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The effect of environmental neurological components on math performance in unsuccessful female students

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The aim of this study was to investigate the effect of brain-based learning training on improving the math performance in unsuccessful female students with emphasis on environmental components. In this study, quasi-experimental methods with pre-test and post-test with control group was used. Participants were 30 female students whom selected from the statistical population of second and third grade students of Urmia public primary schools according to the mathematics scores in the second and third grade of elementary school and also the teacher-made test. Due to the descriptive nature of the assessment system, which uses qualitative terms [such as need for more effort, acceptable, good, very good, excellent] instead of grading students, 30 students at the level of need for effort were randomly selected and randomly assigned to experimental and control groups. The parents of the experimental group were trained in brain-based learning during a two-hour session. The learning environment was changed based on the environmental components affecting the brain (light, nutrition, oxygen, color, music, water). The teacher then taught his lessons based on the principles of brain-based learning in 10 sessions. For both groups (experimental and control), KEY-MATH Test of Mathematics were excited in pre-test and post-test. The results showed that brain-based learning training had a significant effect on improving students' mathematical performance in unsuccessful female students.

Keywords
brain-based learning training, environment-oriented neurological components, mathematics performance

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Introduction

Mathematics education is a branch of the humanities that has gained significant importance in scientific circles worldwide, particularly in developed countries, in recent years. Various educational approaches have been designed to improve students' math skills, one of which is Brain-Based Learning (BBL). Despite the diverse teaching methods used in the education system, little attention has been paid to the structure and function of the brain in teaching (Holland, 2005). In this regard, Shemshiri (2007) stated that Geake (2005) believes that the relationship between neuroscience and education should be two-way, and educators should ask questions related to neuroscience projects and, in parallel, use educational data from neuroscience experiments. According to Kawai (2004), learning and education can be considered a new field of natural sciences that encompasses the entire realm of human life. This new field has been introduced with various titles such as "mind, brain, and education" (Shemshiri, 2007) and brain-based education or brain-compatible education (Jensen, 2000).

Brain-Based Learning is a new approach to education and understanding the path that the brain naturally designs for learning meaningful and organized education material, which has been introduced since 1980, and its research is expanding (Jensen, 2011, translated by Saifi and Nasrati). The human brain is a complex system that is still viewed as a simple tool for storing and retrieving information in schools (Holland, 2005). It seems that quickly passing over the qualitative structure of problems in a quantitative manner can lead to undesirable progress in students' math skills, and the brain-based learning strategy has been able to be an effective intermediary teaching method in processing math content (Hasani, Dastjerdi, & Pakdaman, 2015).

Brain-Based Learning refers to understanding the rules and regulations of the brain for meaningful and organized learning and designing education based on them (Tamski, 2007). Brain-Based Learning focuses on concepts that create an opportunity for transferring knowledge, gaining and retaining information (Abdi & Ahmadian, 2011). By considering the functioning of the brain and discovering ways to maximize its functioning, Brain-Based Learning helps in the learning process and facilitates it, indicating that strengthening brain features leads to improved brain performance and positive effects on learning (Dickesi & Gouzosil, 2014). According to Aghazadeh (2021), math education in a brain-based manner requires attention to structures in schools. The mutual adaptation of the environment, experiences, information processing, and logical structures related to the brain with mathematical educational programs and methods is essential and should be

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considered. The most effective components in Brain-Based Learning, each of which has its sub-components, are alertness combined with calmness, coordinated immersion in complex experiences, and active information processing (Aghazadeh, 2021). The Brain-Based Learning strategy is a learner-centric strategy that is easily usedby teachers who utilize learners' cognitive abilities (which is important for making learning more meaningful) (Battaglona et al., 2018).

