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EFFECT OF BRAIN-BASED LEARNING ON STUDENTS' MATHEMATICS PERFORMANCE AT ELEMENTARY LEVEL

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ABSTRACT
Brain-Based Learning (BBL) is an instructional approach that addresses students' achievement and learning goals from the perspective of the human brain. It entails specialised learning procedures centred on how human memory, attention, motivation, and conceptual cognitive learning work. The current experimental study was designed to investigate the effect of BBL approach on elementary students' academic performance in mathematics. The study employed a single subject A-B-A research design. The participants under investigation were eighth graders of a public school selected using an intact group. During the treatment phase (B), the principal researcher taught students the concepts related to financial arithmetic, polynomials and factorisation focusing activities; visual storytelling, back-to-board, role play, i-Think maps brainstorming and visual imagery. These activities were based on 12 BBL principles. During the course of the study, the researchers collected data nine times using one-tier MCQs based tests. The data were analysed using visual analysis and one-way repeated measure ANOVA. Partial eta value (.317) revealed that BBL significantly affects students' academic performance. To improve students' mathematics performance, the researchers recommended practitioners to teach elementary level mathematics using BBL principles-based activities.
Keywords: Academic performance, brain-based learning, one-tier MCQs, visual analysis, visual storytelling.

INTRODUCTION
Mathematics is an essential subject taught from school to university (Asfar et al., 2022), and mathematical competence and learning are necessary to address everyday life problems (Kong & Matore, 2021). Mathematical problem solving involves various basic to complicated social processes (Adiansha et al., 2021) and several students believe mathematics is a challenging (Kohar, 2022), demanding, and uninteresting subject (Almerino et al., 2019). Mathematical complexity is impacted by learners' willingness to tackle it (Sudarwo & Adiansha, 2022). Many pupils struggle in mathematics because they lack confidence in their capacity to solve mathematical issues (Riskiningtyas & Wangid, 2019).

In today's challenging world, learning mathematics is becoming essential for an individual's real growth (She et al., 2018). Recognising ideas, arguments, and relationships in mathematics requires conceptual knowledge (Mazana et al., 2019). Mathematical relationships, communication skills, and learner conceptual understanding must be developed to their full potential, seeking to obtain all the learning skills that must be attained (Guner, 2020). For students' knowledge of the learning resources to grow efficiently, effective teaching plays a critical part in developing their analytical skills (Rahman & Kharisudin, 2019). Learners must begin building new information from prior knowledge and experience while studying mathematics with comprehension (Suarsana et al., 2018). It is also evident that integrating mathematical ideas and ideas from other domains is understood as the ability to make

conceptual achievements (Husna et al., 2018). Sugiarti et al. (2021) also argued that students' mathematical literacy could not be isolated from the way of learning sciences.

A student's readiness for life in a contemporary society heavily depends on their mastery of mathematics (Rohatgi & Scherer, 2020). It is also evident from the literature that an increasing number of issues and circumstances that arise in everyday life (Mastoni et al., 2020), particularly those that occur in the workplace, call for some knowledge of mathematics, reasoning skills, and arithmetical techniques to be adequately comprehended and solved (She et al., 2018). For students, mathematics is helpful as they deal with problems and difficulties in their private, professional, social, and academic facets of life. Knowing how well-prepared students are to use mathematics to comprehend crucial issues and come up with meaningful solutions when they graduate from school (Güre et al., 2020).

Brain-Based Learning (BBL) supports learning by following how the brain is biologically structured for learning (Solihat, 2017). In view of Triana and Zubainur (2019), learning is logically and scientifically validated and in line with how the brain processes information is known as BBL. Because BBL stresses experiences that encourage the brain over time so that it has a great memory, it may be employed in learning (Wijayanti et al., 2021). This learning approach emphasises how the brains acquire learning (Erişti & Akdeniz, 2016), acquire insights (Ofen et al., 2016), and develop in an educational environment (Davidesco et al., 2021). By participating in interactive conversations (Khalil et al., 2019), the learners actively deepen their comprehension of the problem throughout this learning process (Ali et al., 2020).

