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RESEARCH PAPER

Neuroscientific Study on the Effect of Brain-Based Learning on Students' Intrinsic Motivation to Learn Mathematics

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ABSTRACT

The focus of the present paper was to investigate the impact of Brain-Based Learning (BBL) on students' intrinsic motivation to learn and perform mathematics. Based on the implications of neuroscience in schools, the researchers designed the current experimental research with a single-subject A-B-A research design. The respondents were 39 eighth-graders enrolled in a boy's public secondary school in the academic year 2022-2023. As per the study design, it had three stages. Students were taught mathematics using the traditional lecture method in the baseline phase (A) and withdrawal phase (A). In comparison, in the treatment phase (B), the participants were taught mathematics using activities based on the BBL principles. The Mathematics Motivation Scale (MMS) was used to collect data during all study phases. The data were analysed using visual analysis and one-way repeated measure ANOVA. The researchers concluded that BBL had significant effect on students' intrinsic motivation to learn and perform mathematics. The teachers were recommended to develop and use BBL-based activities in mathematics teaching at elementary level.

Keywords: Brain-Based Activities, Brain-Based Learning, Intrinsic Motivation, Mathematics Learning, Visual Analysis

Introduction

Mathematics is now a basic course of study across all levels of education, from primary school to university (Udjaja et al., 2018). Mathematics is considered a compulsory subject in Pakistan till matric (Amjad et al., 2022). It is being taught at all levels and is viewed as one of the most challenging subjects in school (Steuer et al., 2022). It requires students to memorise formulas (Pournara & Adler, 2022), closely follow examples (Udjaja et al., 2018), and deal with less engaging subject matter (Appelgate & Jurgenson, 2022). It is prevalent that a good memory is essential for success in mathematics because students have to learn a sheer volume of formulas and equations (Pascual, 2022). However, the key is solving a mathematical problem using the correct method (Nematillayevna, 2021).

Mathematics affects our routine life and academic career (Warne et al., 2019). Being good at mathematics is essential for a personal and country's economic development (Maass et al., 2019; Nordhaus, 2019). Being involved in multiple disciplines is crucial to a country's progress in science and technology (Bano et al., 2018; Marpa, 2021). Mathematics is a subject that helps one make sense of the world around them in fields as diverse as engineering (Faulkner et al., 2019), physics (Retnawati et al., 2018), sociology (Rozgonjuk et al., 2020), chemistry (Venkatasubramanian, 2019), and even in arts (Pahmi et al., 2022). Mathematics' impact on the scientific and technological communities is multifaceted, extending to all fields of research and development, product design, and commercial operations (Engelbrecht et al., 2020). Because of the wide-ranging implications of mathematics, it has emerged as a central component of modern educational curricula (Alayont, 2022). The argument is further emphasised that mathematics education should equip students with the information and abilities necessary to succeed in rapidly developing countries (Bal-Taştan et al., 2018; Tokac et al., 2019).

Mathematics has traditionally had a negative connotation as a challenging, uninteresting, and frightening subject (Pohan et al., 2020). It may not be an overly optimistic assumption, but a solid understanding of mathematical principles is crucial, as learning more advanced ideas in the field often necessitates first acquiring a solid grounding in the fundamentals (Davies et al., 2021). On the other hand, the teacher is responsible for selecting the most appropriate instructional strategy, considering the nature of the subject matter and the desired outcomes for the students' learning (Nematillayevna, 2021). As a result, students gain content knowledge and the skills to apply that knowledge, the dispositions and strategies for effective learning, and the interpersonal functioning necessary to thrive in a classroom and beyond (Susanti & Suripah, 2021).

Khan et al. (2020) argue that the mathematical proficiency of Pakistan's students lags behind that of their peers in other disciplines. Overall, students' mathematical performance was evaluated as inadequate, and students feel less motivated to learn mathematics. Results from the National Educational Assessment System's examination of pupils' performance in mathematics also showed great concern. They pointed out that students from grades four and eight score poorly on a world platform. Stojanović et al. (2021) argued that factors such as teachers' teaching skills, students' quality, and motivation are significant contributing factors to students' performance in mathematics. It is also evident from the literature that in mathematics classes, students feel less motivated, which leads them to get lower grades (Núñez et al., 2019).