The brain is the site of all types of learning, both at the level and the meaningful level, and all learning revolves around this organ. The aim of every teaching method is to improve the learning and academic progress of learners. In brain-based education and learning, some educational measures based on principles compatible with brain learning are implemented, and the learning environment is prepared in terms of light, oxygen, water, nutrition, music, color, and sleep, and the effects of these factors on the mathematical performance of students are examined. Relevant research on brain-based education and learning has shown that the proper application of brain-based learning principles in teaching and learning has increased math grades and academic progress of students. For example, Hasani, Dastjerdi, and Pakdaman (1394) investigated the effect of brain-based learning on the attitude and academic progress in math of fifth-grade students in a semi-experimental and unequal control design study. These researchers held five training sessions for the class teacher and three training sessions for parents and other school personnel on brain-based learning. They made some changes in the effective components of the learning environment, including classroom color, nutrition, water, natural scents, and music. Then, math teaching was implemented in the experimental group using brain-based learning for three months. Data analysis showed that brain-based learning had a significant and meaningful effect on the attitude and academic progress in math of students. Adiansha and colleagues (2017) also found in their study on the effect of brain-based learning and creative thinking on the ability to learn mathematical concepts in elementary students that the level of grades in the group that learned the lesson using brain-based learning was higher than the level of grades in the group that learned the lesson using the traditional learning model.

A semi-experimental study has shown the effects of brain-based learning on the academic progress of physics students in a regular school in Malaysia (Saleh and Subramanian, 2019). Mineard (2016) investigated the effects of teaching self-defense strategies using brain-based learning on students' perception of self-defense and related skills who had language learning difficulties in a private school. The results indicated that 61% of students who did not have a correct definition of

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self-defense before the training achieved a correct understanding of it. Additionally, this teaching method was effective in improving and enhancing life skills and strategies in elementary students, and those who had an internal control center performed better than those who had an external control center (Cover, 2013). Jazouli, Solehatin, and Siahriyal (2019) examined the effects of brain-based learning and project-based learning on the performance and learning outcomes of visual learners in basic mathematics at the Faculty of Teaching and Education at Halu Oleo University in Indonesia in an experimental study with a posttest design. The students' performance in mathematics was evaluated through tests and data related to their learning style were collected through questionnaires. The results showed that students with a visual learning style who were taught using brain-based learning strategies performed better and achieved higher grades compared to the group taught using project-based learning. Therefore, these researchers concluded that learners who prioritize visual learning style show better adaptation and compatibility with brain-based learning strategies. Jalali, Pourshafie and Daneshmand (1398) conducted a semi-experimental study with a pretest-posttest control group design to investigate the effects of brain-based learning on anxiety and academic performance in mathematics of seventh-grade students. The results showed that although this strategy did not have a significant effect on reducing students' anxiety, it was successful in improving their grades and academic performance in mathematics.

Brain-based learning refers to understanding the rules and regulations of the brain for meaningful and organized learning. The basis of brain-based learning is that the brain is naturally programmed for meaningful learning, and just as any specialist needs to be familiar with the elements involved in their field for better performance (for example, a doctor needs a complete understanding of the body for treatment), teachers also need to be aware of brain learning and use principles compatible with the brain to create a sustainable and fundamental learning in students' minds (Wolfe, 2001). Therefore, in the present study, due to the importance of mathematics in elementary schools, the aim was to investigate the effects of brain-based learning on improving the performance of unsuccessful third-grade elementary school students in mathematics.

Materials and Methods

The current study is a semi-experimental design, which involved one experimental group and one control group selected from the participants. Only female participants were used to control for the gender variable. The independent variable was brain-based learning strategy, which was

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implemented in the experimental group, while no intervention was conducted on the control group. Finally, changes in the dependent variable were measured in both groups, and used as a criterion for necessary comparisons. In general, the design of this study was a pre-test post-test design with a control group. The statistical population used in this study included all second and third-grade female students of government elementary schools in region 2 of Urmia education and training. Given the descriptive nature of the current assessment system in elementary schools, unsuccessful students in mathematics were identified through observations, work portfolios, and teacher-made tests in both second and third grades. In the descriptive evaluation, instead of giving a grade to the student, qualitative expressions such as "need for more effort," "acceptable," "good," "very good," and "excellent" are used, and in this study, 30 students who needed more effort in mathematics in both second and third grades were randomly selected and placed in two experimental and control groups.

