Effects of integrating a brain-based teaching approach with GeoGebra on problem-solving abilities

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ABSTRACT

B-Geo Module is a module that has been developed using the brain-based teaching approach (BBTA) integrated with GeoGebra Software (B-Geo Module) is expected to help students' problem-solving abilities of the topic of Differentiation. The BBTA is a strategy that uses brain-based learning techniques. It was created to be consistent with the individual brain's tendencies and ideal functions in order to ensure that pupils can learn efficiently. Therefore, the proposed of this study is to explore the possible effects of the B-Geo Module on problem-solving abilities for the Topic of Differentiation. A quasi-design of pre-test and post-test experiments was utilized in this study, which included 118 form 4 pupils from rural secondary schools. For school selection, the researchers employed cluster sampling approaches, and for sample selection, they used an intact group. The schools were separated into two groups: experimental and control. The experimental group used the B-Geo Module, while the control group used traditional ICT modules. The instrument used was the Problem-Solving Test of Differentiation. The results of the data analysis showed the effectiveness of the B-Geo Module in the problem-solving abilities in the topic of Differentiation among rural secondary school pupils. The multimedia such as GeoGebra can be the tools for BBTA to facilitate Additional Mathematics teachers in secondary schools to help students solve problem and improved their learning in the topic of Differentiation.

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1. INTRODUCTION

In the 21st century, Additional Mathematics teachers and students need to continue to innovate and evolve, following changes in the global arena. Teaching and learning using multimedia are very important so that students and teachers can familiarize themselves with the use of the latest technology for the subject of Additional Mathematics. In fact, the Program for International Student Assessment (PISA) 2015 was also implemented for the first time based on multimedia [1]. According to a preliminary report of the Malaysia Education Blueprint (PPPM) 2013-2025, the first wave, which was to bring about the government's desire for the seventh PPPM shift, engendered the Ministry of Education to allocate the largest capital for infrastructure and technology in schools. However, according to the Inspectorate of Schools (JNJK) inspection report from 2012 and 2013, the percentage of Malaysian instructors utilizing multimedia was relatively low, at 1.20% in 2013 and 0.00% in 2012 [2]. Previous studies suggest that despite the many benefits of using technology in teaching mathematics, overall technology utilization in the classroom is slow [3]. This is due to a lack of support modules and teaching assistance resources for the topic of Differentiation that include the use of multimedia to aid students' problem-solving abilities. Based on the researchers' preliminary study as well, only 22.2% of teachers have used the Teaching module that involve multimedia during the teaching and learning process of Additional Mathematics in the classroom [4].

Most students assume that Additional Mathematics is very difficult in understanding concepts and problem-solving questions. Learning Additional Mathematics became more difficult because it was more abstract and required them to make higher reasoning. It is because at this stage that a more constructive approach is needed and should be introduced to help students understand learning more effectively. The teaching and learning of Additional Mathematics require an accurate and thorough conceptual understanding in addition to numeracy skills that involve high thinking power and creativity. Appropriate strategies in the teacher's Daily Teaching Plan and interesting teaching aids can have a positive impact in the implementation of the learning process and teaching of Additional Mathematics students. Students' problems in answering problem-solving questions in the subject of Additional Mathematics should be given due attention. Weaknesses in these subjects can result in a lack of opportunities to further their studies to a higher level and follow certain courses that require Additional Mathematics knowledge and skills.

In problem solving of daily life, the first step to solving a given problem should be to translate from the context of the question to the abstract level of Differentiations [5]. Then the abstract problem is solved, and subsequently the solution is translated back into its context. The first step clearly demonstrates students' conceptual understanding of variable knowledge, algebra skills, and calculus concepts because this step relies on the identification of not only appropriate concepts in a given context but also relationships among them. Identifying appropriate concepts may involve the selection of one or more variables from several concepts. For example, to solve the problem of differentiation of the first law, $\frac{dy}{dx}$, i.e., students need to understand the concept of the gradient tangent to a curve and the concept of limits. If teachers can find out students' problems in a particular topic such as Differentiation topics, teachers can use it to improve curriculum and pedagogy to ensure students' conceptual understanding can be improved so that they can create problem-solving questions more effectively.