Influence of BBL on Learning and Motivation

Brain-Based learning has its roots in Neuroscience (Lim et al., 2019) and was first time used in education in the USA in the 1990s (Ferreira & Rodríguez, 2022). In its broadest sense, neuroscience studies how the brain functions to learn and remember, from the smallest cellular level to the largest neural circuits (Glaser et al., 2019). To learn in a way compatible with one's brain, one must know how to teach based on what experts have found about the brain. To teach in a manner that is in harmony with the brain, one must apply the principles and techniques that have been uncovered through research on the brain (Ferreira & Rodríguez, 2022). Insights into how the brain works, what influences the brain, and brain researchers' understanding of the educational implications of these insights has improved throughout time (Tan & Amiel, 2022). Caine and Caine (1991), one of the pioneers of the BBL, mentioned that effective teaching must have the following three approaches to be adopted in line with the 12 principles of the BBL.

Relaxed Alertness: Triana and Zubainur (2019) argue that this situation concerns a pleasant atmosphere of peaceful attention created when students are given a difficult task. To tackle an issue successfully, students need to relax and enjoy themselves. According to Saleh and Mazlan (2019), to ensure that students are always responsive to learning, creating a challenging learning atmosphere in which they feel safe but engaged with the minimal danger of threat from physical settings is vital.

Orchestrated Immersion: The term "orchestrated immersion" refers to putting students in situations where they are physically, mentally, and emotionally immersed in a topic so that they may better retain and apply the information they are learning (Saleh & Mazlan, 2019). Triana and Zubainur (2019) explain that students can solve difficulties using their methods, cementing the principles in their memory. The student's ability to think critically and acquire new information is crucial to every learning activity.

Active Processing of Experience: It involves setting up environments conducive to learning, such as small discussion groups, that encourage students to actively engage with the material (Triana & Zubainur, 2019). It allows students to actively analyse information inwardly, appreciate, unite, and produce pertinent views or choices. It will enable students to explore information inwardly, enjoy, connect, and build relevant ideas or options (Saleh & Mazlan, 2019).

Motivation for Mathematics Learning

Learning motivation for mathematics is influenced by several factors and types of motivation (Hung et al., 2019). According to Wilkie and Sullivan (2018), internal and external motivations can also be influenced using various techniques. When an individual is intrinsically motivated, they are driven to succeed for their own sake. The other type of motivation is extrinsic motivation, which comes from external sources. When it comes to studying mathematics, extrinsic motivation is more likely to be strengthened from the outside. It's challenging for students to develop intrinsic motivation for learning, but extrinsic motivation is easier to cultivate because it comes from external sources like instructors' motivation and peers' approval of a positive learning environment. Emphasising intrinsic motivation, El-Adl and Alkharusi (2020) argue that if all students are intrinsically motivated to succeed, they will feel good about themselves as they work toward their learning achievement. When pupils have a deep interest in doing something because they see personal value in it and appreciate the potential benefits to their future.

Heyder et al. (2020) believe most students fail in mathematics. After analysis of the data, they indicated that intrinsically motivated students could perform better in mathematics. They further investigated the effect of environmental factors on students' intrinsic motivation to learn mathematics and revealed that teachers' beliefs and teaching styles affect students' innate abilities and intrinsic motivation to learn mathematics. Froiland and Worrell (2016) also supported the argument that intrinsically motivated students outperform their less-motivated counterparts in various academic measures, including enthusiasm, challenge-seeking, involvement, and performance. In addition, Musu-Gillette et al. (2015) found a correlation between elementary school students' levels of intrinsic motivation in mathematics and their subsequent interest in and success in mathematics-intensive fields of study and work. They found that students' intrinsic motivation keeps on decreasing with time.