To collect data, the "Iran Key Math Mathematics Test" was used. This scale has been used to determine the abilities and weaknesses of students in various areas of mathematics and to determine their abilities and weaknesses in various areas of mathematics. In this test, the individual's overall performance is divided into three areas, including: 1) basic concepts area, consisting of three sub-tests of counting, whole numbers, and geometry, 2) operations area, consisting of five sub-tests of addition, subtraction, multiplication, division, and mental calculation, and 3) application area, consisting of measurement, time and money, estimation, data analysis, and problem-solving sub-tests.

Procedure

To observe the ethical aspect of the research, justification sessions were held for the parents of the students. The teacher, with basic knowledge of the brain and principles of brain-based learning and the influential factors on the brain and learning, designed her lesson plans and teaching methods in a brain-based education course. The parents of the students, with their knowledge of the above-mentioned topics and control over some factors such as the students' adequate sleep and brain-compatible nutrition (which were not controlled by the researcher), cooperated in providing a brain-based learning environment.

The independent variable was brain-based learning strategy, which had three parts: In the first part, the researcher taught brain-based learning topics to the teacher, parents, and students, including the physiological structure of the brain, the effect of psychological stress on the brain and learning,

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brain-based learning principles and components, and the influential environmental components on the brain and learning. The basic components of brain-based learning were alertness with calmness, synchronized immersion in complex experiences, and active information processing.

In the second part, the researcher prepared a brain-based learning environment based on the influential factors on the brain. These factors included light, water, nutrition, oxygen, color, and music. In the third part, the teacher implemented the lessons practically in the classroom under the supervision of the researcher in ten sessions. The research design was an unequal control group design, and its specifications are illustrated in Figure 1 as follows:

1. The experimental group and control group were evaluated simultaneously with the Iran Key Math Mathematics Test.
2. The brain-based learning was taught to the experimental group by designing a brain-based learning environment as the independent variable (X), while the control group did not receive any intervention in this regard.
3. Both groups were evaluated with the Iran Key Math Mathematics Test under the same conditions in the post test.

Results

Table 1 presents descriptive indices for the study groups in the components related to mathematical performance in the pretest. The results show that there is no significant difference between the pretest scores of the experimental (brain-based) and control groups in any of the mathematical performance components (significance level greater than 0.05). Table 2 shows descriptive statistics for the study groups in the components related to mathematical performance in the posttest. The results indicate that the mean scores of the experimental group, who received brain-based intervention, had a significant increase compared to the mean scores of the control group after the intervention.

Table 3 shows the dependent t-test results for comparing the mean score differences between the two groups in mathematical performance components. The mean score differences between pretest and posttest in the components of concepts, operations, and applications in the experimental group are significantly higher than the control group ($p<0.001$). This indicates the significant effect of brain-based teaching on enhancing the mathematical performance of students after the

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intervention. Therefore, it can be concluded that brain-based teaching is an appropriate method for improving mathematical skills in students and learners.

Table 1. descriptive indices for the study groups in the components related to mathematical performance in the pretest

Component	Group	Mean	SD	N
Concepts	Experimental	16.33	2.90	15
	Control	15.33	2.02	15
Operation	Experimental	27.27	3.51	15
	Control	28.67	3.26	15
Application	Experimental	26.60	3.56	15
	Control	27	3.72	15

Table2. descriptive indices for the study groups in the components related to mathematical performance in the posttest

Component	Group	Mean	SD	N
Concepts	Experimental	23.80	2.21	15
	Control	16.73	2.05	15
Operation	Experimental	48.07	4.83	15
	Control	31	3.05	15
Application	Experimental	50.13	5.82	15
	Control	28.87	4.47	15

Table 3. dependent t-test results for comparing the mean score differences between the two groups in mathematical performance components