Based on the issues and ideas, the study needed to be done to help the teachers in terms of developing a multimedia module for Additional Mathematics, especially for the topic of Differentiation in order to help enhance students' problem-solving abilities. Based on previous studies [6], [7], information and communication technology (ICT) modules have been successfully developed. These multimedia modules have solved problems in terms of problem-solving abilities faced by students when learning Mathematics. Furthermore, the goal of this study is to explore the possible effects of the brain-based teaching approach with the integration of GeoGebra Software on problem solving abilities of Differentiation topics in rural secondary schools in Malaysia.

2. LITERATURE REVIEW

2.1. Brain-based teaching approach

The brain-based teaching approach is a system that implements the 12 principles of brain-based learning outlined by previous researchers [8], [9] using three teaching techniques. The three elements of teaching associated with brain-based learning, namely: i) Calm and sensitive (emotional climate) - creating a full learning environment by flooding students with many educational experiences; ii) Integration of various enriched experiences (teaching) - eliminating fear among students while maintaining a very challenging environment; and iii) Active Processing (reinforcement) - allowing students to actively integrate and access information.

The brain-based teaching approach is considered to promote learning because of its comprehensive approach to students. It is a learning strategy that improves attention, understanding, meaning, and memory by following the best operating principles of the brain's natural operations [10]. Learning that is "genuine," in the sense that it is related to real-world problems and applications, can help students learn better [8]–[11]. The difficulty, in fact, is for teachers to diversify teaching approaches and transform the paradigm from "one with all" to "enriched environment" for each student, because the development and maturation of the brain is dependent on one's experiences [8], [10]–[12]. The 12 principles of brain-based learning are discussed in Table 1 [8], [9].

Table 1. Principles of brain-based learning

No. of Principle		Description of principle
P1	The brain is a parallel processor.	Teaching should begin with providing pupils with experiences that expose them to the realities of life. The brain can divide the event into small chunks or as a whole. Finally, students can connect the event to their own activities.
P2	Learning engages the entire physiology.	Because all of these things affect the brain, brain-based learning should take into account students' needs in terms of sleep, diet, environment, and emotions. The physiological state of a person has an impact on his or her memory. Learning requires both sensory and muscular movements. When the uses of all the senses and body are combined, learning will be more effective because the mind and body are interconnected with each other.
P3	The search for meaning is innate.	All students should be taught using the imaginative ways utilized to teach bright kids. Learning requires a steady atmosphere in addition to attracting students' attention to meet the needs of new discoveries and information. The brain's natural nature is to receive stimuli, respond, and find meaning in them. When kids have priorities, interests, and ideas from their own experiences, understanding is easier to acquire.
P4	The search for meaning occurs through "patterning".	The brain has a proclivity for remembering a lot of information. The brain will be able to store all of the needed information and experience in order to establish new patterns for meaningful learning. Unfilled brain capacity will generate new patterns and relate them to previously understood ones.
P5	Emotions are critical to patterning.	To develop long-term memory, students' emotions must be stable. The brain is extremely sensitive to changes in emotions. Every experience is shaped by emotions, which decide whether the brain accepts it positively or negatively. Effective learning can be enhanced with extensive emotional experience, and emotional and physical responses will result in good understanding [13].
P6	Every brain simultaneously perceives and creates parts and wholes (Brain is social)	The connection between educators' and students' past experiences, as well as others, can be used in the everyday learning process to persuade students that learning does not have to be formal. Because learning is cumulative, good teaching is instruction that increases students' understanding and skills over time. Informal learning with social interaction is particularly good at building trust, sharing information, and working together to solve issues. Meaningful learning will result from social interactions and relationships with the environment and other people.
P7	Learning involves both focused attention and peripheral perceptions.	The educational environment in its entirety is critical. The use of music is critical as a means of enhancing and influencing natural information acquisition. To encourage learning and increase students' interest, educators must emphasize students' needs by giving motivation and direction. Individuals will absorb all the stimuli and information, but they will always choose according to their personal priorities, beliefs, and differences.
P8	Learning always involves conscious and unconscious processes.	The link between educators' and students' previous experiences, as well as others, can be used in the everyday learning process to persuade students that learning does not have to be formal. Students will discover their own strengths and limitations and attempt to overcome them. In order to gain relevant information, students must be given adequate time to contemplate and participate in an activity or experience on their own.
P9	Humans have at least two types of memory: a spatial memory system and a set of systems for rote learning.	Long-term spatial memory and semantic memory are two types of memory (rote learning memory). Contextual memory entails a variety of systems for comprehending events, whereas semantic memory distinguishes between facts, abilities, and procedures. Curiosity, new experiences, and expectations fuel it. In some circumstances, the rote learning method might be beneficial. However, in most cases, retention is short, and this interferes with the knowledge creation process. Long-term memory is usually the result of learning through a variety of approaches and daily routines.
P10	Humans understand and remember best when facts and skills are embedded in natural spatial memory.	Students must build relationships through exposure, repetition, and practice in order to add to and enrich their current experiences, resulting in a brain that is more compact and capable of new and deeper comprehension. Brain development can be stimulated by experience.
P11	Learning is enhanced with challenge and inhibited by threat.	To increase the learning process, the teaching tactics employed should be enriched with challenges, but any threats such as punishment, caning, or other things that can cause pupils to feel uneasy should be avoided. It is critical to have a secure study environment in order to maximize learning. Effective mental and emotional functioning can be impaired due to anxiety and will lead to failure [14].
P12	Every brain is unique.	Everyone's brain is different, and information and skills that are entrenched in real life experience work better. All pupils should be able to use their own intelligence to make decisions about how they want to interpret the world. One's brain is distinct due to the diversity of one's background, socioeconomic status, race, gender, and religion.

