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RESEARCH PAPER

The Effect of Brain-Based Learning on Students' Self-Efficacy to Learn and Perform Mathematics: Implication of Neuroscience into School Psychology

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ABSTRACT

Neurosciences is emerging as an interdisciplinary field that is making progress toward having a meaningful impact on school psychology. The present study was designed to integrate neuroscience with the brain's capacity to affect students' self-efficacy by deploying neuroscience-based instructional practices for mathematics. This experimental study aimed to examine how Brain-Based Learning (BBL) influences elementary school students' self-efficacy to learn and perform in mathematics. The A-B-A research design was used for the current single-subject investigation. Thirty-nine eighth-graders from a public secondary school participated in the study. Mathematics Motivation Scale (MMS) was used to collect data from respondents throughout the study stages. One-way repeated-measures ANOVA and visual analysis were deployed for the analysis of data. The results reveal that in the baseline phase (A), students' self-efficacy mean scores (M1 = 3.63, M2 = 3.58, M3 = 3.64) were lower than in the treatment phase (B) mean scores (M4 = 4.64, M5 = 4.75, M6 = 4.70). Mean scores (M7 = 4.12, M8 = 4.06, M9 = 4.00) decreased from treatment phase (B) to withdrawal phase A. The results indicate that significance rise of self-efficacy in the treatment phase (B) was due to the intervention applied to students. The use of BBL-based activities like visual imaging, role playing, and brainstorming were suggested to enhance students' self-efficacy in mathematics classes.

KEYWORDS A-B-A Design, BBL-Based Activities, Brain-Based Learning, Neuroscience, Self-Efficacy

Introduction

The concept of self-efficacy was given by Bandura (1977); according to him, it influences individuals' choices for behavioural settings. Bandura (1986) defines self-efficacy as someone's level of self-efficacy, their confidence in their ability to take the actions that will lead to desired outcomes in terms of performance. It has its roots in social cognitive theory (Gecas, 1989; Jiang et al., 2019; Maddux & Stanley, 1986) and has a pertinent role to play in educational settings (Gundel et al., 2019; Hendricks, 2016). It refers to a person's belief in their abilities to complete an upcoming performance. That view holds that self-efficacy is primarily a criterion-referenced assessment of one's performance rather than an emphasis on one's cognitive skills (Van-Dinther et al., 2011). In education, the self-efficacy hierarchy is structured to help students acquire meaningful beliefs about their talents across a wide range of subject areas and sub-areas (Panadero et al., 2017).

The origin of Brain-Based Learning (BBL) can be traced back to the field of neuroscience. Neuroscientists could better understand "how the brain processes" with cutting-edge brain imaging technologies like MRI (Jazeel et al., 2020). Neuroeducation is an emerging and rapidly changing field that bridges the gap between neuroscience and education (Bhargava & Ramadas, 2022). In the view of Caine & Caine (1995), BBL in teaching and learning takes a holistic view of learning and emphasises the brain's unique capabilities. The learning method named BBL was designed to work with the way the human brain functions (Bada, 2022). Although all forms of education are fundamentally brain-based, BBL is a method for maximising the brain's potential during classroom learning (Yatim et al., 2022). BBL uses strategies discovered through neuroscience and cognitive science studies to improve educational practices (Williams et al., 2010). It is a student-focused and instructor-guided approach that makes the most of students' natural cognitive strengths and aptitudes while emphasizing acquiring knowledge with real-world applications (Uzezi & Jonah, 2017). In brief, BBL is an approach to learning and instruction that uses the insights gained from studying the human brain and the studies that have already been conducted on the topic (Sani et al., 2019).