Component	**Group**	**Mean difference**	**DF**	**T**	**p**
Concepts	Pretest	-7.47	14	-9.81	0.001
	Posttest				
Operation	Pretest	-20.80	14	-13.50	0.001
	Posttest				
Application	Pretest	-23.53	14	-13.70	0.001
	Posttest				

Discussion

In this study, the effect of brain-based learning on improving mathematical performance was investigated. The results of this study, which is consistent with the findings of Ululola (2011) and Errol and Karaduman (2018), show that brain-based teaching has a positive impact on improving students' mathematical performance. In this study, based on the activities carried out according to the three environmental components of brain-based learning in teaching (alertness accompanied by calmness, synchronized immersion in complex experiences, and active processing of information), the quality of learning and the level of mathematical performance of students increased. Nourin et al. (2017) also demonstrated that brain-based learning had a significant

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positive effect on the math grades of elementary students, especially those whose pre-test scores were above average.

In this study, the teacher's awareness of the structure and function of the brain, as well as how it works, and considering the positive and negative environmental components that affect it, helped to design an appropriate teaching method and provide lesson plans based on this method. Also, the teacher and students' awareness of the psychological pressure's impact on the brain and learning has been effective in creating a pleasant learning environment without stress and eliminating factors that create stress and psychological pressure (external rewards, intense competition, etc.). Changing the classroom lighting from white fluorescent light to yellow (incandescent bulb) has reduced psychological pressure and stress on the brain and had a positive effect on students' motivation and interest in learning and group activities. Another factor that has reduced students' calmness and decreased their alert mental state and, consequently, had a negative impact on their learning quality, is the lack of easy access to drinking water in the classroom environment. By providing water bottles and addressing thirst, it has helped create mental calmness in learners and solved the brain's essential need for water, which constitutes about 78% of the brain's weight, and had a positive effect on learning quality and mathematical performance. Furthermore, students' awareness of the brain's need for water and its impact on learning has influenced their accuracy and concentration in learning.

One of the environmental factors in this study that had a positive impact on creating calmness in learners and also had a significant impact on creating a rich learning environment was the use of music during task performance and rest periods. As Martin (2006) stated, music increases learning, memory, and creativity by calming the nervous system. In this study, music has not only increased the energy and motivation of students towards learning but also strengthened their math problem-solving skills. By activating most of the students' brain regions, it has helped them to improve their learning. Other environmental factors such as proper nutrition and brain-compatible diets, adequate sleep, and better oxygen supply to the brain have also helped to create a suitable environment for optimal learning in the brain. In this regard, Staki et al. (2007) conducted a study in which they compared two teaching methods, two brain hemispheres teaching and music teaching, using a pre-test-post-test experimental design among second and third-grade students who had math learning difficulties, with a focus on neural circuit reorganization to reduce the symptoms of math learning disability in girls. Their results showed a significant difference

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between the reduction of symptoms of math learning disability in the experimental groups compared to the control group. Brain mapping with the bio-med device also showed that music and two brain hemisphere teaching caused changes in bio-electric activities and activation of frontal, parietal and other math-related brain centers, and two hemisphere teaching reduced the symptoms of math learning disability in students in all areas related to math (concepts, applications, and operations). According to these researchers, the experimental groups showed higher performance in math than the control group. Therefore, by using the mentioned methods, the reorganization of neuronal circuits in the brain can be created and the symptoms of math learning disability can be reduced.

Considering the appropriate and useful time for teaching and rest, it has provided the possibility of transferring information from short-term memory to long-term memory and also provided the necessary time for processing information and concepts. By better storing learning materials in the brain and connecting lessons together (subject or theme-based learning) for better significance, recall and learning of materials have increased. Providing rich experiences for students (diverse teaching methods and using their senses, cooperative and active learning) and familiarizing students with how their brain system learns has had a positive effect on their math performance. Overall, by considering a set of activities based on the three brain-centered learning components (alert restfulness, immersion in complex experiences, and active information processing), the active cortex (neo-cortex) is activated, and therefore math performance is improved. Ghalabi, Ghooabi, and Moghaddam (2017) conducted a quasi-experimental study to compare music therapy and active memory training on improving academic performance in students with math learning disabilities using a pre-test-post-test design. The results showed that both research hypotheses that predicted improved academic performance in students with math learning disabilities through music therapy and active memory were confirmed, and the music and active memory variables had a significant correlation in explaining the improved academic performance of students with learning disabilities.

