



Transforming students' perspectives: Boosting biological mathematical attitudes with brain-based learning model

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ARTICLE INFO	ABSTRACT
<p>Article history Received: 18 October 2024 Revised: 05 December 2024 Accepted: 14 December 2024</p> <p>Keywords: Biological Mathematical Attitude Brain-Based Learning Model Numeracy Literacy</p>	<p>In the digital era, data and information in biological sciences are increasingly presented in quantitative forms that require processing and analysis, making it essential to train students in numeracy literacy. This study aims to see changes in students' biological mathematical attitudes through the application of the Brain Based Learning Model combined with numeracy literacy tasks. This study used a quasi-experimental method with a pretest-posttest non-equivalent group design. The research sample consisted of 28 students in the experimental class and 30 students in the control class who were selected randomly. The instrument used was a biological mathematical attitude questionnaire with 15 statements on a Likert scale. The results showed that the N-Gain score for students' biological mathematical attitudes was higher in the experimental class with a medium category of 0,51, while in the control class it was in the low category with a score of 0,29. This shows that the Brain Based Learning model is more effective in increasing students' positive attitudes towards the integration of mathematics in biology learning. Based on the results of this study, teachers are expected to consider using the Brain Based Learning Model as a potential alternative learning model, especially in supporting the implementation of the independent curriculum. In addition, it is hoped that other researchers can explore the potential of the Brain Based Learning Model on broader biology topics and other levels of education to expand its positive impact.</p>

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INTRODUCTION

Understanding students' attitudes toward the use of mathematics in the context of biology is an important step in the process of developing effective quantitative reform because it will affect their behavior and achievement (Andrews et al., 2017; Flanagan & Einarson, 2017). The research of Thompson et al. (2013) shows that one of the challenges of integrating mathematics into biology subjects is the existence of negative student attitudes toward mathematics. From a theoretical perspective, mathematical attitudes are important for the development of students' quantitative skills because these attitudes are thought to influence student motivation. Student performance depends on how well they expect to perform a task, as well as the value they place on the task (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000). Students who are confident that they can succeed in performing a task will be motivated to persist and complete it (Wigfield & Cambria, 2010). This attitude can also emerge in the learning of biology material integrated with mathematics, which can affect student performance on quantitative tasks given by teachers (Andrews et al., 2017). This attitude is known as a mathematical-biological attitude. The study of Nuraeni et al. (2020) showed that quantitative literacy-based learning in biology material can facilitate students to develop quantitative literacy skills, thereby improving students' biological mathematical attitudes. In other words, students' biological mathematical attitudes are influenced by the learning process that trains numeracy literacy skills.

Shonkwiler & Herod (2009) explain that biology has a synergistic relationship with mathematics. Biological phenomena have complex problems and mathematics provides a way to understand and solve problems in biology. The selection of genetic material, especially heredity in humans in this study, is based on the consideration that the material involves many numbers and symbols in calculations, in addition to containing basic biological content that students need to understand (Duncan & Reiser, 2007; Elmesky, 2013). In addition, based on the results of an interview with a biology teacher at a high school in Bandung City, information was obtained that many students still face difficulties when working on biology problems, especially genetics.

The emergence of negative views of students toward mathematics is a factor that reduces students' interest in learning biology, especially those related to calculations and analysis of various quantitative information presentations (Azzahra et al., 2024). To facilitate students in improving their numeracy literacy and biological mathematical attitudes, the role of teachers as facilitators during the learning process is needed. The selection of learning models by teachers is one of the strategies that determines the success of learning (Widiastuti & Kurniasih, 2021), including in efforts to improve students' biological mathematical attitude abilities.

Learning that focuses on students' brain abilities is important in supporting learning success. For this reason, it is necessary to apply a potential learning model to support these learning activities, one of which is through the implementation of the Brain-Based Learning model. Brain-based learning comes from a neuroscience study on how brain function can run optimally (Jensen, 2008). The focus of Brain-Based Learning is how the brain works with a combination of senses, experiences, and learning to create a fun classroom environment (Haghighi, 2013). This learning model emphasizes student involvement in the learning process (Azzahra & Dwiputra, 2024; Helmahria et al., 2017). This is intended to encourage positive attitudes towards biology learning that is integrated with mathematics because students feel more involved and have control over their learning. In addition, the Brain Based Learning model, which has the characteristic of encouraging the connection of concepts with real experiences (Jensen, 2008; Suarsana et al., 2018), is expected to help students see the relevance of mathematics in the context of biology, thereby changing their view of mathematics into something more meaningful. Through tasks in the form of practice questions by following the syntax of the Brain Based Learning model carried out during learning, it is expected to make students more confident in facing and solving biological problems that contain quantitative data, especially in the material of heredity in humans which has a very close relationship with students' daily lives. This learning activity helps reduce students' fear of biological material that contains calculations and forms a more positive attitude.