Students' learning can be boosted by employing these methods since they allow them to learn in ways with which they are physiologically most at ease (Connell, 2009). BBL incorporates and integrates academic interventions grounded in research and practical aspects of psychological learning, which could be its most salient feature (Koşar & Bedir, 2020). A BBL approach to education takes the learner's time and effort when fostering an engaging and meaningful environment. Neuroscience significantly affects individuals' self-efficacy (Luzzato & Rusu, 2019). Being rooted in neuroscience, many educationists have deployed BBL to explore its effect on students' self-efficacy to learn and perform mathematics (Imanuel & Mariani, 2019; Rahman & Kharisudin, 2019). Imanuel and Mariani (2019) found that teaching strategies based on how the brain works improved students' perceptions of their learning abilities. It is evident from the literature that participants' academic success and performance can be boosted through BBL when coupled with extensive learned knowledge. The relationship between pupils who undergo BBL and their performance can be further strengthened through the development of academic self-efficacy (Riskiningtyas & Wangid, 2019). The experimental group's post-treatment self-efficacy scores are much higher than the control group.

Mathematics is a significant and compulsory subject to be taught till the secondary level in Pakistan (Chishti & Rana, 2021). In the current era of science and technology, mathematics has assumed a paramount role. Students' ability to think analytically, logically, and appropriately in the face of everyday challenges was greatly aided by their familiarity with mathematical concepts (Malik & Rizvi, 2018). It is evident from the literature that students face difficulties in mathematics and get lower grades at the national (Aslam et al., 2019; Malik & Rizvi, 2018) and international levels (Mazana et al., 2019; Morán-Soto & Benson, 2018). Self-efficacy and students' confidence in their abilities to learn and solve problems in mathematics have become a prominent focus of studies examining the elements that motivate students to perform well (Morán-Soto & Benson, 2018). It is also evident from the literature that mathematical self-efficacy and learning strategies in teaching mathematics have received scant attention in the study literature, particularly among elementary-level students (Rozgonjuk et al., 2020). Based on the argument, the current paper aims to investigate the effect of BBL on students' self-efficacy to learn and perform mathematics at the elementary level.

Literature Review

To better understand how a BBL approach might help secondary school students to improve their self-efficacy toward mathematics, Hussien (2016) conducted an experimental study. Data was collected using a self-developed scale for measuring students' self-efficacy. The data collected both before and after the intervention were analysed. From the analysis, the researchers revealed that students' self-efficacy was significantly enhanced using the proposed BBL model in their instructions. Sukoco and Mahmudi (2016) attempted to characterise how lessons based on the BBL affect students' mathematical self-efficacy and sense of competence in this area. It was a quasi-experiment, and data was collected using a multi-criterion assessment (MCA) test and a self-efficacy measure. The study results demonstrate that BBL-based instruction improves students' mathematics communication skills and confidence in their mathematical abilities. Oghyanous (2017) also conducted a study to examine how using the BBL approach of instruction affected the self-efficacy of adolescent EFL students. Ninety students between were initially recruited for the study. The researchers used the BBL approach's three strategies to execute BBL with the experimental class. The three strategies used were relaxed alertness, active processing, and orchestrated immersion. Statistical analysis revealed that the BBL approach significantly improved students' self-efficacy.

The purpose of the research conducted by Imanuel and Mariani (2019) was to evaluate the effectiveness of BBL supplemented by Schoology on students' self-efficacy to think creatively about mathematics. The results of the current mixed-method study showed that students who were taught using BBL had higher self-efficacy than their counterparts. To further explore the effect of BBL on students' self-efficacy, Riskiningtyas and Wangid (2019) conducted an experimental study to compare the results of the BBL and direct instruction approaches on students' perceptions of their abilities in mathematics. They used a self-efficacy questionnaire for the collection of the data. They used simple independent sample *t*-test to analyse the data. Self-efficacy was raised to a greater extent in the experimental group, where a BBL approach was implemented, compared to the control class, where direct instruction was used. Rahman and Kharisudin (2019) conducted an experimental study. They found that two participants with a higher level of self-efficacy have a higher-level ability for problem-solving. At the same time, two respondents with medium SE are classified as having the moderate problem-solving ability.