A different perspective on BBL is an instructional approach that focuses on how well the brain functions and how the usage of the right and left brain is evenly distributed (Mariyam, 2017). It aims to enhance students' cognitive skills to reach their full potential (Solihat, 2017) and students' comprehension abilities and raise their degrees of scientific knowledge (Sugiarti et al., 2021). Students can observe and experience the functioning of a whole nervous system throughout BBL-based lessons (Rahman et al., 2019). It is also evident that BBL strategies and tactics utilised in the classrooms, commonly known as student-centred teaching (Fatima et al., 2020), which help students learn more effectively, are the subjects of pedagogical guidance in neuroscience (Kitchen, 2021).

The BBL works well with the current instructional methods used in various subjects (Prasetyo et al., 2021), including languages (Vīnerte & Sabourin, 2019), humanities (Jeste et al., 2020), and sciences (Susilowati & Wutsqa, 2022). This approach is used in a classroom setting that is brain-friendly and non-threatening to maximise knowledge and reduce the use of the traditional approach, which merely encourages rote memorisation (Noureen et al., 2017). The BBL teaching approach helps pupils learn from personal experiences and develop insightful ideas (Al-Balushi & Al-Balushi, 2018). It not only raises pupils' academic achievement but also fosters cooperation, teamwork, and dedication (Duncan, 2020), which enables pupils to draw lessons from their experiences in life, which is advantageous to both educators and pupils (Ali et al., 2020). The literature also found that the BBL approach perceives learning as a means that requires engagement and fosters creativity through obstacles (Cheung et al., 2020). It entails a lasting behaviour change resulting from building a knowledge based on practice and experience (Koşar & Bedir, 2018). Therefore, knowledge acquisition is a crucial component of learning because developed learning could be used when required unless remembered (Moust et al., 2021).

The literature reveals that Pakistani students face challenges in mathematics achievements (Aslam et al., 2019) and get lower mathematics grades (Ashraf et al., 2022). Mazana et al. (2019) illustrate that low achievement in mathematics results in students' boredom, dropout and less interest in classroom activities. It is also evident that students with lower achievements frequently blame fate and become less motivated (Malik & Rizvi, 2018). Low mathematics scores also lead to students' stress and anxiety, resulting in their dropout (Wang et al., 2015). Yu and Singh (2018) emphasised that instructional approaches influence students' performance in mathematics. The BBL has been identified as one of the critical teaching approaches to be investigated in the twenty-first century. There has been a growing interest in this approach as long as those who support it continue their efforts to create a link between educational practices and the way the brain learns. It is the process of adapting instruction to the learner-centred teaching processes of the human brain (Koşar & Bedir, 2018). Therefore, to observe the effect of BBL on students' performance in mathematics, the researchers designed the current

experimental study at the elementary level in Pakistan. The current study provided evidence that how students' performance can be enhanced and students can be motivated to for different activities.

REVIEW OF LITERATURE

Changing one's behaviour to gain new knowledge, skills, and the ability to complete mathematical tasks helps students' learning (Kristanto & Pradana, 2021). There are several ways to learn, including using something and then reflecting on what you've learned. Learning mathematics is a great technique to improve an educational institution's ability to teach pupils to make them valuable citizens of society (Lapada et al., 2020). Students love teaching methods and class engagement when comprehending, interpreting, recalling, and relating ideas and concepts to one another (Triana & Zubainur, 2019). Cognitive learning methods will be efficient if knowledge can be perceived as visuals, flowcharts, know the extent, circles, structures, and other techniques (Jazuli et al., 2019).

According to Caine & Caine (2002), the BBL is an effective teaching approach that helps them learn innovatively. It strives to attain all of its learning abilities. Instead of simply remembering knowledge, the BBL is designed to help students learn it in a way that sticks with them long after school is over. It's all about how our brains learn. Understanding the principles of brain processing and structuring education following these principles is an integral part of BBL (Badriyah et al., 2020). Suarsana et al. (2018) also argued that developing a student's capacity to comprehend a topic, oration and the relationship among them is essential. Ozden and Gultekin (2008) also emphasised that the development of students' concepts, which is necessary to comprehend the course materials fully, relies heavily on conceptual understanding of the topics.