It is also evident from the literature that pupils' intrinsic motivation generally increases at the start of elementary school but decreases over the first few years of learning (Weidinger et al., 2017). Several students see a more significant decrease than others, while some experience no decline. Disparities in academic results may explain some of these personal characteristics in intrinsic motivation. Learners' intrinsic motivation depends on satisfying their requirements for competence, instruction, and teaching activities (Ryan & Deci, 2016). Obtaining good grades should fulfil a student's motivation for learning, but receiving poor grades should weaken their sense of intellectual ability and, as a result, reduce their intrinsic motivation. Furthermore, in elementary school, the lower a student's scores, the lesser their associated intrinsic motivation (Corpus & Wormington, 2014).

BBL and Students' Motivation

Neuroscience and BBL have educational implications, and it had been used to study various aspects of education, students' motivation (Al-Balushi & Al-Balushi, 2018), academic performance (Amjad et al., 2022), problem-solving skills (Pohan et al., 2020) in various subjects. Mekarina and Ningsih (2017) commented that BBL is one of the effective teaching approaches for mathematics students, and it can enhance motivation and proficiency in mathematics among students. All students involved in the learning process can use the outcomes of BBL. Students using BBL can improve their mathematical skills by using the right proportion of the brain during the learning process. Students can make optimum use of their brains in mastering concepts related to mathematics. Yu and Singh (2018) investigated the relationship between teachers' teaching strategies and students' motivation for mathematics learning. After applying the SEM analysis among different variables, the researchers found a positive relationship between teachers' teaching strategies and their self-efficacy and motivation.

El-Adl and Saad (2019) conducted a study to examine how a BBL program influences students' working memory and motivation in the classroom among Omanis in high school. Participants in the study's treatment group showed significant improvement in working memory and academic motivation. This research helps elucidate the relationship between working memory capacity and students' motivation to succeed in school among Omanis in high school. Effendi and Marlina (2021) also explored the effect of the BBL model on the learning motivation for mathematical communication at the secondary level. The results of their quantitative study revealed that there is an effect of learning motivation on their mathematical communication when they are being taught using the BBL model.

Many researchers have used various teaching methods in Pakistan to increase students' motivation to learn mathematics (Farooq et al., 2020; Talpur et al., 2021). It is still a cause for concern why students fail to achieve higher grades at all levels, particularly at the elementary level (Mushtaq, 2021). The current study was designed to investigate students' intrinsic motivation (IM) to learn and perform mathematics in the eighth grade. It will show how students' intrinsic motivation will be affected when the researchers deploy the brain-based learning (BBL) approach in mathematics class. The study's objective is to investigate the effect of the BBL on students' intrinsic motivation (IM) to learn and perform mathematics at the elementary level. Based on the study objective, the researchers developed a null hypothesis that BBL does not significantly affect elementary-level students' intrinsic motivation (IM) to learn and perform mathematics.

Material and Methods

Research Design

The positivistic worldview guided the current study, and the researchers used a quantitative approach to different process phases. It is an 18-week experimental study that has three different stages. The research design of the current experimental study is single-subject *A-B-A*. It was carried out in three stages of equal length (6-weeks). The first stage is A (baseline phase), where the students are taught eighth-grade mathematics using the traditional lecture method. The second stage is B (treatment phase), where the students were taught eighth-grade mathematics using activities based on BBL principles. The third stage of the study is A (withdrawal phase), in which the researchers withdrew the intervention, and students were again taught mathematics using the earliest traditional lecture method.

Participants

The respondents of the current study were eighth-grade students enrolled in a public boys' secondary school in the district Kasur. The sample of the study comprised on 39 eighth graders who were selected as the intact group. As it was a single-subject study, the researchers chose the whole class enrolled during the academic year 2021-2022 as the study sample.