Sani et al. (2019) conducted an experimental study to explore the effect of BBL on their self-efficacy in their abilities for science subjects. The N-Gain value for the study's experimental class was .004, while the N-Gain score for the control class, which relied on the traditional method, was .078. Analysis revealed that students in the control class had more self-efficacy than in the experimental group, which negates the effectiveness of BBL on students' self-efficacy, as mathematical self-efficacy is a crucial skill. Therefore Rusyda et al. (2020) also conducted an experimental study to enhance students' self-efficacy for mathematics. They collected data from the 7th-grade students through a self-efficacy scale. The study's results indicated that students taught using BBL had significantly improved mathematics self-efficacy than their counterparts. The study by Riskiningtyas et al. (2020) illustrated how BBL boosts students' self-efficacy in their ability to do mathematics. Confident students kept trying till they figured out the math problem. Teachers were crucial in promoting students' self-efficacy in learning independently. For its potential to outperform other learning models, BBL was selected. The students' sense of self-efficacy increased as a result. To summarise, BBL can be used as a learning method to boost students' self-efficacy in mathematics.

Hypothesis

The experimental study focused on exploring the effect of BBL on eighth graders' self-efficacy to learn and perform mathematics. Based on the study focus, the researchers designed the following null hypothesis and tested it using the one-way repeated measure ANOVA at the significance level of .001.

Material and Method

The current experimental study was designed by following the positivist worldview. The study was conducted on one group only, and the design of the present single-subject study was *A-B-A* in nature. Following the study design, the process was divided into three phases; *A* (baseline), *B* (intervention), and *A* (withdrawal).

Participants

The study participants were the eighth-graders of a public sector secondary school in district Kasur, selected using the intact sampling technique. These 39 students were enrolled in a high school during the academic year 2021-2022. These students have been taught in the same school for the last three years. They knew each other and had a suitable emotional attachment and understanding of each other.

Measure

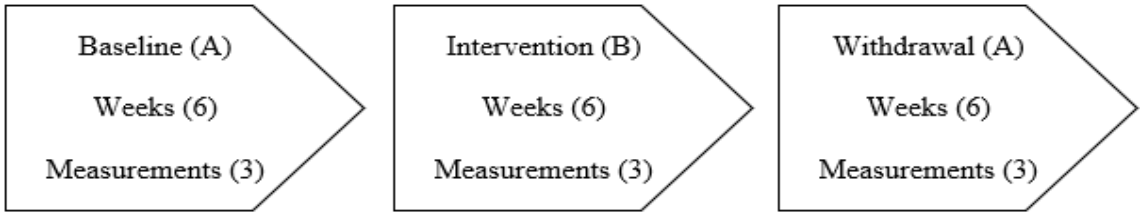
The researchers used a scale developed by Zakariya and Massimiliano (2021) to collect data from study participants. The mathematics Motivation Scale (MMS) consists of 24 items measuring different factors related to students' motivation for mathematics. Students' self-efficacy to learn and perform mathematics is one of these factors. Students' self-efficacy to know and serve mathematics was measured by the statements like, "I believe I will receive an excellent grade in mathematics exams," and I am confident that "I can do an excellent job on assignments and tests in mathematics." The scale was developed in the five-point Likert Scale with options strongly disagree to agree strongly. The current scale was developed and validated through expert opinions and statistical techniques. The scale's reliability (overall nine measurements) was determined using Cronbach's Alpha, which was between .73-.86, which is satisfactory as per the defined criteria by Hair et al. (2021) for the acceptability of the scale. Hair et al. (2021) argue that if the Cronbach Alpha values vary between .60 - .70, the scale is satisfactory, and if it varies between .70 – .90, then the scale is good and acceptable.

Procedure

As the current 18-week experimental study's research design was *A-B-A*, the progression of the study had three phases of equal length (6 weeks). During the baseline phase (*A*), the students were taught units 1-3 of eighth-grade mathematics using the traditional method (lecture method). The researchers took three measurements using MMS during the study's first phase. In the study's second phase, *B* (intervention phase), the researchers taught three units (4-6) of eighth-grade mathematics using activities based on the BBL principles. These activities were developed based on ensuring students' sense of accomplishing mathematical tasks and challenges related to financial mathematics (concepts of banking, online banking, compound proportion, conversion of currencies, profit/markup, leasing, profit-loss, discount, income tax, and insurance for humans and vehicles), polynomials (linear, quadratic, cubic and biquadratic and different operations on polynomials) and factorisations (basic algebraic formulas, factorisations, manipulation of algebraic expression and simultaneous linear equations).