Every person can benefit greatly from a strong understanding of mathematics. Because of our technological age, it is virtually difficult to exist without some knowledge of mathematics (Ibrokhimovich, 2022). The learner learns to rationally describe his activities, do them effectively, and avoid using unnecessary words or terms while describing a solution to a specific situation (Putnam, 2020). Adxamjonovna (2021) argue that mathematics is a complex subject, where students need to understand the concepts in detail with a fundamental understanding of the mathematics topics as it will help them in future life to apply in various fields of life. Various studies on pupils' mathematics performance in Pakistan, undertaken by researchers and organisations, reveal that student mathematics performance is lower than in other disciplines (Naz et al., 2020; Shoaib & Ullah, 2019). The overall mathematics performance of the learners was determined to be lower. It is also revealed that children consistently score low in mathematics (Khan et al., 2020). Researchers have closely investigated students' achievement and the techniques that affect the students' academic performance for the mathematics curriculum's emphasis on enormous gaps in learners' mathematics achievement (Alvi & Nausheen, 2019; Batool et al., 2020).

In the Pakistani context, various approaches have been deployed to improve and measure students' mathematics achievements; total quality management (Mahmood & Ismail, 2018), metacognition (Habib & Rana, 2020), the effect of ICT (Ishaq et al., 2020; Khan, 2020), the influence of physical facilities (Arshad et al., 2018), executive functioning (Hania et al., 2019), parental influence (Ahmed et al., 2019), the effect of cooperative learning (Atiq et al., 2021) and problem-solving (Ahmad et al., 2022). Even then, students' mathematics results are still unsatisfactory (Mughal et al., 2021; Ullah et al., 2018). There is a need to find any practical approach that is cost-effective and easy to use in classrooms to enhance their mathematics performance.

In the international context, there has been seen that BBL plays a crucial role in improving students' academic performance in various subjects; in terms of sciences achievement (Al-Balushi & Al-Balushi, 2018), Biology achievement (Harden & Jones, 2022), Physics achievement (Achor & Gbadamosi, 2020) on students' reading skill and writing skill (Reilly et al., 2019), on English teaching and achievement (Akman et al., 2020), and students' speaking skill (Khalil et al., 2018) and all the studies found that BBL has a significant influence on students' academic achievements. The above argument has also been widely used to improve mathematics achievement.

Mathematics is taught as a numerical and symbolic topic, with several missed opportunities to expand students' visual understanding and knowledge (Fuson, 2019). Teachers who are good at mathematics frequently use manipulatives, visuals, and activities to improve their students' level of comprehension (Boaler et al., 2016). Researchers have better understood how our brains function in the last several years while we read and learn math. When we process information, different parts of our

brains flare up and discuss with one another, forming what scientists call "distributed networks" in our heads. The dorsal and ventral visual circuits are two brain pathways activated while we concentrate on mathematics problems (Glasauer et al., 2018). The cognitive processing of mathematical information is supported by broadly distributed neural circuits (Kucian et al., 2018). When the learning environment in the classroom is optimised, students are better able to grasp a subject. In school, active learning ought to be inventive and imaginative. To help students learn, educators should use teaching methods that make the environment more favourable to students' understanding (Suarsana et al., 2018).

Each person has unique talents and features, which make them unique in a class of students with diverse potentials (Rahman & Ahmar, 2017). Each student in the class has unique learning tendencies regarding mathematics. Therefore, mathematics should be taught with activities based on BBL to enhance their performance in mathematics (Jazeel et al., 2020). Various past studies have been conducted to know teachers' awareness (Amjad et al., 2020) and readiness (Amjad et al., 2021) to explore the activities to teach these students with varied potentials. AL-Ayash et al. (2016) also developed students' kinesthetic and emotions regulating class activities based on the principles of BBL. They concluded that they also had a significant influence on their performance in the classrooms.

Ryoo et al. (2018) taught mathematics to students in a longitudinal study with activities related to brainstorming to encourage students' mathematics understanding. The study findings indicated that these activities significantly influenced their mathematics scores. Gong et al. (2021) also emphasised the use of new teaching methods and activities based on brainstorming and revealed it influenced participants' performance. Al-Bayati and Mizban (2022) also carried out an experimental study to explore the effect of brainstorming-based activities on students' performance. They revealed student groups taught using the brainstorming activities significantly impacted their academic performance compared to the control group. Filgona and Sakiyo (2020) investigated the effectiveness of brainstorming activities on students' performance in junior school students. The results revealed that brainstorming-based instructions significantly affected their academic performance.

