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Development of Grade 11 student Learning Achievements on Quadratic Functions Using Brain-Based Learning (BBL) Management

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Abstract

Integrating the knowledge of neurology in teaching has been an idea for learning management design for decades. The current study found the potential of brain-based learning (BBL) for developing high school students' mathematics learning achievement. The purposes of the study were to investigate the effects of BBL learning management on grade 11 students' learning achievement of quadratic functions and to examine students' satisfaction with the BBL as the main principle of learning activities design. The participants were 36 grade 11 students selected by the cluster sampling method. The instruments were brain-based learning management, a learning achievement test, and a satisfaction questionnaire. The statistics used in data analysis were percentage, mean score, standard deviation, a paired t-test, and the index of effectiveness with the determining criteria of 75/75. The findings indicate the benefits of the BBL on mathematics education. They illustrate how learners nearing the end of high school could understand a complex mathematical idea using the BBL instructional strategy.

Keywords: brain-based learning, mathematics learning achievement, quadratic functions

1. Introduction

Mathematics is important to human intellect, logic, and understanding selves and the world (Golding, 2018). The knowledge of calculation fosters mental discipline, logical thinking, and rigor. In education, mathematical knowledge helps students understand science, social studies, music, and art (Redfors et al., 2014). Moreover, mathematical abilities and knowledge contribute to the growth of engineering, the sciences, and medicine, among other fields. Therefore, governments around the world make efforts and allocate resources to assist education stakeholders in determining the optimal approach for teaching the subject.

A quadratic function is an important topic in mathematics teaching. It can be applied in numerous real-world situations such as characterizing the trajectory of a ball, calculating the height of a thrown object, and optimizing corporate profits. When utilizing a quadratic function to solve an issue, it may be essential to locate the vertex or describe a segment of the parabola (Gelfand, 2003). In detail, a quadratic function has one or more variables with a maximum exponent of two. Since a quadratic function's highest degree term is second degree, it is also mentioned as a degree 2 polynomial. In addition, quadratic functions have at least one second-degree term making them algebraic (Flanders & Price, 1975). The concept of quadratic functions makes it complicated and challenges learners in comprehending and applying it in mathematical problem-solving.

It should be noted that there are factors affecting mathematics learning. Variables such as short-term memory, long-term memory, the capacity to recall mathematical knowledge, and visual and spatial perceptual abilities influence students' likelihood of success in mathematics (Hmelo-Silver et al., 2007). Moreover, mathematics is a long-term and continuous learning concept (Atteh, 2020). The content students learn in grade 4 is essential in learning the concept they learn in grade 5. Consequently, students who do not comprehend the previous math concept are unlikely to comprehend the concept being taught in class. This causes them to lose interest in and motivation for learning mathematics and develop a negative attitude toward the subjects. Studies indicate that mathematics and other calculation-based subjects are the most difficult subject in high school, which is not surprising (e.g., Erinosho, 2013; Gafoor & Kurukkan, 2015; Michael, 2015).

In Thailand, mathematics is also one of the crucial problems in its education. Especially, when it comes to complicated concepts taught in high school, mathematics is perceived as a difficult course and even an

impossibility by several students (Leegrajang & Pluangnuch, 2012). This leads to unsatisfactory mathematics test scores at the national level, as Thai high school students have never scored above one-third of the possible points (National Institution of Education Testing Service, 2019). Likewise, the 2018 PISA test shows that the country was ranked only at level 1 ($\bar{x}$ = 419, S.D = 88) in mathematics (The OECD Programme for International Student Assessment, 2019).

These numbers are the results of difficulties faced by Thai students in mathematics classes. According to Inprasitha (2010), Thai students often struggle with multiplication tables, addition, and subtraction. Number facts are crucial for studying math and grasping complex topics. They also face computational weaknesses which could be exemplified by carrying the wrong number during multiplication or division, transposing the wrong number while writing down the final answer, or writing numbers in the wrong column during long division. Moreover, they could not maintain attention in learning. Mathematicians must be attentive in class, on assignments, and on tests. Students who don't double-check their work before submitting could do poorly. On the other hand, mathematics teaching in the Thai context can also be considered as an account of the problem as it prioritizes memorizing and exemplifying over making students understand the mathematical concepts and practice of mathematical problem solving on the subject matters (Saethow, 2019). This hinders the growth of students' thought processes; consequently, they cannot apply what is demonstrated in class to the solution of other mathematical problems.