Based on the BBL principles, the researchers developed activities like visual storytelling (visual imagery and picture metaphor), role play (emotions in learning, kinesthetic and auditory), back-to-board (brainstorming and verbal), and i-Think Map (demonstration of students' understanding and confidence). During the intervention phase (*B*), the researchers used MMS to measure students' self-efficacy to learn and perform mathematics at regular intervals (fortnightly). The researchers removed intervention in the third phase of the study (*A*). They again taught students for the subsequent three units (7-9) by deploying the lecture method and measured students' responses using the MMS. The study progression and the detail of the collection of the data are provided in the Figure 1.

Study Progression and Data Collection



In Figure 1, the researchers show that the current experimental study had three phases of equal length (6 weeks). In each step, the researchers collected data using MMS at the regular interval of 2 weeks.

Results and Discussion

Overall, 39 elementary eighth-graders participated in the current experimental study. After collecting data during the baseline phase (*A*), intervention phase (*B*), and withdrawal phase (*A*). Data were firstly analysed using visual analysis (Fraenkel et al., 2012) and one-way repeated measure ANOVA. Statistical Package for Social Sciences (SPSS) version 26 was used to analyse data. The results are presented below.

Effect of BBL on Students' Self-efficacy to Learn and Perform Mathematics

During the current experimental study, the researchers took nine measurements using MMS. The results of visual analysis are presented in the Figure 2.

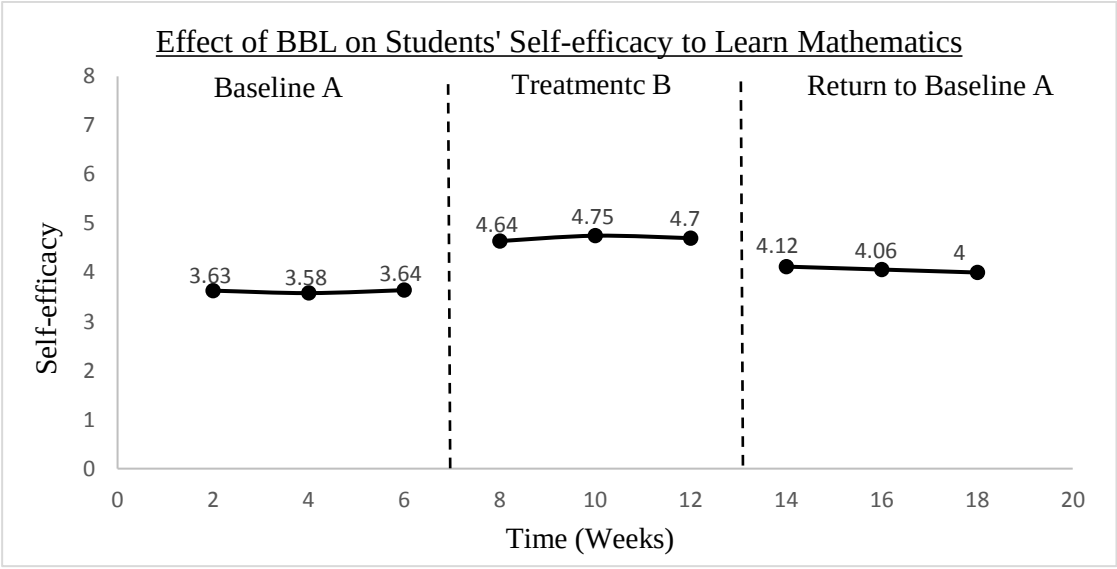


Figure 2 Effect of BBL on Students' Self-Efficacy to Learn and Perform Mathematics