Mekarina and Ningsih (2017) conducted a study in the class based on the results that the learners' performance in mathematics is lower. One of the contributing issues is that schooling does not give pupils the freedom they need to maximise their brain's potential. Using the BBL, the research aimed to increase students' performance in mathematics. They carried out an experimental study on high school learners. The study showed that using the BBL strategy can improve students' performance in mathematics. To study the effect of BBL on junior high students' conceptual comprehension of polyhedrons, Suarsana et al. (2018) also conducted an experimental investigation and revealed it had a positive impact on their conceptual understanding and achievements. Studying the impact of BBL on academic achievement in mathematics in 7^{th} grade girls during the 2014-2015 academic year. Jalali et al. (2020) conducted a study and found that mathematics scores after treatment were significantly higher in the treatment group than in others. There is sufficient literature support for BBL in the current experimental study. Therefore, the researchers aimed to investigate the effect of BBL on elementary students' academic performance. The researchers also tested a null hypothesis that BBL has no significant effect on elementary students' academic performance in mathematics.

METHODS

Following the positivistic worldview, the researchers used a quantitative approach to investigate the phenomenon under study. In the current single-subject experimental research, the researchers opted for the A-B-A research design to investigate BBL's effect on students' mathematics academic performance.

Participants

Study participants were elementary students enrolled during the academic year 2021-2022 in the public schools of the district of Kasur, Punjab. Using the intact group, the researchers selected an eighth-grade class consisting of 39 students of a public secondary school.

Intervention

The current 18-week study was carried out in three phases of an equal number of weeks following the study design. The first stage was a baseline (A) where the respondents were taught with the lecture method. In the second phase (B) of six weeks, the researchers applied the intervention and taught students with activities based on the BBL principles. In the study's third phase (A), the researchers withdrew the intervention and taught the students the typical teaching method again. During the intervention phase, the researchers developed the following activities based on the BBL principles.

Table No. 1 List of Activities and Features Based on BBL Principles

Treatment/Activity	Features	BBL Principles
Visual Storytelling	• Visual imagery • Picture metaphor	• The brain understands and remembers best when facts and skills are embedded in natural spatial memory. • Learning always involves conscious and unconscious processes. • Appropriate environment, music, and aroma excite rain activity. • Each brain is unique.
Role Play	• Emotion in learning • Kinesthetic • Auditory	• A positive climate stimulates brain function. • Learning is enhanced by challenges and inhibited by threats. • Learning engages whole physiology. • Each brain is unique.
Back to Board	• Kinesthetic • Brainstorming • Verbal	• The search for meaning is innate. • The search for meaning comes through the brain patterning process. • Learning always involves conscious and unconscious processes. • Learning engages whole physiology. • Complex and active experiences involving movement stimulate brain development. • Each brain is unique.
i-THINK Map	• Brainstorming • Visual imagery • Demonstration of students' understanding	• The brain is unique and a parallel processor. • The brain can quickly grasp and remember facts and skills embedded in its memory space. • Learning always takes place in two memory approaches, retaining facts, skills, and procedures or making sense of experience.

Table 1 shows the detail of activities developed on the BBL principles. During the intervention phase, students were taught mathematical topics related to financial arithmetic, polynomials and factorisation.