Measure

The researchers adopted a Mathematics Motivation Scale (MMS) developed initially by Zakariya and Massimiliano (2021) to collect data from the respondents. It was designed on a five-point Likert scale with options ranging from strongly disagree (1) to strongly agree (5). It had different items to measure students' intrinsic motivation. The intrinsic motivation of the study respondents was measured using the statements like "If I can, I want to get better grades in this class than most of the other students." Cronbach's Alpha was used to assess the scale's reliability (across all nine measurements), and the results ranged from .73 to .86, which is satisfactory and meets the standards Hair et al. (2021) set for the scale's acceptance. According to Hair et al. (2021), the scale is deemed satisfactory if the Cronbach Alpha values range between .60 and .70 and good and acceptable if they fall between .70 and .90.

Procedure

The current study was conducted using the single subject *A-B-A* experimental research design. It had three overall stages, and in the first stage, A (baseline), the researchers taught the first three units of eighth-grade mathematics and measured their intrinsic motivation three times using the MMS at the regular interval of two weeks. The second stage of the study is the treatment phase (*B*). The researchers taught units 4-6 with the help of activities based on the BBL principles. For getting the perceived effect of the BBL intervention, all the activities were designed by following the approaches of the BBL; a) relaxed alertness, b) orchestrated immersion, and c) active processing. For better class engagement and to have students' good social and emotional involvement, the researchers developed activities for their brainstorming. They were given different mathematical situations to tackle and discuss with their peers. In role-playing activities, students were assigned different roles to play for better comprehension of financial mathematics. Students were assigned the roles of judge, lawyer, and petitioner for the division of the inherited property following the passing of a father who left behind three sons, a daughter, and a widow in one of the exercises. Activities like i-Think maps were designed, and students were given different maps, sketches, tree maps, and flowcharts to think, relate and identify the valid options for teaching concepts related to the factorisation and other functions of algebraic expressions. For teaching different concepts from the unit covering the topics related to simultaneous linear equations, the researchers developed activities related to the visual imagery of the students. They were shown short videos, simulations, and graphics about simultaneous linear equations. During the intervention phase (*B*) of six weeks, the students were taught with the help of activities designed according to the BBL principles. The researchers measured students' intrinsic motivation at the regular interval of two weeks. In the third and last stage, A (withdrawal), the researchers withdrew the intervention. Students were taught the following three units (7-9) again with the lecture method, and again the researchers took three measures of students' intrinsic motivation fortnightly. The process of the 18-week study is presented in Figure 1 below.

