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The Effects of Integrated Brain-Based Learning and Skills Training in Linear and Quadratic Functions Among Grade 11 Students

Jatuporn Mekwan[1] & Apantee Poonputta[1]

[1] Faculty of Education, Mahasarakham University, Thailand

Correspondence: Apantee Poonputta, Faculty of Education, Mahasarakham University, Thailand.

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Abstract

The purposes of the study were 1) to investigate the effectiveness of integrated brain-based learning and skills training on grade 11 students' learning achievement in linear and quadratic functions 2) to compare the achievement of grade 11 students before and after using integrated brain-based learning and skills training, and 3) to study students' satisfaction with the integrated brain-based learning and skills training. The participants were 40 grade 11 students in a Thai public school selected by the cluster sampling method. Research instruments were 1) a learning management plan 2) skills training 3) a learning Achievement Test, and 4) a Satisfaction Questionnaire. Statistics used in data analysis were percentage, average, standard deviation, and paired samples t-test. The results of the study indicate that 1) the effectiveness of the integrated brain-based learning and skills training on grade 11 students' learning achievement in linear and quadratic functions, 2) the achievement on grade 11 students after learning with the learning management was significantly higher than before using the treatmen, and 3) students was satisfied with the learning processes during the implementation of the learning management plan. The result of the study contributes to the area of mathematics education as it presents an alternative instructional method that combines the benefits of teaching principles to teach a complicated concept in mathematics. Moreover, it illustrates how the two principles are integrated to form a learning management plan that could drive learners' learning process.

Keywords: linear and quadratic functions, BBL, skill training

1. Introduction

Learning mathematics requires the acquisition of a range of skills and the comprehension of intricate concepts (Akhter & Akhter, 2018; Atteh, 2020). Specifically, in such a complex concept as linear and quadratic functions, students need to develop abilities to manipulate algebraic expressions, solve equations, graph linear and quadratic functions, etc. (Bowden, 2018). Apart from the difficulty in comprehending these mathematical concepts, learners also have may face difficulty understanding the concept of a function and how it represents a relationship between two variables (Nielsen, 2015). This can be accompanied by learning to connect what they learn in class to real-world situations or to more complex problems. These obstacles demotivate students, create issues in mathematics classes, and necessitate an effective instructional approach.

Thailand, as the context of this study, also faces challenges in mathematics education, with the concept of linear and quadratic functions being a particularly problematic area (Inkeeree et al., 2016; Saethow, 2019). Research has shown that Thai students often struggle with basic mathematic concepts such as calculation, graphing, and equation solving (Suwannatrai & Thongmoon, 2020; Wongyai & Nuannoom, 2011). Additionally, traditional teaching methods in Thailand have been criticized for being overly teacher-centered, with an emphasis on the dissemination of information rather than student learning and engagement (Inkeeree et al., 2016; Saethow, 2019). This approach fails to consider the diverse needs and learning styles of students and often results in unengaging and demotivating learning environments. As a result, there is a need for innovative approaches to mathematics education in Thailand that address these challenges and promote student success in mathematics.

Educational approaches that strive to engage and inspire students in their learning have gained popularity in recent years, as they have the potential to boost student achievement. According to MacTavish and Kolb (2006), for authentic learning to occur, it is crucial for teachers to be genuinely invested and fully present in the classroom, enabling students to model this behavior. The stimulating learning atmosphere would inspire students to study more diligently (Miller et al., 2011).

Brain-based learning and skills training are two techniques within the domain of mathematics education that have gained considerable attention. Brain-based learning is an approach to education that takes into account the way the brain functions and processes information. It involves using a variety of teaching strategies and techniques that engage multiple senses and promote active learning, such as hands-on activities, problem-solving tasks, and collaboration (Caine et al., 2016; Jensen & McConchie, 2020). Skills training is a method of teaching that focuses on helping students develop specific skills. It involves breaking down a task or concept into small, manageable steps, providing step-by-step instructions and ample opportunity for practice, and providing feedback on progress (Salas et al., 2012).

In this study, we aimed to investigate the effectiveness of combining brain-based learning with skills training on the development of learning achievement in linear and quadratic functions among Grade 11 students. It is expected to show implications for mathematics education, as it aims to provide insights into alternative instructional methods for teaching these mathematical concepts and how these approaches can be integrated into a learning management plan to enhance student learning.