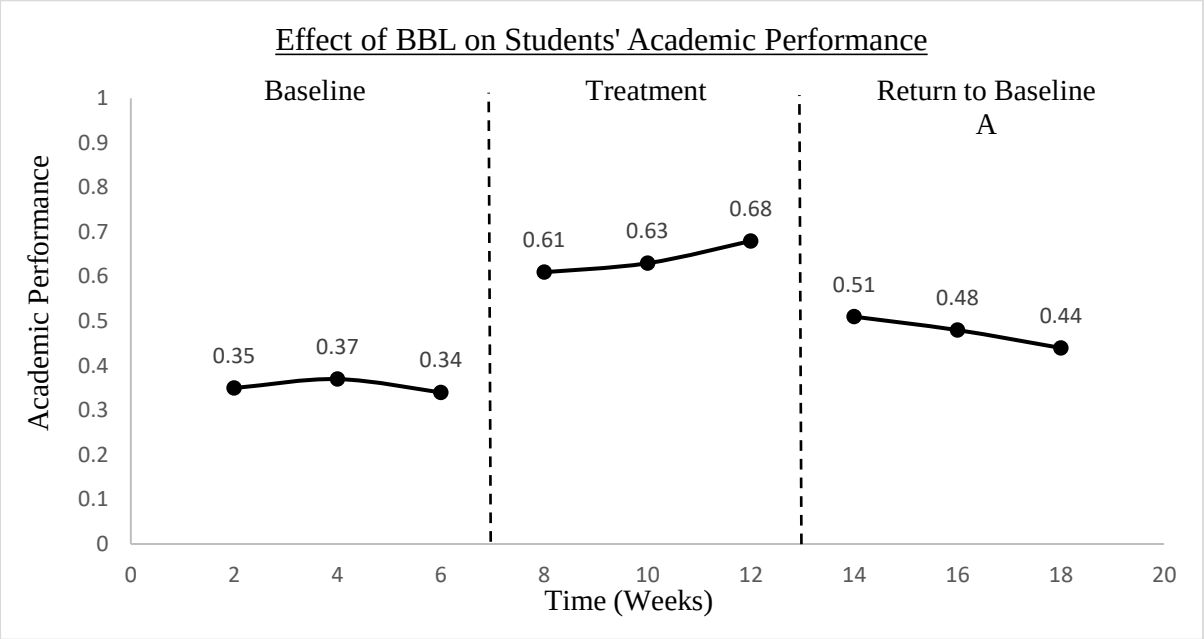
Instrument Development and Data Collection

For data collection, the researchers developed one-tired MCQs based tests which measured the performance of their concept comprehension. Overall, nine tests were developed for measuring students' performance for 1-9 units, and each test consisted of 25 MCQs. After developing these tests, the researchers sought expert opinions from the three assessment experts (Ph.Ds.) and three practitioners (teachers teaching elementary-level mathematics). The MCQs were revised on the feedback provided by the experts. After seeking expert opinion, these tests were piloted, and the researchers ensured their reliability by measuring Cronbach's Alpha (which ranged from .70 to .87 for these nine tests). The researchers also carried out the item difficulty and item discrimination analysis of the tests. The MCQs falling in the range of item difficulty index, 0.30-0.70, and discrimination index greater than 0.2 were selected. During all three stages of the study, the researchers collected data on students' academic performance in mathematics at a regular interval of two weeks. Overall, the researchers took nine tests (3 for each stage).

ANALYSIS AND RESULTS

After collecting the data, it was screened out and the missing values were adjusted. The researchers used SPSS (Version 26) for the data analysis process. After testing the assumptions of parametric tests (normality, equal variance, independence, and no outliers), the researchers analysed it using visual analysis. One-way repeated measure ANOVA was also deployed to measure the mean difference within the subjects. The results are presented below in the form of figures and tables.

Figure No. 1 Students' Academic Performance in Mathematics



The above graph shows the results of students' academic achievement in eighth-grade mathematics during the 18-week experimental study. Students' academic performance (M_1 = .35, M_2 = .37, M_3 = .34) is lower in baseline (A) than in the treatment (M_4 = .61, M_5 = .63, M_6 = .68) phase (B), during which they were taught topics related to financial arithmetic and factorization using the BBL principle-based activities. Towards the end of the experiment, the third phase baseline (A) shows a decline (M_7 = .51, M_8 = .48, M_9 = .44) in the academic performance of the students. The analysis revealed that the improvement in scores in the treatment phase (B) was the result of using BBL-bases activities following BBL instructional approach. The decline in performance in the withdrawal phase supports the argument that the performance improvement in treatment phase was only because of the intervention applied to them. For testing the hypothesis and measuring the effect size, the researcher deployed one-way repeated measure ANOVA and tested the assumption of sphericity.