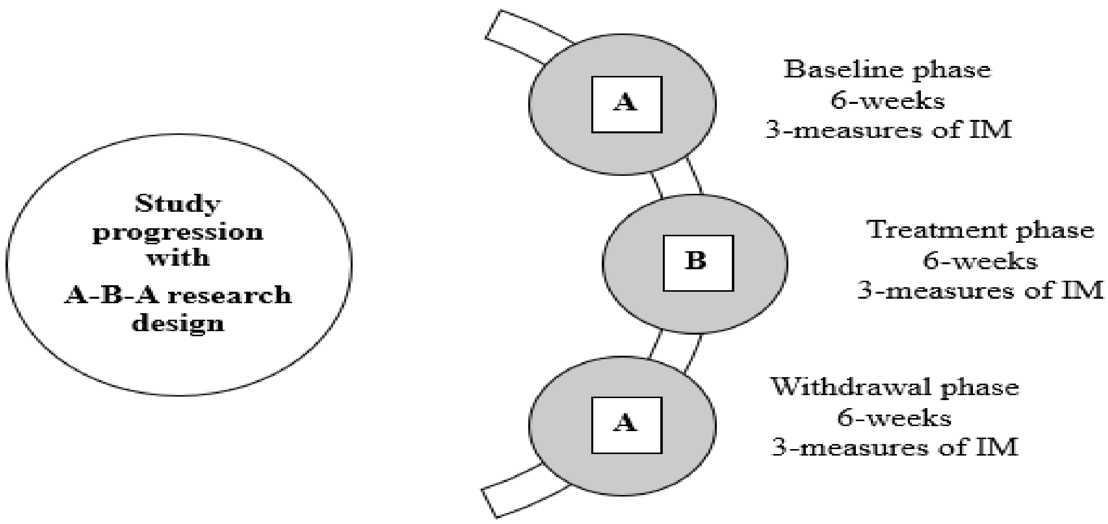

Figure 1 Phase-Wise Study Progression

In Figure 1, the researchers presented the phase-wise study progression. It had three phases, and each phase consisted of six weeks. During each stage, three measurements for intrinsic motivation to learn mathematics were measured using MMS, which are interpreted below in the results section.

Ethical Considerations

During the present experimental study, the researchers followed research ethics for adolescents. All the respondents and their parents have presented a consent form for volunteer participation in the present study. After being recruited for the current investigation, they were given a briefing on the research process, study duration, and code of ethics to be followed. They were assured of their anonymity and confidentiality. Thus, their names and locations were not asked; hence there is no danger of losing confidentiality. It was also ensured that the experiment was conducted in natural settings and that no such intervention or activity was developed which could harm them. All the activities were aligned with the school culture and education calendar. All the activities were performed during the 45 minutes length. Considering the mother and national language, the researchers used a bi-lingual version (English & Urdu) of MMS so that they may understand each item and respond accordingly.

Results and Discussion

The researchers collected data nine times during the current longitudinal experimental study. MS Excel and Statistical Package for Social Sciences (SPSS) version 26 were used for data analysis. The researchers deployed the visual analysis (using MS Excel) and one-way repeated measure ANOVA (using SPSS) to explore the effect of the BBL on students' intrinsic motivation to learn and perform mathematics at the elementary level. The impact of teaching with activities based on the BBL approaches and principles on eighth-graders' intrinsic motivation is presented in Figure 2.