2.2. GeoGebra software

The current learning techniques and instructional aids must be diverse, and they cannot solely rely on traditional classroom procedures. Many various types of tools, resources, and instructional methods are introduced into our educational system as a result of the ongoing integration of technology into the educational process. Technology can be employed for both meaningful learning and thorough comprehension of a subject [15]. Students can use computer software to interact with educational materials aimed at developing required abilities and solving everyday issues utilizing their mathematical backgrounds. For this learning technology to be worthwhile, it must be practical and compatible with our educational system. When new technology is employed in the classroom, there is evidence of a link between ICT-enabled activities, a good attitude toward mathematics, increased mathematical learning, and students' performance [16], [17]. According to Jonassen *et al.* [18], technology is used as a mindtool to enhance deep introspective cognition and is essential for effective learning. Many educators throughout the world who utilize ICT in their education have become aware of the presence of open-source software. This includes software like GeoGebra, which is a good example of software that can be used in the process of learning mathematics.

GeoGebra is a dynamic mathematics and open-source software that may be used to teach and learn mathematics for free. GeoGebra is a software package that includes geometric, algebraic, statistics, and calculus functions. GeoGebra derives its name from the word’s "geometry" and "algebra." GeoGebra has created its program with the use of spreadsheets, graphics, mathematics, and statistics in an easy-to-use package to keep up with the current innovations. GeoGebra has also established itself as a global leader in dynamic mathematics, science, technology, engineering, and mathematics software for teaching and learning. According to previous studies [19], [20], GeoGebra could be a beneficial new platform for online learning on a daily basis (e-learning). Moreover, previous studies has shown that students and teachers view the GeoGebra software positively [21].

2.3. Problem solving abilities

The term mathematical problem solving refers to a thought process that occurs to overcome barriers between a given situation and an expected goal state through a sequence of affective thought processes as well as specific behavioral responses, i.e., the individual involved does not know how to move forward from a given situation to the state of the expected goal. Several mathematics education experts have put forward various definitions of the meaning of problem solving. According to Miller and Hudson, problem-solving is defined as a planned process of achieving a desired goal using knowledge, thinking experience, and is a learning situation in which the goal is achieved through a selection of processes and execution of certain operations [22]. Meanwhile, according to other research, problem solving is a process of using certain strategic measures to achieve the desired goal in order to solve a problem [18].