From the described learning challenges, it is evident that students' attitudes towards mathematics play a crucial role and cannot be overlooked. Learning that emphasizes cognitive engagement is essential to achieving educational success. To address this, implementing a potential learning model such as Brain-Based Learning (BBL) becomes a pivotal strategy. This model leverages an understanding of how the brain learns best, fostering active and meaningful engagement in learning activities. Through this approach, it is anticipated that students will develop a more positive perception

of biology learning, especially when it is integrated with mathematics. This research aims to evaluate the effectiveness of the Brain-Based Learning model in improving students' attitudes towards mathematics.

METHODS

Research Design

This study uses a quasi-experimental method to evaluate the effect of implementing the Brain Based Learning model on the mathematical biological attitudes of high school students in human heredity material, then the results were compared with other groups using conventional learning methods. The research design used is Pretest Posttest Non-Equivalent Control Group Design based on Wiersma's (1995) guidelines. In this design, two sample groups are included, namely, the experimental group and the control group. Both groups are given pretest and posttest with different treatments.

Table 1

Pretest Posttest Non-Equivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experiment	O1	X1	O2
Control	O2	X2	O2

Description:

O1: Pretest to reveal students' biological mathematical attitudes

O2: Post-test to reveal students' biological mathematical attitudes

X1: Treatment in the form of implementing the Brain-Based Learning model

X2: Treatment in the form of implementing a learning model commonly used by teachers.

Population and Samples

The population of this study was the biological mathematical attitudes of class XII students at a high school in Bandung City who were studying human heredity in the 2023/2024 academic year. The research sample was in the form of biological mathematical attitudes of students in two sample classes. The determination of the research sample was carried out by random sampling, namely, samples were taken randomly from two classes from the existing classes. From the two selected classes, a lottery was held to determine the treatment for each class. The first lottery was for the experimental class, namely Class XII IPA 2, consisting of 28 students who were given learning treatment using the Brain-Based Learning model. The second lottery was for the control class, namely class XII IPA 1, consisting of 30 students who were given treatment using the conventional learning model.

Instrument

Biological mathematical attitudes in research refer to three aspects of value formulated by Andrews et al. (2017), namely interest, utility value, and perceived cost (burden/level of difficulty) felt by students toward the use of mathematics in learning human heredity material. Students' mathematical-biological attitudes were measured using the Math-Biology Value Instrument (MBVI) which has been modified from Andrews et al. (2017). The instrument is a questionnaire containing 15 statements with options in the form of a Likert scale, namely strongly agree, agree, disagree, and strongly disagree. This questionnaire was given before and after learning activities to students in both sample classes.

Procedure

Brain Brain-based learning model learning activities were held in three meetings. The application of the Brain-Based Learning model uses seven learning stages formulated by Jensen (2008), namely pre-exposure, preparation, initiation and acquisition, elaboration, incubation and memory insertion, verification and checking, and celebrations and integration. In general, the learning activities carried out as an effort to improve students' biological mathematical attitude aspects can be seen in Table 2.

Data Analysis Techniques

The students' biological mathematical attitudes obtained through filling out the questionnaire will be calculated using a scale. The scale form used in the student questionnaire is converted into a score. The values obtained from each student are then subjected to statistical tests using IBM SPSS Software.

Data processing begins with a prerequisite test consisting of a normality test and a homogeneity test. This is then continued with a hypothesis test, namely a mean difference test, to determine the difference in the average of the control class and the experimental class. To determine the value of the increase in students' biological mathematical attitudes, a normalized gain analysis (n-gain) is carried out.

Table 2
Learning Activities with Brain Based Learning Model

Syntax	Learning Activities	Targeted Biological Mathematical Attitude
Pre-exposure	<ol style="list-style-type: none"> 1. Teachers build positive relationships with students 2. Students build conceptual maps through concept map presentations and video viewing 3. Students answer several teacher questions related to the stimulus provided 	Interest
Preparation	<ol style="list-style-type: none"> 1. The teacher explains the learning material in general 2. Students respond to the presentation of the material delivered by the teacher 	Interest, Utility value
Initiation and Acquisition	<ol style="list-style-type: none"> 1. Students work on numeracy literacy tasks independently 2. Teachers accompany students in working on tasks 	Interest, Utility value, Perceived cost
Elaboration	<ol style="list-style-type: none"> 1. Students discuss the content of learning about heredity in humans through group discussions 2. Teachers facilitate learning activities that allow students to explore the subject using appropriate learning modes (visual, audio, kinesthetic) 	Interest, Utility value, Perceived cost
Incubation and Memory Insertion	<ol style="list-style-type: none"> 1. Students are given the opportunity to take a short break (listening to music) 2. Students repeat the material through teaching media prepared by the teacher 	Interest
Verification and Checking	<ol style="list-style-type: none"> 1. Students check their understanding through quizzes/questions and answers 2. Teachers explore students' understanding of the material that has been given previously 	Interest, Utility value, Perceived cost
Celebrations and Integration	<ol style="list-style-type: none"> 1. Teachers appreciate students' work 2. Students are given the opportunity to express their feelings 	Interest, Utility value

RESULTS AND DISCUSSION

The biological mathematical attitudes of students in this study were measured using a questionnaire given before and after learning. Furthermore, the data obtained in the scores were converted into values. The comparison of student achievement scores in the experimental and control classes was analyzed using IBM SPSS™ and is presented in Figure 1.