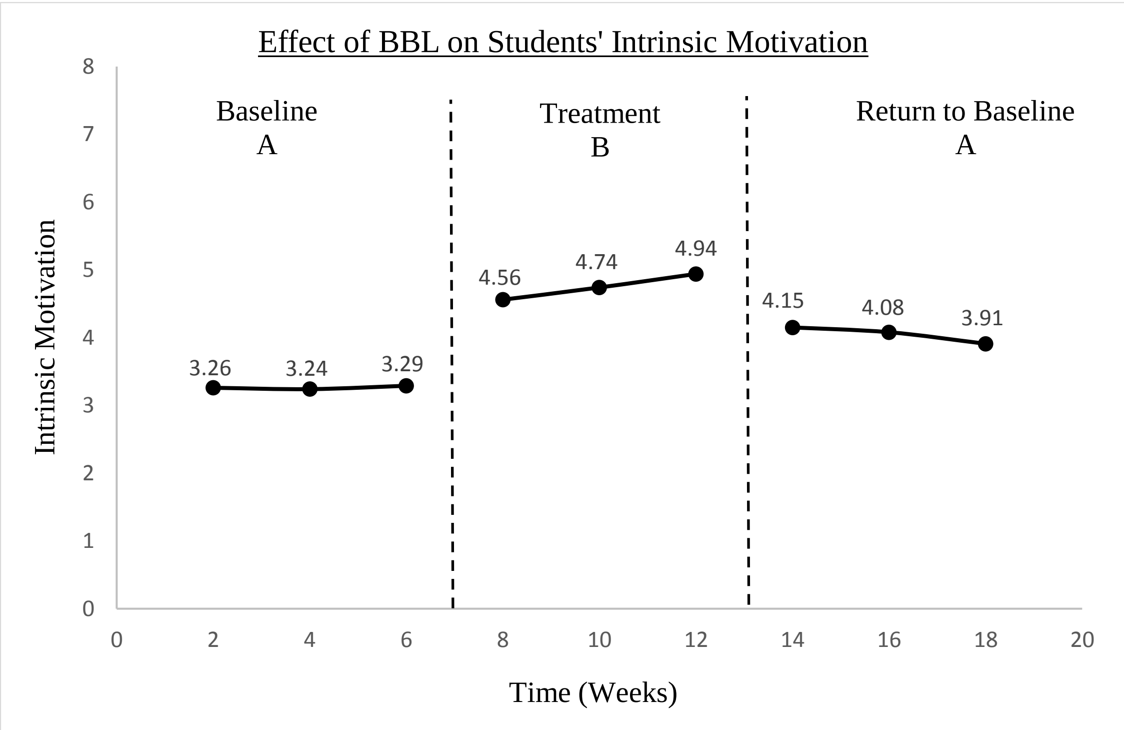

Figure 2 Effect of BBL on Students' Intrinsic Motivation to Learn Mathematics

In Figure 2, the researchers presented the results for the effect of BBL on students' intrinsic motivation to learn and perform mathematics during the treatment phase. The graph shows that during the baseline phase (*A*), when students were taught using the traditional lecture method, their intrinsic motivation scores (M_1 = 3.26, M_2 = 3.24, M_3 = 3.29) are lesser than the scores during the treatment phase (*B*) (M_4 = 4.56, M_5 = 4.74, M_6 = 4.94) when they were taught using the BBL. The results of the treatment phase showed a significant increase in students' intrinsic motivation when the students were taught the activities based on the BBL approaches and principles. In the third phase (*A*), when the researchers withdrew the intervention, the scores (M_7 = 4.15, M_8 = 4.08, M_9 = 3.91) showed a decline from the treatment phase (*B*). The current visual analysis revealed that the increase in mean scores in the treatment phase (*B*) and the decrease in the mean score values in the withdrawal phase (*A*) were owed to the BBL intervention.

The null hypothesis was tested by deploying one-way repeated measure ANOVA, and the mean scores among different phases of the study were explored at the significance level of .001. One-way repeated measure ANOVA assumes that the variance of the differences among study phases will be the same. The results for the assumption of sphericity are presented in Table 1.

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
Intrinsic motivation	.000	288.775	35	.000	.340	.369	.125

Table 1 represents that Mauchly's W = .000 < .001. It shows that Mauchly's test statistic is significantly different. The assumption of sphericity is violated. It is evident from the literature that when the assumption of sphericity is violated, then the adjusted sphericity will be used. As the value of adjusted sphericity is higher than .75, Huynh-Feldt's correction is used to interpret the results of BBL on students' intrinsic motivation, presented in 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	3.26	.607	39	2.95	132.71	Intrinsic motivation	111	.000	.75
Week 4	3.24	.669	39						
Week 6	3.29	.648	39						
Week 8	4.56	.348	39						
Week 10	4.74	.275	39						
Week 12	4.94	.125	39						
Week 14	4.15	.420	39						
Week 16	4.08	.427	39						
Week 18	3.91	.624	39						

Assumed sphericity is 132.71, higher than .75. Therefore, Huynh-Feldt's correction is used to interpret the difference among mean values for students' intrinsic motivation in nine measurements of three phases. Table 2 reveals how BBL influences eighth-graders' intrinsic motivation during the intervention phase. It further shows that after Huynh-Feldt's correction, sphericity adjustment reveals F (2.95) =111, p = 000 < .001, ηp^2 = .75. It also revealed that partial eta is greater than .14, which suggests that effect size is statistically significant as per the criteria (Latoszek, 2020). Hence, it indicates that BBL activities significantly affected students' intrinsic motivation to learn mathematics. The analysis revealed that the data did not support the second null hypothesis, and students' intrinsic motivation to learn financial arithmetic, polynomials, and factorisation topics was found to be significantly affected by the BBL-based activities such as visual imagery, role play, i-Think map, and brainstorming throughout the treatment phase (B).