Students’ problem-solving skills can be seen from their ability to answer questions related to justification, mathematical thinking, generalized findings as well as relationships between facts [23]. Nevertheless, several recent studies still find that students' problem -solving skills are at a low level [24]–[29]. Solving mathematical problems with the help of computers is something that has long been discussed by previous researchers. Computer supported collaborative learning (CSCL) was presented by [30] in a case study conducted to evaluate the effectiveness of computer-based teaching methods using GeoGebra Software with self -problem solving skills in schools. The proposed method uses the Sternberg problem-solving model (six steps of problem-solving) and for self-study. The use of activity sequences that combine observation, execution and ultimately self-reflection during the CSCL process using GeoGebra Software has also been proposed to be effective [31]. Although students are not accustomed to GeoGebra Software to solve problems collaboratively, teaching methods designed through a technology aligned network produce positive learning gains that generally confirm its contribution. In particular, students improved their problem-solving abilities while reducing the problem-solving period. Meanwhile, in previous study reported on the findings that the use of GeoGebra helps students improve their mathematical understanding by enabling alternative avenues of problem solving, and in some cases, helping to diagnose their learning difficulties [32], [33].

3. RESEARCH METHOD

3.1. Research design

This study used a quasi-experimental pre-test-post-test non-equivalent control group design. Even if several experiments had no effect, this design was appropriate for the study's objectives, which were to identify at least one attribute that differentiated the groups with different predicted results [34]. The quasi-experimental study design utilized is shown in Table 2.

According to Table 2, the pre-test that measures students' starting ability level is represented by O_1 in this study. O_2 represents the post-test, which examines performance following treatment. This was done to compare the effectiveness of the two groups' interventions. The pre-test O_1 accomplishment would be utilized as a covariate to reconcile the original disparities between groups if it did not demonstrate equality across groups for the respondent's initial level of ability [35]. The participants in this study were 118 fourth-grade students from rural secondary schools, divided into two groups (60 experimental students and 58 control students). Both groups consisted of students from different schools. The researchers' experimental study methodologies for both groups are shown in Table 3.

Table 2. Quasi-experimental study design

Group	Pre-test	Treatment	Post-test
Experimental group (B-Geo Module)	O_1	B-Geo Module approach	O_2
Control group (P ICT)	O_1	ICT approach	O_2

Table 3. Experimental procedures

Action	Timeframe
Brain-based teaching approach integrated with GeoGebra Software Workshop and ICT Workshop	1 day
Pre-test	1 hour
Teaching & learning activity	10 weeks, 70 minutes per week
Post-test	1 hour

3.2. Research instruments

Problem solving ability was measured using the Differentiation Topic Problem-Solving Test (UPMTP) instrument. These problem-solving questions were adapted by the researchers using Malaysian Certificate of Education (SPM) questions. To construct the items in this test, then a Test Specification Table (JSU) was constructed first to produce a set of items that tested the problem solving as shown in Table 4. There are 10 items in the Differentiation Topic Problem Solving Test. Where, the tenth item is to measure the problem-solving abilities in the Differentiation Topic. One mark represents 1.5 minutes according to the SPM format of the Additional Mathematics subject. Therefore, the researcher gave time for one hour for the respondents to answer this Differentiation Topic Problem Solving Test.

For content validity, four teachers with over ten years of experience teaching Additional Mathematics courses and six mathematics lecturers who are content experts in Differentiation topics assessed and evaluated the UPMTP instruments. After then, a pilot study of 70 Form 4 students was conducted to determine the instrument's reliability.

Table 5 shows that item 9 is a particularly difficult question. As a result, this item was enhanced, and the researcher conducted interviews with students and teachers to determine the difficulty level of item 9. Most of the students giving answers did not have enough time to answer the question because it had taken a long time to answer the previous question. Teachers discovered that students are still less proficient in fast calculations as a result of interviews with students. Form 4 students have not yet adjusted to the Additional Mathematics examination, and they dislike proving problems. This item has also been evaluated by specialists and is an adaption of the SPM examination questions. As a result, the researchers determined that this item was adequate and might be improved upon.