2. Literature Review

2.1 Linear and Quadratic Functions

The concept of linear and quadratic functions is one of the important topics in school mathematics education. Briefly, a linear function is a function of form f(x) = mx + b, where m and b are constants. A quadratic function is a function of form f(x) = ax^2 + bx + c, where a, b, and c are constants. Linear functions have a constant rate of change, meaning that the slope of the line representing the function is always the same. Quadratic functions, on the other hand, have a variable rate of change. The graph of a quadratic function is a parabola, and the direction of the parabola can depend on the value of the coefficients (Abramowitz & Stegun, 1965).

Frequently, linear functions are employed to model situations with a constant rate of change, such as the distance-time relationship (McMullen, 2015). For instance, if you are traveling at a constant speed, the distance you have traveled can be represented by a linear function with time as the input variable and distance as the output variable. Meanwhile, quadratic functions are employed to simulate situations with a variable rate of change (Bowden, 2018). The height of an object thrown into the air, for instance, can be modeled by a quadratic function with time as the input variable and height as the output variable. As the object hits the apex of its trajectory and begins to fall back to the ground, its height will first climb at a rate that is rapidly increasing but will ultimately begin to decline. Population expansion, the spread of illness, and product demand are examples of real-world phenomena that can be described using linear or quadratic functions.

Therefore, teaching linear and quadratic functions need the development of graphing skills, algebraic skills, and problem-solving skills (Abramowitz & Stegun, 1965; Bowden, 2018). In detail, to comprehend the concept of linear and quadratic functions, learners should be able to understand how the slope of a line and the shape of a parabola relate to the underlying function (McMullen, 2015). Moreover, Furthermore, being able to manipulate and solve equations and simplify expressions is crucial for working with linear and quadratic functions. This involves understanding the algebraic techniques needed to solve for variables, rearrange equations, and simplify expressions (Schumacker & Lomax, 2015). Lastly, to understand the mathematical concepts behind linear and quadratic functions, it is also important for students to be able to apply their knowledge to solve real-world problems (Gelfand, 2003). For example, students should be able to determine the slope of a line to understand the rate of change of a quantity or use a quadratic function to find the maximum height of an object thrown into the air.

Therefore, teachers need to use educational approaches that are tailored to their students. One effective approach is to make real-world connections by showing students how linear and quadratic functions can be applied to real-world situations, such as the height of an object thrown into the air or the spread of disease (Lovell, 2008). In addition, using a variety of representations, such as graphs, equations, and word problems, can help students better understand the concepts behind linear and quadratic functions. This can help them develop a deeper understanding of the material (Nielsen, 2015). Finally, teachers need to differentiate instruction, as students learn at different rates and in different ways. By providing extra support for struggling students or offering enrichment activities for more advanced students, teachers can help all students learn about linear and quadratic functions at their own pace (Samuels, 2011).

2.2 Brain-Based Learning

Brain-based learning (BBL) is an educational approach that is based on the idea that how we learn is influenced by how our brain works. The goal of brain-based learning is to take advantage of the brain's natural learning

processes to create more effective and efficient learning experiences. Scholars have presented perspectives on how the BBL should be utilized in education (Caine et al., 2016; Jensen & McConchie, 2020; Tileston, 2011). Caine et al. (2016) suggested that the study of the brain should be the first step in the educational process. Learning can be facilitated by difficulties, but it can be hampered by threats. In addition, Jensen and McConchie (2020) added that BBL is a learning philosophy. It's a set of concepts, knowledge, and abilities for making better learning decisions. One of the main goals of brain-based learning is to tailor instruction to the unique needs and learning styles of individual students. By using approaches that are based on how the brain learns and processes information, educators can create more effective and efficient learning experiences for their students (Tileston, 2011). There are several key principles to consider when designing brain-based learning activities. First, it is important to recognize that the brain is actively involved in learning and constructing new knowledge, rather than simply being a passive recipient of information. Additionally, emotions play a key role in learning and can either facilitate or hinder the process. Brain-based learning also emphasizes the importance of social interaction and the need to present information in a way that is meaningful and relevant to students. Finally, it is believed that the brain is adaptable, and learning can stimulate brain development.

Regarding teaching linear and quadratic functions, the BBL has the potential in developing important topics in learning the concept. The method emphasizes the importance of tailoring instruction to the unique needs of individual students, using a variety of teaching methods, and making connections to real-world situations. When applied to the teaching of linear and quadratic functions, brain-based learning can help students develop a deeper understanding of the concepts, encourage collaboration and problem-solving, and differentiate instruction to meet the needs of all students. By using brain-based approaches, teachers can create engaging and meaningful learning experiences that help students learn and retain important mathematical concepts.