It can be shown that mathematical issues in the Thai setting are essential and require careful consideration to solve. In this circumstance, brain-based learning (BBL) could be presented as an alternative method to handle the difficulties of the situation. On the ground principle, brain-based learning refers to teaching methods that are founded on scientific findings regarding how the brain learns. This includes cognitive development which influences how students learn and factors affecting brain function such as age, society, emotion, etc. (Jensen & McConchie, 2020). The BBL Brain-based learning is also mentioned as accelerated learning – a technique and philosophy that employs brain research to create optimal learning chances (Birkholz, 2004). Consequently, the method employs the knowledge of brain functions in the design of learning. For instance, the fact that the brain functions effectively under emotional well-being is used to develop learning activities that make students joyful before they begin learning. One of the influential models of BBL was presented by Caine and Caine (1994) which focus on 3 stages of emotional climate, instruction, and consolidation. The detail of Caine and Canine's BBL model could be seen in Figure 1.

Brain-based learning (BBL)

Emotional climate	**Instruction**	**Consolidation**
↓	↓	↓
Engage social interaction	Engage abilities to receive both detail and larger view	Engage capacity to learn form memorizing isolate facts and biographical events
Engage emotional connection	Engage capacity to recognize master essential patterns	Engage abilities to focus attention and learn from peripheral contexts
Engage their innate searching meaning	Engage the psychology in learning	Engage conscious and unconscious processing
Reduce treat and enhance self-efficiency	Acknowledge and engage the development and shift	Engage individual styles and uniqueness

Figure 1. Principles of brain-based learning (adapted from Caine et al., 2005)

In detail, the BBL focuses on helping learners to be relaxed and alert which are the emotions that the brain functions best in learning. The learning activities should contribute to social interaction and emotional connection. This is to let them be eager to search for the meaning of the subject matter and enhance their self-efficiency in learning.

The instruction principle emphasizes orchestrated immersion in the complex experience. The learning activities should allow students to comprehend both small details and a larger picture of what they learn. They should also be designed to let learners understand the patterns creating optimal opportunities for learning.

Lastly, the consolidation principle enables learners to actively process their experiences, thereby creating ideal ways to consolidate their acquired information and abilities. In accordance with this principle, activities should promote both conscious and unconscious learning. The content should be concise but meaningful to let students pay attention to it. This would aid students in memorizing and comprehending the essential contents.

The influence of BBL on mathematics education can also be found in previous studies (e.g., Abid, 2021; El Adl, 2020; Noureen et al., 2017; Verma, 2021; Vihokpaibul, 2020). These studies exemplified the positive effects of the BBL on students' mathematical knowledge and skills in various areas such as learning achievement (Abid, 2021; Noureen et al., 2017), mathematical skills (El Adl, 2020), mathematical learning skills (Vihokpaibul, 2020), and mathematical anxiety (Verma, 2021). The method appears to be effective in addressing both emotional and instructional obstacles in learning mathematics and has the potential to aid students in overcoming the difficulties of learning quadratic functions. Consequently, the current study adopted Brain-based learning as the primary principle of a learning management design and examined its efficacy on the learning achievement of 11^{th}-grade students. The satisfaction of students with the method was also evaluated to provide evidence that could substantiate its contribution to learning psychology benefits.

2. Methodology

2.1 Research Design

The study was designed with a quasi-experimental approach. There was only one group of participants whose performances in the pre-test and post-test were compared. Moreover, their performances during and after finishing the process of learning were used as evidence to support the effectiveness of the BBL as the principle of the learning management design. The satisfaction with the learning management was also examined to provide a broader picture of how the BBL could affect a mathematics class.

2.2 Participants

The participants were 36 grade 11 students selected by the cluster sampling method. The participants were in a public high school in the Thai context where mathematics is considered one of the most crucial problems of its education. The students had reported having only mathematics education only in school. They willingly joined the study and were informed about ethical issues before signing a consent form.