Table 4. Test Specification Schedule (JSU) according to Anderson Taxonomy level

Objectives	No. of items	Anderson taxonomy level	Subtopic of Differentiations				Mark
			2.1	2.2	2.3	2.4	
Problem solving questions	Item 1	Analyzing		/		/	4
	Item 2	Applying		/		/	4
	Item 3	Analyzing		/		/	4
	Item 4	Evaluating		/	/	/	4
	Item 5	Evaluating		/		/	4
	Item 6	Applying		/	/	/	4
	Item 7	Analyzing		/	/	/	4
	Item 8	Analyzing		/		/	4
	Item 9	Creating		/	/	/	4
	Item 10	Evaluating		/		/	4
Total	10						40

Table 5. Difficulty index and difficulty level for UPMTP instruments

No item	Difficulty index	Difficulty level	Items accepted/rejected
1	0.47	Moderate	Accepted
2	0.55	Moderate	Accepted
3	0.33	Moderate	Accepted
4	0.69	Moderate	Accepted
5	0.64	Moderate	Accepted
6	0.69	Moderate	Accepted
7	0.38	Moderate	Accepted
8	0.22	Hard	Accepted
9	0.12	Very Hard	Accepted after revision with experts
10	0.20	Hard	Accepted

Items 3, 6, 7, and 9 were also revised and examined with experts based on Table 6, because this item was taken from SPM questions, experts have confirmed that it can be utilized. As a result, the researcher chose to keep the items pending expert approval. Overall, the Problem-Solving Test instrument has an alpha value of 0.72, which is higher than the threshold of validity accepted [36].

Table 6. Discrimination index for UPMTP instruments

No item	Discrimination index	Items accepted/rejected
1	0.59	Very good
2	0.79	Very good
3	0.29	Marginal needs to be improved
4	0.49	Very good
5	0.39	Good
6	0.26	Marginal needs to be improved
7	0.25	Marginal needs to be improved
8	0.42	Very good
9	0.24	Marginal needs to be improved
10	0.38	Good

3.3. Data analysis techniques

The descriptive analysis and inference analysis utilizing the ANCOVA test were utilized to analyze the data. Because the pre-test scores for the problem-solving questions in Differential Topics for the two groups, namely the experimental and control groups, were different, the ANCOVA test was applied. As a result, in the ANCOVA analysis, the Problem Solving of the Topic of Differentiation Pre-Test (UPMTP) was adjusted and changed into Covariates. The SPSS program version 26 was used to run the ANCOVA test. To compare the scores of problem-solving abilities between the two groups of students, the test was conducted at a significance level of 0.05.

4. RESULTS AND DISCUSSION

The mean, minimum, and maximum values of the pre-test and post-test questionnaires, as well as the tests for students following the B-Geo Module teaching strategy and the ICT teaching approach, were determined using descriptive statistical analysis. After the prerequisites for utilizing ANCOVA analysis were met, inferential statistical analysis was done to get significant differences on the dependent variables of the two experimental groups using ANCOVA analysis.

The mean problem-solving pre-test score for the B-Geo Module teaching technique is lower than the mean problem-solving pre-test score for the ICT teaching strategy, according to the findings in Table 7. Meanwhile, the B-Geo Module teaching approach's mean problem-solving post-test score is slightly higher than the ICT teaching approach's mean problem-solving post-test score (Table 7). The Levene test has a significant result of 0.53, which is higher than the p>0.05 threshold. As a result, the assumption of variance homogeneity was followed.

Table 7. Value description of and problem-solving pre-test and post-test scores for B-Geo Module teaching approach and ICT teaching approach

Types of treatment approaches		N	Mean score	Standard deviation
B-Geo Module approach	Problem-solving pre-test score	60	3.73	2.37
	Problem-solving post-test score	60	16.58	5.66
ICT teaching approach	Problem-solving pre-test score	58	4.91	1.87
	Problem-solving post-test score	58	12.90	4.75

Since the research question has a covariate that is the score of the problem-solving pre-test, then the analysis of this study uses ANCOVA test. The result of the Levene test is insignificant (p>0.05) suggesting that uniform variance assumptions between the two groups of teaching approaches has been adhered. The result of the one-way ANCOVA test conducted shows a significant difference between the two groups of teaching approaches on the mean of the problem-solving pre-test scores for the topic of Differentiation, F (1,118) = 9.98, p <0.05 with a size effect of 8.0%. Thus, the null hypothesis (H_{0a}) is subtracted, suggesting that the teaching approach affects problem-solving abilities for students learning the topic of Differentiation. A summary of the results is shown in Table 8.