Table No. 2 Mauchly's Test of Sphericity

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Academic Performance	.022	133.995	35	.000	.769	.934	.125

Table 2 indicates that the sphericity value is W = .022 < .05, it indicates that Mauchly's assumption is violated. It is evident that when sphericity is not established, Greenhouse-Geisser and Huynh-Feldt corrections are considered for effect size interpretation (Field, 2013). It is argued that when the value of assumed sphericity is greater than .75, the Huynh-Feldt correction is used. When its value is lesser than .75, the Greenhouse-Geisser correction should be used for interpretation of effect size (Bagchi & Raizada, 2019) as the value of the assumed sphericity is 4.99 > 0.75. Therefore, the researchers used the Huynh-Feldt correction and applied it to the adjusted degree of freedom and the *F*-ratio to interpret students' academic performance within the group to investigate the effect of BBL-based activities on students' academic performance in mathematics. The results are provided in table 3 below.

Table No. 3 Mean and Standard Deviation Values and Tests of Within-Subjects Effects

Variable	M	SD	N	Df	*Effect*	Sphericity assumed	*F* ratio	Sig.	Partial Eta Squared
Week 2	.35	.176	39	6.15	Academic performance	4.99	17.62	.000	.317
Week 4	.37	.191	39						
Week 6	.34	.185	39						
Week 8	.61	.175	39						
Week 10	.63	.182	39						
Week 12	.68	.231	39						
Week 14	.51	.192	39						
Week 16	.48	.177	39						
Week 18	.44	.178	39						

Table 3 indicates the mean and standard deviation values along with the corrected degree of freedom and *F*-ratio for the study hypothesis. It was carried out to find out how teaching grade VIII pupils using BBL-based activities during the intervention phase affected their academic performance in mathematics. Students' academic performance in mathematics revealed significantly different score F (6.15) = 17.62, p = 000 .05, η_p^2=.317. The value of partial eta is greater than .14, which shows that BBL-based activities significantly affected students' academic performance.

Estimated Marginal Means of Academic Performance in Mathematics

The result of students' estimated marginal means of their academic performance in mathematics during the 18 weeks experimental study process is shown in the following figure.

Figure No. 2 Mean Score of Students' Academic Performance in Mathematics During Baseline, Teaching Through BBL, and Withdrawal Phase

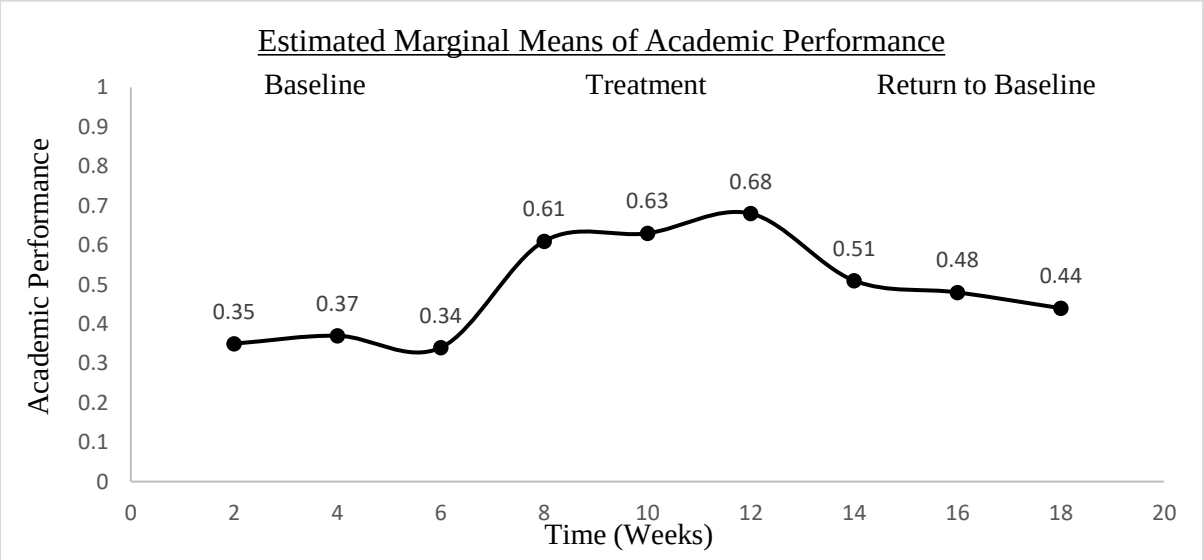


Figure 2 displays trends in the means scores for nine measurements of students' academic performance throughout different study phases. In the first baseline phase (A), no trend is observed as the means values show a marginal change. At the same time, the change in the score from baseline (A) to treatment phase (B) is significantly higher. A positive trend is observed in the treatment phase (B) as the mean scores keep increasing. In contrast to the treatment phase, in the withdrawal phase (A), the negative trend is observed as the mean values decrease towards the end of the study.