2.3 Instruments

2.3.1 Brain-Based Learning Management

The learning management plan was designed using the principle of Brain-based learning introduced by Caine et al. (2007). Class activities emphasize student-centered environments, with involvement and information processing encouraged. The students were also instructed to remain calm and receptive to new information. Lessons were developed so that students may learn from isolated material and effectively apply it. There are 6 learning plans including quadratic functions, quadratic function graph 1, quadratic function graph 2, quadratic function graph 3, quadratic function and quadratic function graph problem solving 1, and quadratic function and quadratic function graph problem solving 2.

2.3.2 Learning Achievement Test

Originally, there were to be 37 items on the exam, but only 25 were selected following instrument development. 20 items are multiple choices while 5 items are mathematical problem-solving assessments. The evaluation of the item shows an IOC of 1.00. The test was developed in a preliminary study that consists of 26 students with similar qualifications. The discrimination and difficulty of each test item were 0.20–1.00 and 0.20–0.80 respectively. Overall, the test provides 35 maximum points which are divided into 20 points from multiple-choice items and 15 points from 5 written items. Moreover, the test reliability tested by alpha Cronbach correlation was 0.72.

2.3.3 Satisfaction Questionnaire

The questionnaire consists of 10 positive statements regarding learning management. The IOC of each item is 1.00.

2.4 Data Collection and Data Analysis

The participants took a pretest prior to the treatment. While learning with the management plan, their scores on learning activities were collected and used to indicate the process effectiveness of the method. The participants took a post-test at the end of the learning process. The post-test scores were used to compare with the pre-test and indicate product effectiveness. The questionnaire was employed in the last stage of data collection. The statistics used in data analysis of the learning management plant effectiveness was the index of effectiveness with the determining criteria of 75/75. The learning achievement test was accessed by a paired-sample t-test, and the questionnaire result was analyzed by mean score and standard deviation. The participant's answers were analyzed by the following interpretation: 4.50–5.00 =very high, 3.50–4.49 = high, 2.50–3.49 = moderate, 1.50–2.49 dissatisfied, and 1.00–1.49 = highly dissatisfied.

3. Findings

The effectiveness of the BBL on the quadric function learning achievement is determined by the participants' performances during the learning process and after finishing the process.

As a result, the brain-based learning management index of effectiveness (E_1/E_2) was 87.93/82.22 reaching the determining criteria of 75/75 (Table 1). This could be interpreted that a learning management plan designed with the principle of BBL is effective in developing the participants' learning achievement of quadratic functions.

Table 1. The effectiveness of the BBL on the quadratic function learning achievement

Effectiveness	Full mark	$\bar{x}$	S.D.	Percentage
Process effectiveness (E_1)	52	45.72	4.59	87.93
Outcome effectiveness (E_2)	35	28.78	2.79	82.22
Index of effectiveness (E_1/E_2) = 87.93/82.22				

Additionally, the comparison between students' learning achievements in the pre-test and the post-test signifies the improvement. In detail, a paired t-test indicates the participants' average score on post-test ($\bar{x}$ = 28.78) was significantly higher than the pre-test ($\bar{x}$ = 14.64), t =*23.89*, p = 0.00 (Table 2). It could be interpreted that the participants' learning achievement of t quadratic functions was positively affected after the BBL learning management plan was employed in their class.

Table 2. The Comparison between participants' learning achievement before and after the treatment

Learning achievement	**n**	**$\bar{x}$**	**S.D**	**t**	**df**	**Prob.**
Pre-test	36	14.64	4.61	23.89*	35	0.00
Post-test	36	28.78	2.84			

Note. * Prob. < 0.05.

The results of the study indicate that the participants' overall satisfaction with learning quadratic functions in the BBL learning management was at a very high level ($\bar{x}$= 4.76). In summary, participants viewed BBL learning management as the instructional technique that enabled them to successfully pay attention to learning, engage in a relevant learning environment, and enjoy updated and technology-integrated activities. Consequently, it can be asserted that participants were satisfied with their experience studying quadratic functions through the BBL learning management plan (Table 3).