Table 8. One-way ANCOVA test results for test scores of problem-solving in Differentiation topics

Source	Total Squares Type III	Degree of freedom	Mean Squared	F	Sig.	Partial Eta Squared
Problem-solving pre-test	126.68	1	126.68	4.78	0.03	0.04
Teaching approach	264.70	1	264.70	9.98	0.00	0.08
Total	29323.00	118				

To control the impacts of the covariate, the estimated marginal average of the problem-solving post-test scores was determined. The average problem-solving post-test score for students following the B-Geo Module teaching technique for the topic Differentiation was 16.30 as shown in Table 9. Meanwhile, students who follow the ICT teaching approach get an average score of 13.19 on the problem-solving post-test on the topic of Differentiation in Table 9. The average test score of problem-solving abilities of the topic Differentiation for students using the B-Geo Module teaching approach is higher than the average test score of problem-solving abilities of the topic for students using the ICT teaching approach, according to these findings.

Table 9. Marginal average estimated results of problem-solving post-test score for teaching approach using the B-Geo and P ICT modules

Teaching Approach	Average	95% Confidence Interval	
		Lower limit	Upper limit
B-Geo Module Teaching Approach (B-Geo Module)	16.30[a]	14.96	17.64
ICT Teaching Approach (PICT)	13.19[a]	11.82	14.56

Based on the analysis of students' answers in the experimental group in UPMTP, students who follow learning using the B-Geo Module teaching approach can answer problem-solving questions better than students who follow learning using the conventional approach (PICT). This is because of the integration of brain-based teaching approached with GeoGebra software, students can see firsthand examples of Differentiation Topic concepts and the way the work is done while answering problem-solving questions. The findings of this study support the opinion of [20] who stated that GeoGebra software, students can see directly examples of concepts in daily life and subsequently able to process concepts in answering problem-solving questions. Students will learn better if learning is "authentic", in the sense that it relates to real-world problems and applications [8], [10], [11], [37].

Since a person's brain development and growth are influenced by their experiences, the true challenge for teachers is to vary their teaching approaches and transform their paradigm from "one size fits all" to "enriched environment" for each student [8], [10]–[12]. The teacher's purpose in this study is to create an ideal classroom atmosphere that stresses instructions that accommodate how the brain learns. It can increase brain function in accurately processing and creating data, according to each student's level.

5. CONCLUSION

Based on the findings, it can be concluded that the brain-based teaching approach with GeoGebra integration improved students' problem-solving abilities in the topic of Differentiation. The effectiveness is shown by the results of the ANCOVA Test with a value of $F(1,118)=9.98$, $p<0.05$ with a size effect of 8.0%. Students can develop their problem-solving abilities by actively participating in activities that use the B-Geo Module. This means that using a brain-based teaching approach and GeoGebra software to assist students understand the concept of Differentiation and solve problems related to it.

Unlike traditional methods of schooling, which are often said to inhibit learning and ignore the brain's natural learning process, brain-based teaching is thought to improve learning, particularly in understanding the concept of the subject and solving problems, because of its holistic approach to students. It's a method of learning that follows the best working principles of the brain's natural functions, with the purpose of improving attention, comprehension, meaning, and memory.

Furthermore, the GeoGebra Software is crucial since it improves students' learning, particularly their problem-solving ability. The findings of the researchers show that employing a new technique from the traditional approach employed by teachers can increase students' problem-solving abilities on the issue of Differentiation. Furthermore, the findings of this study reveal that using GeoGebra software is one of the ways in which students can increase their conceptual knowledge of the issue of Differentiation.

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