2.3 Skill Training

The process of learning or enhancing a certain skill or combination of talents is referred to as skill training (Salas et al., 2012). Skill training can consist of a range of activities, such as practice, coaching, or instruction, and is intended to assist individuals to acquire new abilities or improve existing ones. The strategy can be implemented in a variety of situations, such as sports, the arts, vocational training, and academic disciplines. The precise abilities that are developed depend on the training's environment and objectives (Swerdlow, 2013). A person may obtain skill training in a sport to improve their athletic ability or in a trade to acquire a new craft or trade, for instance.

Skill training can be an effective approach to teaching math skills in education (Ozola et al., 2014). By using activities such as practice, explicit instruction, coaching, collaboration, and game-based learning, teachers can help students improve their proficiency in math skills. For example, providing students with opportunities to practice math skills through drills, worksheets, and other exercises can help them improve their proficiency, and explicit instruction in math concepts and techniques can help students understand how to perform specific tasks. Additionally, individualized coaching, such as working one-on-one with a teacher or tutor or using adaptive learning software, can help students develop specific math skills (Galindo, 2019). Giving students math problems to solve can help them develop their problem-solving skills and apply their knowledge to real-world situations and encouraging collaboration can help students learn from each other and develop their teamwork and communication skills. Using games and other interactive activities can also make learning math skills more enjoyable and engaging for students.

Therefore, it is possible to integrate brain-based learning and skill training in the teaching of linear and quadratic functions. By emphasizing individual differences in learning, teachers can use skill training activities, such as drills and exercises, that are tailored to the needs and learning styles of each student. Additionally, the social and emotional aspects of brain-based learning can be supported by skill training activities. For example, teachers can use problem-solving tasks and collaborative learning to engage students' emotions and encourage them to think critically about linear and quadratic functions. Then, explicit instruction and worksheets can be used to clarify and deepen students' understanding of the concepts.

2.4 Previous Studies

Moreover, the two principles have also been employed in previous studies in the mathematics education area. The benefits of brain-based learning in mathematical education can be seen in several studies (Abid & Al, 2021; Mekarina & Ningsih, 2017; Suarsana, Widiasih, & Suparta, 2018; Verma, 2021). Specifically, the method was proven to be effective in improving students' learning achievement (Abid & Al, 2021; Mekarina & N ingsih, 2017; Suarsana, et al., 2018), increasing students' motivation (Mekarina & Ningsih, 2017), and reducing class anxiety (Verma, 2021). Likewise, skill training has also been used in studies in several studies (e.g., Behzadi,

Lotfi, & Mahboudi, 2014; Bernacki, Vosicka, Utz, & Warren, 2020; Galindo, 2019). In brief, Behzadi et al. (2014) found that training in reading and study skills positively affected students' mathematical learning achievement. The result of Bernacki et al. (2020) indicated that skill training in digital learning skills benefited mathematics learners' knowledge development. Lastly, Galindo (2019) found that school students can benefit from skill training in mathematics.

Therefore, the findings of numerous research studies suggest that brain-based learning and skill training are instructional approaches with the potential to effectively facilitate the acquisition of knowledge and skills related to linear and quadratic functions in mathematics education. Both approaches have been widely validated in the field, with evidence indicating that they can be highly effective in promoting student learning and engagement. Moreover, it is possible to integrate these approaches by designing activities that combine their most effective features, taking into account individual differences among students. The current study was conducted based on the rationales mentioned above, and the purposes of the study were to investigate the effectiveness of integrated brain-based learning and skills training on grade 11 students' learning achievement in linear and quadratic functions and to study students' satisfaction with the integrated brain-based learning and skills training in the process of linear and quadratic function learning.

3. Methodology

3.1 Participants

The participants were 40 grade 11 students in a Thai public school used by the cluster sampling method. They were studying in the second semester of the 2022 academic year.

3.2 Research Instruments

3.2.1 Integrated Brain-Based Learning and Skill Training Learning Management

Learning activities in the learning management plan were designed to use the strong points of both methods in teaching linear and quadratic functions. In short, the class started by leading activities to prepare learners' emotions for learning. Learning material and leading questions were used to draw the class's attention to linear and quadratic functions. The teaching activities combined class discussion and explicit instruction. The exercises were given considering the progress of each student. Moreover, immediate feedback was given one by one when students make mistakes. 8 sub-learning plans were used each week of data collection. The first 5 plans were for linear functions, and 3 plans were for quadratic functions. The learning management plan was evaluated by professional teachers and scholars (n = 3) to provide its content validity, and it was found at a very hight level ($\bar{x}$ = 5)

3.2.2 Linear and Quadratic Learning Achievement Test

The test was designed to have 20 multiple-choice question items. The test results in 20 points in total. It was used as a pre-test and a post-test in the data collection. The post-test score is also used to identify the product effectiveness of the learning management. All the test items were proved to have content validity with the IOC of 1.00.