Research has supported the positive effects of brain-based learning on the skills, abilities, and attitudes of learners in mathematics. Based on their findings, it can be understood why this strategy is effective in improving academic performance (Yuzzi & Junah, 2017). Compared to teacher-centered learning, brain-based learning has positive effects on students' learning, progress, attitudes, motivation, and knowledge (Yuzzi & Junah, 2017). Therefore, this strategy has the

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potential to create a positive attitude towards mathematics in learners and increase their learning motivation. This strategy also plays a role in improving and strengthening communication skills related to mathematics (Sakoko, 2016; Triana & Zubainur, 2019) and has an impact on improving academic progress and learning motivation in mathematics (Macarena & Ningsih, 2017).

Moreover, brain-compatible learning may have a role in reducing anxiety towards mathematics since Pardel, Zare Moghadam, Mosavi, and Ghorbani (2019) demonstrated the effectiveness of brain-based teaching on reducing test anxiety in a semi-experimental study with a pre-test and post-test design with a control group. Brain-compatible learning also has an effect on increasing executive functioning components such as planning and problem-solving (Saifi et al., 2018a) and cognitive flexibility and selective attention in students (Saifi et al., 2018b). This strategy has also had an impact on self-regulated learning and academic engagement in students, where a significant difference was observed between the experimental and control groups in self-regulated learning (47%) and academic engagement (53%) (Ebrahimi & Sardari, 2021).

Khalili Sadraabadi, Ebrahimi Ghavam, and Radmanesh (2017) and Abdolmaleki (2018) showed in their research that brain-based teaching has a significant effect on improving self-regulated learning and metacognitive beliefs in students. Viswanatham and Solomon (2016) also demonstrated that the use of brain-based teaching significantly improved students' academic engagement. Therefore, the use of brain-based strategies in the teaching process can improve cognitive abilities, self-regulated learning, cognitive flexibility, selective attention, planning, problem-solving, reduce math anxiety, create a positive attitude towards mathematics, increase learning motivation and academic engagement. Based on the results of the mentioned research studies, it can be expected that brain-based learning can improve the learning level of unsuccessful students and enhance academic performance in mathematics. Additionally, music and strategies related to memory, cognition, metacognition, and brain hemispheres or neurocognitive aspects of learning have been shown to have a positive effect on the learning and improvement of academic performance in mathematics in students with learning difficulties, consistent with the research background mentioned (Pardel et al., 2019).

According to Jalali, Pourshafiee, and Daneshmand (2019), designing an environment based on the components of brain-based learning strategy can lead to the teacher working with purposeful information processing in an active way and learners also actively processing the information. This approach links new knowledge to previous knowledge and internalizes them, leading to

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meaningful learning experiences. This learning approach creates a sense of calmness and considers the challenges created by the lesson as an opportunity to increase learning. Generally, activities designed based on the three components of brain-based learning, class organization, and lesson plan design, lead to an improvement in academic performance in mathematics for students. The use of music to calm the nervous system provides conditions for increased learning and improved performance. Generally, emphasis on proper nutrition, adequate sleep, and adequate oxygen supply to the brain play a role in this academic progress.

Limitations and recommendations: One of the limitations of this study is the implementation of the research on a sample of female students. Therefore, caution should be exercised when generalizing the results. Repetition of the study in other educational levels and grades is recommended.

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Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

FM, MT and SA contributed to the study conception and design, material preparation, data collection and analysis. All authors contributed to the article and approved the submitted version.

Ethics statement

The studies involving human participants were reviewed and approved by ethics committee of Urmia University, Urmia, Iran.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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