In Figure 2, the researchers represent the effect of BBL on eighth graders' self-efficacy to learn mathematics during the current experimental study. In the baseline period (*A*), students' self-efficacy scores (M_1 = 3.63, M_2 = 3.58, M_3 = 3.64) are lesser than the scores (M_4 = 4.64, M_5 = 4.75, M_6 = 4.70) in the treatment phase (*B*). It shows a significant increase in students' self-efficacy scores in learning and performing mathematics from baseline to intervention (*B*). While in the withdrawal phase (*A*), the scores (M_7 = 4.12, M_8 = 4.06, M_9 = 4.00) showed a decline from the treatment phase (*B*), it further explains that the increase in the second phase was due to the treatment provided to students using the BBL. The analysis shows that BBL is an instructional approach that significantly affecting students' self-efficacy to learn and perform mathematics.

The researchers tested the assumption of sphericity. Sphericity is described as the state in which the variances of all permutations of subgroups are equal (Lane, 2016). Mauchly's test of sphericity is carried out to test the assumption of sphericity in the current inferential statistics. It is used to determine whether or not the sphericity assumption is satisfied in a one-way repeated measures ANOVA. If this condition is violated, the *F*-ratio increases and the one-way repeated measures ANOVA outcomes become questionable. For hypothesis testing, the researchers deployed the one-way repeated measure ANOVA at the significance level of .001. The results are provided in the Table 1 below.

Table 1
Mauchly's Test of Sphericity

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Self-efficacy	.000	348.931	35	.000	.310	.334	.125

In Table 1, the researchers represent that Mauchly's W = .000 < .001. It shows that Mauchly's test statistic is significantly different. The assumption of sphericity was violated. Accordingly, the researchers established that the sphericity assumption is not met because there are considerable differences in the results of different experimental conditions. When assumed sphericity (Mauchly's *W*) is less than .75, values of the Greenhouse-Geisser corrections are used (Bagchi & Raizada, 2019). The result shows that the sphericity assumption is violated in the current case, and other options will be considered as the assumed sphericity is less than .75. Therefore, Greenhouse-Geisser correction is used to interpret the analysis results in the Table 2.

Table 2
Mean and Standard Deviation Values and Tests of Within-Subjects Effects

Variable	*M*	*SD*	*N*	*df*	Sphericity assumed	*Effect*	*F*-ratio	Sig.	Partial Eta Squared
Week 2	3.63	.431	39	2.48	69.468	Self-efficacy	88.173	.000	.699
Week 4	3.58	.487	39						
Week 6	3.64	.452	39						
Week 8	4.64	.240	39						
Week 10	4.75	.201	39						
Week 12	4.70	.227	39						
Week 14	4.12	.324	39						
Week 16	4.06	.357	39						
Week 18	4.00	.436	39						

In Table 2, it is shown that assumed sphericity is 69.468 is less than .75. Therefore, the Greenhouse-Geisser correction is used to interpret the difference among all the study phases. The researchers reveal how BBL influences eighth-graders self-efficacy during the intervention phase. It further shows that sphericity adjustment after Greenhouse-Geisser correction displays F (2.48) = 88.173, p = 000 < .001, ηp^2 = .699. The value of partial eta is more than .14, which indicates that BBL activities significantly affected students' self-efficacy.

The analysis revealed that the null hypothesis was rejected, and activities like visual imagery, brainstorming, back-to-board, i-Think map, role play, and others based on BBL principles significantly affect students' self-efficacy to learn the concepts related to financial arithmetic, polynomials, and factorisation during the treatment phase (*B*).

Estimated Marginal Mean Score for Students' Self-Efficacy to Learn and Perform Mathematics

The results for the estimated marginal mean scores of students' self-efficacy to learn mathematics during the 18-week experimental study are presented in the Figure 3.