3.2.3 Satisfaction Questionniare

The questionnaire aims to investigate satisfaction with the learning management plan. Therefore, it consists of 11 positive statements regarding the learning experience while learning with it. The item was proven to have content validity by the assessment of 3 raters who were professional teachers and a scholar in mathematics education (IOC = 1.00)

3.3 Data Collection and Data Analysis

The students took a pre-test at the beginning of the first class. The learning management took 8 weeks, and the student's performance in participating in each sub-lesson plan was assessed and recorded. The post-test and the satisfaction questionnaire were employed in the 8th week of the class.

In terms of data analysis, the results of the study relied on the effectiveness of the learning management plan and the participants' satisfaction. The first qualification was assessed by considering participants' performance during learning (process effectiveness) and at the end of the treatment (product effectiveness). The comparison between students' knowledge before and after the treatment was also taken into consideration. Therefore, the statistics used in data analysis were a paired samples t-test and effectiveness index with the determining criteria of 75/75.

Meanwhile, participants' satisfaction was evaluated based on the interpretation of questionnaire results. The

criteria are 4.51–5.00 for highly satisfied, 3.51–4.50 for satisfied, 2.51–3.50 for neutral, 1.51–2.50 for dissatisfied, and 1.00–1.50 for highly dissatisfied. The statistics used in data analysis were mean score and standard deviation.

4. Results

4.1 The Effectiveness of Integrated Brain-Based Learning and Skills Training

The effectiveness of integrated brain-based learning and skills training on students' learning achievement was assessed by considering students' process and product performance and the comparison between their knowledge before and after implementing the treatment. After the process of data collection, the results of the study can be seen below.

Table 1. Effectiveness index of the learning management plan

Effectiveness	Full mark	$\bar{x}$	SD	Percentage
Process (E_1)	66	61.85	5.07	93.71
Product (E_2)	20	17.63	2.11	88.13
Effectiveness index (E_1/E_2) = 93.71/88.13				

The results of the study indicate that the participants' learning achievement reached the predetermined criteria of 75. Their average score on learning activities was 61.85 out of a maximum of 60 points, which is 93.71% of the total marks. The average score on the post-test was 17.63 out of a maximum of 20 points, which is 88.13% of the total marks. Therefore, the effective index of the learning management plan was 93.71/88.13, reaching the predetermined criteria of 75/75. It can be concluded that the learning management plan, which incorporated brain-based learning and skills training, was successful in helping the participants learn linear and quadratic functions and achieve the expected outcomes in both the process and product.

Table 2. Participants' learning achievements before and after the treatment

Learning achievements	N	$\bar{x}$	SD	df	T	Prob.
Pre-Learning	40	6.70	1.91	39	53.00*	.000
Post-Learning		17.63	2.11			

Note. * $p < 0.05$.

In addition, findings indicate an improvement in participants' learning achievement. Table 2 shows that there was a significant difference between participants' average scores in the pre-test ($\bar{x}$ = 6.70, SD = 1.91) and the post-test ($\bar{x}$ = 17.63, SD = 2.11), t = 53.00, p = 0.00. It could be interpreted that brain-based learning and skills training positively affected participants' knowledge of linear and quadratic functions.

4.2 Students' Satisfaction with the Integrated Brain-Based Learning and Skills Training

Table 3. Participants' satisfaction with the integrated brain-based learning and skills training

Statements	**Satisfaction**		
	$\bar{x}$	**SD**	**Interpretation**
1. The content was clear and comprehensible.	4.00	0.91	satisfied
2. Teaching material was diverse.	4.10	0.90	satisfied
3. Teaching material and media were consistent with the content, students' needs, and students' competency.	4.23	0.80	satisfied
4. Teaching media was consistent with learning activities.	4.38	0.81	satisfied
5. Learning activities helped me comprehend the content of the class.	4.20	0.94	satisfied
6. Learning activities encouraged me to present my ideas in class.	4.30	0.88	satisfied
7. Learning activities were amusing and interesting.	4.20	0.99	satisfied
8. Class environment encouraged class discussion.	4.43	0.87	satisfied
9. Class environment encouraged student participation.	4.53	0.68	highly satisfied
10. Class environment provided me with pleasure in learning.	4.15	0.95	satisfied
11. Class environment supported learning process.	4.30	0.82	satisfied
Overall satisfaction with the learning management	4.25	0.87	satisfied

