022.103811

Simamora, R. E., Saragih, S., & Hasratuddin, H. (2018). Improving students' mathematical problem solving ability and self-efficacy through guided discovery learning in local culture context. International Electronic Jour. *International Electronic Journal of Mathematics Education*, *14*(1), 61–72. https://doi.org/https://eric.ed.gov/?id=EJ1227360

Stohlmann, M., & Yang, Y. (2023). Investigating the alignment to mathematical modelling of teacher-created mathematical modelling activities available online. *International Journal of Mathematical Education in Science and Technology*, *54*(5), 671–686. https://doi.org/https://doi.org/10.1080/0020739X.2021.1961030

Sucilestari, R. (2023). Development of brain based learning elementary school science learning modules (BBL). *Cahaya: Journal of Research on Science Education*, *1*(1), 1–14. https://ejournal.ahs-edu.org/index.php/cahaya/article/view/31

Thonsakul, S., & Poonputta, A. (2023). Development of grade 11 student learning achievements on quadratic functions using Brain-Based Learning (BBL) management. *Journal of Education and Learning*, *12*(1), 125. https://doi.org/10.5539/jel.v12n1p125

Tisza, G., & Markopoulos, P. (2023). FunQ: Measuring the fun experience of a learning activity with adolescents. *Current Psychology*, *42*(3), 1936–1956. https://doi.org/10.1007/s12144-021-01484-2

Triwahyuningtyas, D., Ningtyas, A. S., & Rahayu, S. (2020). The problem-based learning e-module of planes using Kvisoft Flipbook Maker for elementary school students. *Jurnal Prima Edukasia*, *8*(2), 199–208. https://doi.org/10.21831/jpe.v8i2.34446

Wijaya, A., Retnawati, H., Setyaningrum, W., Aoyama, K., & Sugiman. (2019). Diagnosing students' learning difficulties in the eyes of Indonesian mathematics teachers. *Journal on Mathematics Education*, *10*(3), 357–364. https://doi.org/10.22342/jme.10.3.7798.357-364

Winarni, E. W., & Purwandari, E. P. (2020). Project-based learning to improve scientific literacy for primary education postgraduate students in science subject. *Jurnal Prima Edukasia*, *8*(1), 67–77. https://doi.org/10.21831/jpe.v8i1.30618

Ye, H., Liang, B., Ng, O. L., & Chai, C. S. (2023). Integration of computational thinking in K-12 mathematics education: A systematic review on CT-based mathematics instruction and student learning. *International Journal of STEM Education*, *10*(1). https://doi.org/10.1186/s40594-023-00396-w