Estimated Marginal Mean Scores for Students' Intrinsic Motivation to Learn Mathematics

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

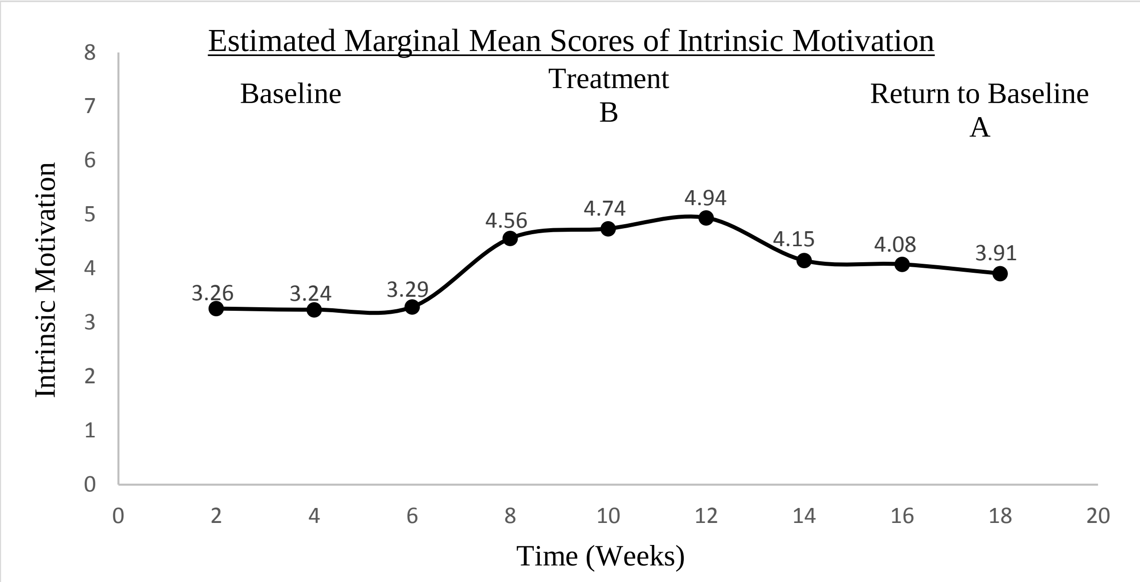

Figure 3
Mean Score of Students' Intrinsic Motivation During Study Phases

In Figure 3, the researchers presented how the mean scores of nine measurements of students' intrinsic motivation to learn mathematics were distributed during the current study's 18 weeks. There is no trend in the initial baseline phase (A). As the treatment phase progresses, the values in the intervention phase (B) continue to rise, demonstrating a positive trend. The withdrawal phase (A) shows a negative trend as the mean values decrease as the research closes. Estimated marginal mean scores also show that the rise in the intervention phase (B) is due to the treatment provided.

Discussion

The current experimental study was conducted to investigate the effect of BBL on students' intrinsic motivation to learn and perform mathematics. It was an 18-week study based on the A-B-A research design. The respondents were taught using the traditional lecture method in the first and last phases. In contrast, in the treatment phase, the respondents were instructed to use activities based on the BBL approaches and principles. The study's results revealed that their intrinsic motivation was raised when students were taught using activities based on the BBL approaches and principles. This increase in intrinsic motivation was owed to the intervention applied in the treatment phase (B). Over the years, teachers and other stakeholders have been worried about enhancing students' motivation to learn mathematics (Farooq et al., 2020; Mushtaq, 2021; Talpur et al., 2021). Therefore, it is a significant finding that a teaching approach enhances students' intrinsic to learn and perform mathematics. Wilkie and Sullivan (2018) argued that intrinsic motivation is one of the leading factors contributing to overall motivation. Thus, it can strengthen the effort to achieve planned goals in mathematics learning. An increase in intrinsic motivation can lead to overall success in school life, as commented by El-Adl and Alkharusi (2020), who believe that if all students are intrinsically motivated to succeed, they will feel good about themselves while they strive for learning attainment when students have a strong interest in something because they find personal value in it or because they recognise its possible future rewards.