Table 3. Participants' satisfaction with the BBL learning processes

No.	Statements	$\bar{x}$	S.D	Degree of agreement
1	Learning activities were enjoyable and learnable.	4.58	0.60	Very high
2	Learning activities were diverse serving class individual differences.	4.78	0.48	Very high
3	Pre-class activities helped students focus more on learning.	4.81	0.40	Very high
4	Learning management was interesting.	4.92	0.28	Very high
5	Learning activities helped me comprehend class contents.	4.94	0.23	Very high
6	The learning material was interesting and learnable.	4.86	0.48	Very high
7	The integration of technology in the BBL learning management was appropriate.	4.69	0.52	Very high
8	The BBL instruction encouraged learning.	4.64	0.67	Very high
9	Students could simply get access to learning material and BBL activities.	4.47	0.55	High
10	BBL and technology used in teaching were modernized.	4.89	0.31	Very high
Average		**4.76**	**0.45**	Very high

4. Discussion

4.1 The Benefits of the BBL on Mathematics Education

The findings indicate that the participants could develop their knowledge of quadratic functions while doing activities and after finishing the learning process of BBL learning management. Moreover, their learning achievement of the matter was improved compared to their prior knowledge before the treatment. Therefore, the results of the study confirm the benefits of the BBL in mathematics education. Apart from learning achievement of early grade high school mathematics concepts (Abid, 2021; Noureen et al., 2017), mathematical skills (El Adl, 2020), mathematical learning skills (Vihokpaibul, 2020), and mathematical anxiety (Verma, 2021), the BBL seems to be effective when being employed to solve the problem of such a complex concept as the quadratic functions.

4.2 The Benefits of BBL Principles in Learning Management Design

The learning management plan in the current study was designed using the principles of Caine and Caine (2007) which focuses on engaging learners' emotions, orchestrating immersion of teaching, and consolidation of knowledge. This induces attention and relaxation in the pupils, preparing them to digest chunks of knowledge about quadratic functions and allowing them to apply what they have learned to similar mathematical problems. According to the study's findings, these processes contributed to the growth of knowledge and academic accomplishment.

4.3 Participants' Satisfaction with the BBL

Moreover, we also discovered participants were happy with their experience studying quadratic functions with the BBL learning management plan. This evidence supports the use of BBL in mathematics education. As BBL learning employs neuroscience in developing learning activities, it is not a surprise that learners were encouraged to be emotional readiness of learning. This contributes to the fulfillment of learning in pre-class, BBL, and post-class activities.

5. Conclusion

In the current study, we were inspired by the potential of brain-based learning for developing mathematics learning achievement of grade 11 students. A quasi-experimental study was designed to prove the effectiveness of the BBL on quadratic function learning achievement in terms of both students' knowledge and learning satisfaction. The findings indicate the benefits of the BBL on mathematics education. They illustrate how learners nearing the end of high school could understand a complex mathematical idea using the BBL instructional strategy. The study's findings could have implications for mathematical education since teachers could apply the BBL principle to their lessons. Therefore, it could be claimed that the study contributes to the area as it provides a piece of evidence to support the benefits of BBL in the Thai context. However, the three principles of emotion, instruction, and consolidation should be specifically brought into account. In addition, teachers should evaluate how their learners' brains function at ages before constructing a lesson plan using the BBL.

For academic implications, future research should examine employing the BBL as the guiding principle for developing instructional materials for additional mathematical learning accomplishments. More techniques (e.g., collaborative learning) should be integrated into the process of BBL. In addition, qualitative approaches are

encouraged since they permit the assessment of how learners progress through the learning activities.

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References

Abid, R. M., & Al, E. (2021). The Effect of Brain-Based Learning on Mathematical Power for Intermediate First Grade Students. *Psychology and Education Journal*, *58*(3), 2526–2538.

Atteh, E. (2020). The Nature of mathematics education; the issue of learning theories and classroom practice. *Asian Journal of Education and Social Studies*, *10*(2), 42–49. https://doi.org/10.9734/ajess/2020/v10i230265

Caine, R. N., & Caine, G. (1994). *Making connections: Teaching and the human brain*. New York: Addison-Wesley.

Caine, R. N., Caine, G., McClintic, C., & Klimek, K. (2005). *12 brain/mind learning principles in action: The field book for making connections, teaching, and the human brain*. Thousand Oaks, CA: Corwin Press.