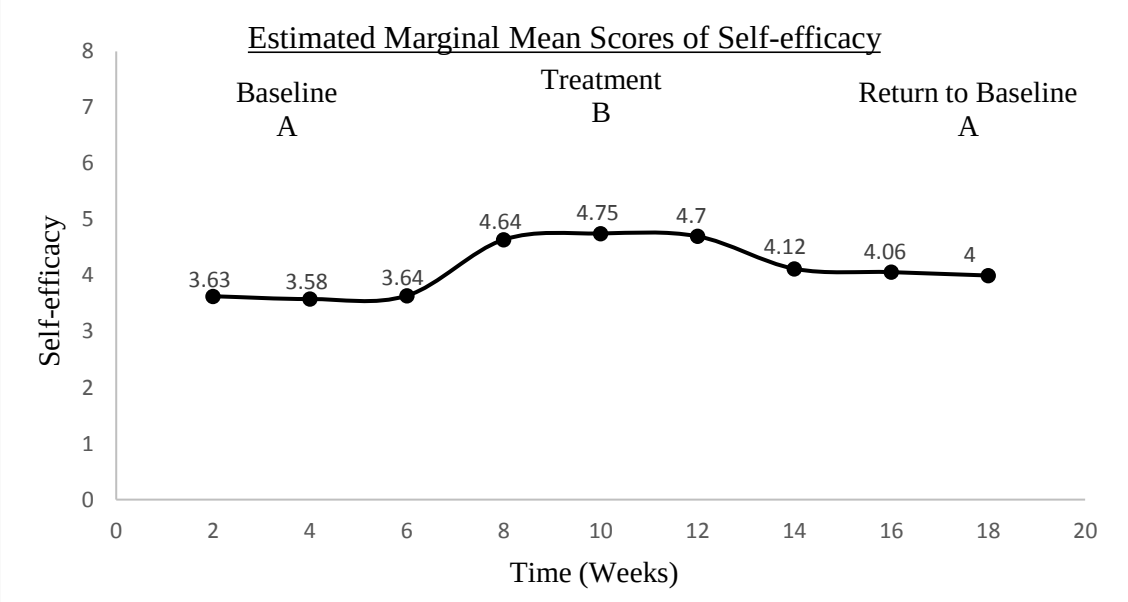


Figure 3 Mean Score of Students' Self-Efficacy to Learn and Perform Mathematics During Baseline (A), Treatment Phase (B), and Withdrawal Phase (A)

In Figure 3, the researchers demonstrate the distribution of mean values of nine measurements taken for students' self-efficacy to learn and perform mathematics during the 18 weeks of the current experimental study. In the initial baseline phase (*A*), no trend is seen. In the treatment phase (*B*), a positive trend is evident as the values keep increasing as the treatment phase advances. In contrast, in the withdrawal phase (*A*), the negative trend is apparent as the mean values decline towards the end of the study.

Students' poor performance in mathematics is one of the challenges for teachers and students (Enikanolaye, 2021; Mabena et al., 2021), for which researchers have applied various interventions and techniques over a period of time to enhance students' self-efficacy to perform mathematical tasks (Amjad et al., 2022; Samuel & Warner, 2021). The focus of the current study was also to see the effect of BBL on students' self-efficacy in performing mathematical tasks at the elementary level. The researchers have found in the present study that BBL is a practical approach that can influence students' self-

efficacy in mathematics. The analysis revealed a significant difference in the results among the study stages (baseline, intervention, and withdrawal). From the findings, it can be seen that mean values for students' mathematical self-efficacy show an increasing trend from the baseline to the intervention phase and then a declining direction from the intervention phase to the withdrawal phase. It is understandable from the results that this increase in mean values from *A* (baseline phase) to *B* (intervention phase) was owed to the BBL approach, which helped students to feel more relaxed and happier. The decrease in mean values from *B* (intervention phase) to *A* (withdrawal phase) also supports the argument that the change in the mean values resulted from the BBL intervention. Now, when the intervention is withdrawn, the results have declined.