It is evident from the literature that most students fail in mathematics because they feel less motivated (Heyder et al., 2020). The current study provides a solution to the problem that they can be taught mathematics using BBL-based activities to enhance their intrinsic motivation. If they feel motivated, they have a higher chance of success in school. This argument is well supported by Froiland and Worrell (2016), who also backed the claim that intrinsically motivated students outperform less motivated classmates in a broad range of academic measures such as passion, challenge-seeking, participation, and performance. It is also imperative to discuss here that students will contribute to their class work if they feel motivated. They will make efforts for their class engagement and participation. Musu-Gillette et al. (2015) commented that motivated students perform better in class activities. They do their assigned tasks and meet the deadlines for completing various projects they are involved in. Suppose the students are taught mathematics using BBL-based activities. In that case, they will be more motivated to learn if they feel their needs in terms of competency, instruction, and pedagogical activities are being met, and they will get good grades. As supported by Ryan and Deci (2016), getting good scores should satisfy a student's motivation to learn. Lower scores might diminish their confidence in their intellectual ability and demotivate them from studying. Therefore, it makes sense that to achieve a higher score and satisfy oneself, feeling motivated is crucial, which can be done with the help of BBL.

The one-way repeated measure ANOVA results indicate that BBL-based activities significantly affected students' intrinsic motivation. It supported the findings of Mekarina and Ningsih (2017), who also concluded that the BBL is one of the best teaching strategies for mathematics students since it increases students' motivation and mathematical proficiency. The estimated marginal mean score shows a positive relationship between the BBL-based teaching approach and the intrinsic motivation of mathematics students. It supported the study findings of Yu and Singh (2018), who investigated the relationship between teachers' teaching strategies and students' motivation for mathematics learning. They also found a positive relationship between teachers' teaching strategies and their motivation. The present study also supported the findings of Effendi and Marlina (2021), who explored that using the BBL model, teachers can enhance students' motivation for mathematical communications.

Conclusion

Enhancing students' motivation to learn mathematics has challenged teachers over the decades. Academia also believes that students' motivation is one of the crucial aspects of their success in school. The current experimental study was designed to investigate the effect of BBL on students' intrinsic motivation to learn mathematics at the elementary level. During the intervention phase of the study, the researchers developed mathematics learning activities based on the approaches and principles of BBL. The visual analysis presented a comparison in all stages of the study, which revealed that the increase in intrinsic motivation during the treatment phase (B) was due to the intervention provided to students for mathematics learning. The decline in intrinsic motivation during the withdrawal phase (A) further supported the study's findings that the results started decreasing when the intervention was withdrawn. Thus, the current study concluded that BBL significantly affects students' intrinsic motivation to learn and perform mathematics.

Limitations, Study Implication, and Future Research

There could be particular limitations in the process of the current investigation. It is an experimental study using a single-subject research design (*A*-*B*-*A*) with a smaller sample size and one specific region (school and class). Although the *A*-*B*-*A* design covers the threats like history and maturation (by providing an equal length of all study phases), there is a debate about the generalisability of the results at a broader level. Another limitation to communicating the results may be repeating the same tool (MMS) for data collection at a regular interval of two weeks. Additionally, due to limited funding, the researchers created BBL-based activities utilising inexpensive, no-cast materials to create a welcoming setting for students' tasks based on mathematical concepts. The limitations mentioned above may restrict the scope of the current study. The study's conclusions could have practical ramifications for students and teachers at the elementary school level. Working in a classroom emphasising BBL may make teachers and students feel more at ease. It may reduce the stress of producing higher achievement scores. The investigation showed that it considerably increased students' intrinsic motivation to understand and use mathematics. As a result, BBL can be used by elementary school mathematics teachers to enhance their pupils' class participation, class engagement, and retention in the class. The current study may suggest a thorough investigation by utilising the qualitative approach to measure the impact of BBL-based activities on students' intrinsic motivation to learn and perform mathematics. Future researchers may replicate the current results by designing an experimental study with a design other than *A*-*B*-*A*.

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