The result of the study also indicates participants' satisfaction with learning management. Overall, it appears that the students were satisfied with the learning management plan ($\bar{x}$ = 4.25, SD = 0.87), with most of the mean scores being above 4.00 (min $\bar{x}$ = 4.00, SD = 0.91, max $\bar{x}$ = 4.53, SD = 0.68). Specifically, The results of the survey reveal that all participants concurred that the content was clear and comprehensible, the teaching material was diverse, the teaching material and media were consistent with the content, students' needs, and students' competency, the teaching media was consistent with the learning activities, the learning activities facilitated comprehension of the class content, the learning activities encouraged the presentation of ideas in class, and the learning activities were amusing and engaging. It appears that the learning management system or class was perceived positively by the participants. It could be interpreted that the integration of brain-based learning and skill training brought about satisfying learning experiences in this study.

5. Discussion

The findings of the study suggest that integrated brain-based learning and skills training is an effective method for improving students' learning achievement in linear and quadratic functions at the grade 11 level, as well as students' satisfaction with the learning processes during the implementation of the learning management plan. The results of the study when in line with previous investigations studies (e.g., Abid & Al, 2021; Mekarina & Ningsih, 2017; Suarsana et al., 2018; Verma, 2021) which also found the benefit of brain-based learning in mathematics classrooms. One possible explanation for the success of brain-based learning in this study is that it accounted for the participants' various learning styles and needs. Individuals have varied ways of processing and remembering information, and brain-based learning systems try to provide a diversity of learning experiences to accommodate these differences (Caine et al., 2016). This may have contributed to the intervention's success, as it allowed all participants to interact with the content in a meaningful way.

Additionally, the results of the study also supported the benefit of skill training in mathematics education as seen in the previous study (e.g., Behzadi et al., 2014; Bernacki, et al., 2020; Galindo, 2019). One possible explanation for the effectiveness of skill training in this study is that it allowed participants to practice and apply the concepts of linear and quadratic functions in a structured and systematic manner. By completing a series of skill-building exercises, participants were able to gradually build their understanding and proficiency in these concepts. Moreover, the use of immediate feedback and personalized coaching in the skill training may have played a role in enhancing participants' learning. This type of support can help learners identify and correct mistakes, as well as build confidence in their ability to solve problems related to linear and quadratic functions (Russell et al., 2020).

The findings of this study reveal that brain-based learning and skill training can be successfully combined and are beneficial in enhancing the learning achievement of participants in linear and quadratic functions. This discovery is significant because it shows that combining these two methods may give a more thorough and efficient method of teaching arithmetic concepts. This is the result of combining the advantages of both strategies. Brain-based learning highlights the significance of engaging and activating numerous brain regions during the learning process, which can assist in the acquisition and retention of new information (Caine et al., 2016). On the other hand, skill training gives learners structured practice and immediate feedback, which can assist them in mastering a particular skill or concept (Salas et al., 2012). By integrating these two strategies, students can benefit from both the holistic and the more specific parts of learning.

6. Conclusion

In conclusion, this study aimed to investigate the effectiveness of an integrated approach combining brain-based learning and skill training on grade 11 students' learning achievement and satisfaction with the learning process in linear and quadratic functions. The results indicated that this approach was effective in improving students' learning achievement and satisfaction. These findings have implications for mathematics education, as they suggest that combining brain-based learning and skill training can effectively teach complex concepts such as linear and quadratic functions. Additionally, this study demonstrates how these two principles can be integrated into a learning management plan that can support learners' learning process.

The findings of this study have several implications for teaching math concepts, such as linear and quadratic functions, in the classroom. One implication is that integrating brain-based learning and skill training can effectively improve students' learning achievement and satisfaction with the learning process. Teachers can use this approach by incorporating activities that engage multiple areas of the brain and by providing structured practice and immediate feedback.

Another implication is that a learning management plan that integrates brain-based learning and skill training can be useful for guiding and organizing the learning process. This plan can serve as a roadmap for teachers and

students, outlining the specific activities and assessments that will be used throughout the lesson.

Several directions for future research could build on the findings of this study. First, it would be interesting to investigate the long-term effects of integrating brain-based learning and skill training on learning achievement and satisfaction. It would also be interesting to compare the effectiveness of this approach to other instructional methods in math education.

Another avenue for research would be to explore the potential moderating factors that may influence the effectiveness of the integrated approach. For example, how does the effectiveness of this approach differ for students with different learning styles or levels of prior knowledge? Additionally, it would be valuable to examine the specific components of brain-based learning and skill training that contribute most to their effectiveness when integrated.

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