El Adl, A. M. (2020). Effectiveness of a Brain-Based Learning Theory in Developing Mathematical Skills and Scientific Thinking among Students with Learning Disabilities in Oman. *Psycho-Educational Research Reviews*, *9*(2), 67–74. Retrieved from https://journals.lapub.co.uk/index.php/perr/article/view/1509/1293

Erinosho, S., Y. (2013). How do students perceive the difficulty of physics in secondary school? An exploratory study in Nigeria. *International Journal for Cross-Disciplinary Subjects in Education*, *3*(3), 1510–1515. https://doi.org/10.20533/ijcdse.2042.6364.2013.0212

Flanders, H., & Price, J., J. (1975). *Algebra*. New York: Academic Press.

Gafoor, K. A., & Kurukkan, A. (2015). Why high school students feel mathematics difficult? An exploration of affective beliefs. In *Online Submission* (pp. 1–6). Retrieved from https://eric.ed.gov/?id=ED560266

Gelfand, M. (2003). *Functions and graphs*. New York: Dover Publications Inc.

Golding, J. (2018). Mathematics education in the spotlight: Its purpose and some implications. *London Review of Education*, *16*(3), 460–473. https://doi.org/10.18546/LRE.16.3.08

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problembased and inquiry learning: a response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 99–107. https://doi.org/10.1080/00461520701263368

Jensen, E. P., & McConchie, L. (2020). *Brain-based learning: teaching the way students really learn* (3rd ed.). Thousand Oaks, California: Corwin.

Leegrajang, Y., & Pluangnuch, N. (2012). The study of mathematics problem-solving skills and learning achievement on multiplication for Prathomsuksa III students using teaching strategies based on CIPPA model. *Journal of Education Graduate Studies Research Khon Kaen University*, *6*(2), 118–126. Retrieved from https://so02.tci-thaijo.org/index.php/EDGKKUJ/article/view/50696/41947

Michael, I. (2015). *Factors leading to poor performance in mathematics subject in Kibaha secondary schools*. Master thesis. The Open University of Tanzania.

National Institution of Education Testing Service. (2021). *2020 Ordinary National Educational Test (O-Net) results*. Retrieved June 24, 2022, from http://www.niets.or.th/th/

Noureen, G., Awan, R.-U.-N., & Fatima, H. (2017). Effect of Brain-based Learning on Academic Achievement of VII Graders in Mathematics Effect of Brain-based Learning on achievement of VII Graders 86. *Journal of Elementary Education*, *20*(2), 85–97. Retrieved from http://pu.edu.pk/images/journal/JEE/PDF/6_v27_2_17.pdf.

Redfors, A., Hansson, L., Hansson, Ö., & Juter, K. (2014). The role of mathematics in the teaching and learning of physics. *Learning Science: Cognitive, Affective and Social Aspects*, *2*, 376–383. Retrieved from https://researchportal.hkr.se/ws/portalfiles/portal/41017235/FULLTEXT01.pdf

Saethow, P. (2019). The factors affecting students learning mathematics in Dusit Thani College, Pattaya. *Dusit Thani College Journal*, *13*(2), 294–306. Retrieved from https://so01.tci-thaijo.org/index.php/journaldtc/article/view/241073/163944

The OECD Programme for International Student Assessment. (2019). *PISA 2018 insights and interpretations*.

Retrieved November 1, 2021, from https://www.oecd.org/pisa/PISA%202018%20Insights%20and%20Interpretations%20FINAL%20PDF.pdf.

Verma, S. (2021). Effect of Brain-Based Learning Strategies on Mathematics Anxiety of Upper Primary School Students. *DEI-FOERAA*, *1*, 26–32. Retrieved from https://www.dei.ac.in/dei/deifoeraa/index.php/archieve/2-uncategorised/9-dei-foeraa-2021

Vihokpaibul, P. (2020). Brain-Based Learning Materials and Mathematics Learning Skills of Primary 1–3 Students. *Palarch's Journal of Archaeology of Egypt/Egyptology*, *17*(9), 1746–1767. Retrieved from https://www.coursehero.com/file/105881928/Brain-Based-Learning-Materials-and-Mathematics-Learning-Skills-of-Primary-1-3pdf/