The current study's findings had practical significance, especially for teachers undergoing continuous stress of students' lower performance and lesser confidence in their abilities to perform in mathematics. It is evident from the literature that students' performance leads to teachers' performance and stress (Farley & Chamberlain, 2021). The current study can help teachers improve students' mathematical performance self-efficacy. Teachers teaching elementary-level mathematics are expected to design the mathematics teaching activities based on the BBL principles and practice to their best potential, enhancing students' confidence to perform challenging tasks related to mathematical concepts. It is also justified with the help of study findings of Imanuel and Mariani (2019), who revealed that students' self-efficacy could be enhanced when they are taught using the BBL approach. The researchers in the current study exactly did the same and designed mathematical activities such as visual storytelling, which helped them to prepare using picture metaphors, an i-Think map which helped students demonstrate their understandings, role play which involved their emotions and kinesthetic skills, back-to-board which enabled them for thinking bigger picture and doing brainstorming for solving mathematical problems which lead to enhance students' self-efficacy to perform mathematical tasks.

The current experimental study investigated that BBL helped students to enhance their self-efficacy to learn and perform mathematics when they were taught the activities based on the principles guided by the BBL. Our study supported the findings of a previous study by Imanuel and Mariani (2019) that examined the impact of using Schoology as an adjunct to BBL on students' perceptions of their abilities in the classroom. Students taught with BBL reported higher levels of self-efficacy. It also supported the findings of Riskiningtyas and Wangid (2019). They conducted an experimental study to compare the effects of the BBL and direct instruction approaches on students' perceptions of their self-efficacy in mathematics. They concluded that self-efficacy was raised to a greater extent in the experimental group, where a BBL approach was implemented, compared to the control class, where direct instruction was used. In contrast, our study contradicted the study findings of Sani et al. (2019). They also conducted an experimental study to explore the effect of BBL on their self-efficacy in their abilities for science subjects. Their study analysis revealed that students in the control class had more self-efficacy than in the experimental group, negating BBL's effectiveness on students' self-efficacy. This misleading argument needs to be further investigated in future studies.

Conclusion

The current experimental study was designed to investigate the effect of the BBL on self-efficacy to learn and perform mathematics in the 8th graders of a public-level secondary school. It was a three-stage study, and in the first phase (A-baseline phase), students were taught mathematics using the traditional lecture method. In the second

stage (B-intervention phase), the researchers deployed the intervention for teaching mathematics. Based on BBL principles, students were taught mathematics using the activities (visual storytelling, brainstorming, i-Think map, back-to-board, and kinesthetic oriented) based on BBL principles, and the analysis revealed that it influenced their self-efficacy in mathematics. Teaching students with the BBL approach was helpful for them in enhancing their mathematical self-efficacy. The researchers withdrew the intervention in the third part of the study (A-withdrawal phase). They taught again with the help of the traditional lecture method of instruction, and analysis revealed that their self-efficacy to learn and perform again declined and showed a negative trend. From this decline, this increase and decrease in mean values were just the results of the intervention. When the intervention was applied, it increased, and when it was withdrawn, it decreased again. The current study presented a detailed overview of the intervention procedure and the development of the related activities. It can surely help teachers teaching mathematics, especially at the elementary level, to guide them on how they can work on students' self-efficacy and get better results in their mathematics performance.

Study Limitations, Implications, and Future Research

The present study may have specific limitations. It was an experimental study confined to a small sample and a single geographical area (school and class). Repeating the same measure to collect data for all measurements may be another limiting factor to providing narrow outcomes. In addition, due to financial constraints, the researchers developed BBL-based activities using low-cost, no-cast material to provide a student-friendly environment for mathematical concept-based tasks. Therefore, it may have poor generalizability, which can limit the scope of the present study. Based on the study findings, it may have practical implications for elementary-level teachers and students. Teachers and students may feel more relaxed while working in a BBL-oriented classroom. The analysis revealed that it significantly enhanced students' self-efficacy to learn and perform mathematics. Therefore, elementary-level mathematics teachers can follow the BBL principles to improve students' class performance, engagement, and social development. Considering the potential of future researchers, the present study may suggest conducting a detailed investigation using the qualitative approach for measuring the effect of BBL-based activities on students' self-efficacy. The present study contradicted the findings of Sani et al. (2019) to explore further how BBL enhanced the self-efficacy of the control group instead of the experimental group. Therefore, it may suggest researchers replicate the current study approach on two groups using other research designs for two groups (experimental and control groups).

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