DISCUSSION

The current study supported the argument provided by Mekarina and Ningsih (2017), who also revealed that when BBL is employed in school settings, it influences their performance in mathematics. The study's treatment phase (B) results indicate a significant improvement in eighth graders' academic performance in mathematics from their baseline phase (A). This argument is supported by the results in the withdrawal phase (A), where the decline in the results shows that this improvement was due to the interventions provided in the treatment phase. The current study also supported the findings of Suarsana et al. (2018), in which they deployed the BBL approach to study the seventh-graders. They also concluded that the BBL was a practical approach that enhanced seventh-graders mathematics performance during the 2014-2015 academic year. It also supported the argument of Jalali et al. (2020), who investigated that the intervention group to which BBL treatment was given showed better results than the control group.

The researchers developed activities based on the BBL principles during the intervention phase. It also included visual imagery-based activities, which had a significant effect on their academic performance, as supported by the argument of Fuson (2019), who believed that mathematics is a kind of subject which should be taught with visual understanding to improve their performance in mathematics. It also supported the idea of Boaler et al. (2016), who emphasised the role of manipulatives and visual activities in improving students' mathematics performance. During the intervention phase, the researchers developed activities related to the features of emotions in learning, auditory and kinesthetic based on the BBL principles and the results revealed it had a positive change in students' academic performance by developing class environment for their climate stimulation for their brain functions, learners were engaged using their physiology, and desirable environment keeping in view their brain uniqueness. The current study also supported the findings of AL-Ayash et al. (2016). They constructed students' kinesthetic and emotional regulating class activities based on BBL principles and determined that they significantly impacted their academic performance.

The researchers also designed activities related to brainstorming the eighth graders' academic performance in mathematics in the current study. The results indicated that it significantly influenced their academic achievement. The current study also supported the findings of Ryoo et al. (2018), who taught mathematics to students in a longitudinal study using brainstorming activities to encourage students' mathematics understanding. The study found that these activities significantly influenced their mathematics scores. It also corroborated the findings of Gong et al. (2021), who emphasised adopting novel teaching methods and activities based on brainstorming and indicated that it influenced participant performance. The current study also backed up the findings of Al-Bayati and Mizban (2022), who conducted an experimental study to investigate the impact of brainstorming-based activities on student performance. They found that student groups taught through brainstorming exercises considerably improved their academic performance compared to the control group.

CONCLUSION

The current experimental study was carried out with a focus on investigating the effect of BBL-based activities on eighth graders' academic performance in mathematics. The researchers designed activities like visual storytelling, brainstorming, back-to-board and i-Think maps based on the BBL principles. In the treatment phase, students were taught mathematical topics related to financial arithmetic, polynomials and factorisation using these activities. The study revealed that students' academic performance measured using the one-tired MCQs test was significantly higher than those in the baseline phase (A) and the withdrawal phase (A). Partial eta value (.317) showed that BBL-based activities significantly affected students' academic performance for the topics related to financial arithmetic, polynomials and factorisation.

RECOMMENDATIONS

Based on the findings, the researchers found that students' academic performance in mathematics can be enhanced using activities based on the BBL principles. The BBL is the critical approach for improving students' mathematics performance. The researchers recommended that as mathematics is a complex subject, therefore, the practitioner should consider that students are unique and their brain is social; therefore, the teachers should develop activities such as brainstorming, visual imagery, kinesthetic, i-Think map, back-to-board, and role play for teaching mathematics and improving

students' academic performance. The researchers hope elementary-level mathematics teachers will use the BBL strategies during their teachings. Teacher training institutions may also introduce BBL principles during mathematics teachers' training programs. To add teachers' voices to using the BBL approach in mathematics, the researchers recommended that future researchers conduct qualitative studies.

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