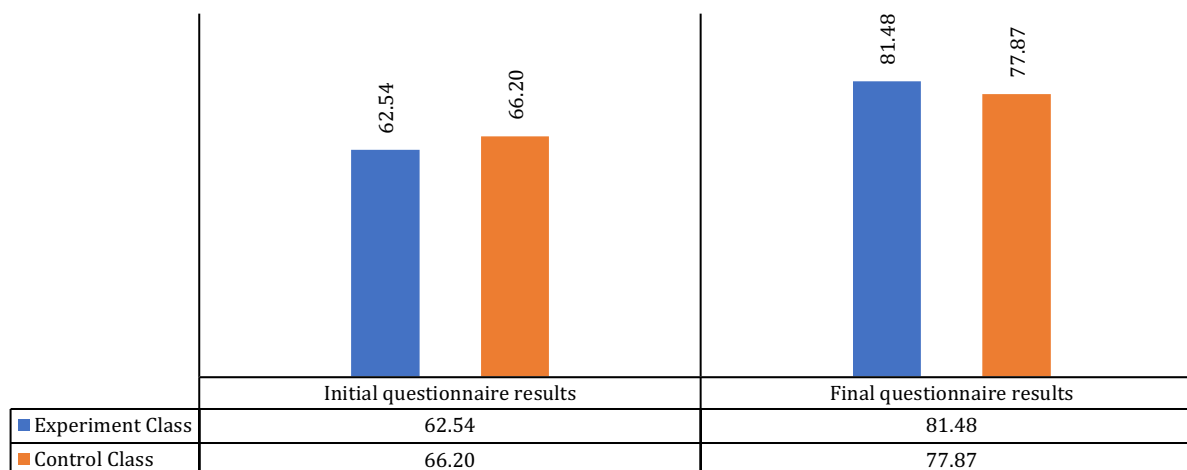


Figure 1. Comparison of Initial and Final Values of Biological Mathematical Attitude Questionnaire

The figure illustrates that the Brain-Based Learning (BBL) model is more effective in enhancing students' biological mathematical attitudes compared to conventional learning methods. Although the control class had a slightly higher pre-learning questionnaire score (66,20) than the experimental class (62,54), the experimental class showed a more significant improvement after the treatment, reaching an average score of 81.48 compared to 77.87 in the control class. This greater increase in the experimental class highlights the positive impact of the BBL approach in fostering deeper engagement and understanding. These results align with previous studies, which demonstrate that learning models designed to activate and utilize brain potential can significantly improve students' attitudes and motivation, ultimately enhancing learning outcomes (Cahyani et al., 2020; Imanuel et al., 2021; Rukminingsih et al., 2021)

To explore further how the effectiveness of the Brain Based Learning model improves students' biological mathematical attitudes, an analysis of the N-Gain Score was conducted. The N-Gain Score calculation was carried out to compare how effective the Brain-Based Learning model intervention was compared to conventional learning that had been implemented. The results of the N-Gain Score calculation from the two sample classes are presented in Table 3.

Table 3
N-Gain Score of Students' Biological Mathematical Attitudes

Group	N	N-Gain Index Criteria for Each Student						N-Gain Average	N-Gain Index Criteria
		High		Medium		Low			
		f	%	f	%	f	%		
Experiment	28	8	28.57	16	57.14	4	14.29	0.51	Medium
Control	30	3	10.00	15	50.00	12	40.00	0.29	Low

Based on Table 3, the Brain-Based Learning (BBL) model demonstrates greater effectiveness in improving student outcomes compared to conventional learning methods. The experimental class, which implemented the BBL model, had a higher proportion of students in the high N-Gain Score category than the control class. Overall, the experimental class achieved an average N-Gain Score of 0,51, classified as moderate, while the control class only reached an average score of 0,29, categorized as low. These findings suggest that the BBL model effectively facilitates cognitive engagement and retention by aligning with how the brain naturally processes and organizes information. This result is consistent with prior studies showing that brain-based approaches improve learning by fostering meaningful connections and reducing cognitive overload (Immanuel et al., 2021; Riskiningtyas & Wangid, 2019). Meanwhile, through Figure 2 below, the distribution of the N-Gain Score of students' biological mathematical attitudes in the two sample classes can be seen.

Based on Figure 2, it can be concluded that the Brain-Based Learning (BBL) model is more effective than the conventional learning model in enhancing students' mathematical biology attitudes. This is indicated by the highest N-Gain Score in the experimental class, which exceeded 0,80, while the control class showed lower score variations, with some students scoring below 0,00. The absence of students in the experimental class obtaining negative scores suggests that the BBL approach provides a more meaningful learning experience and supports the development of students' mathematical attitudes. These findings align with previous research, which revealed that brain-based learning approaches enhance students' cognitive and emotional engagement (Azzahra et al., 2024; Biffle, 2013), ultimately having a positive impact on their attitudes and learning outcomes. The results of the N-Gain Score calculation are presented in Table 4.

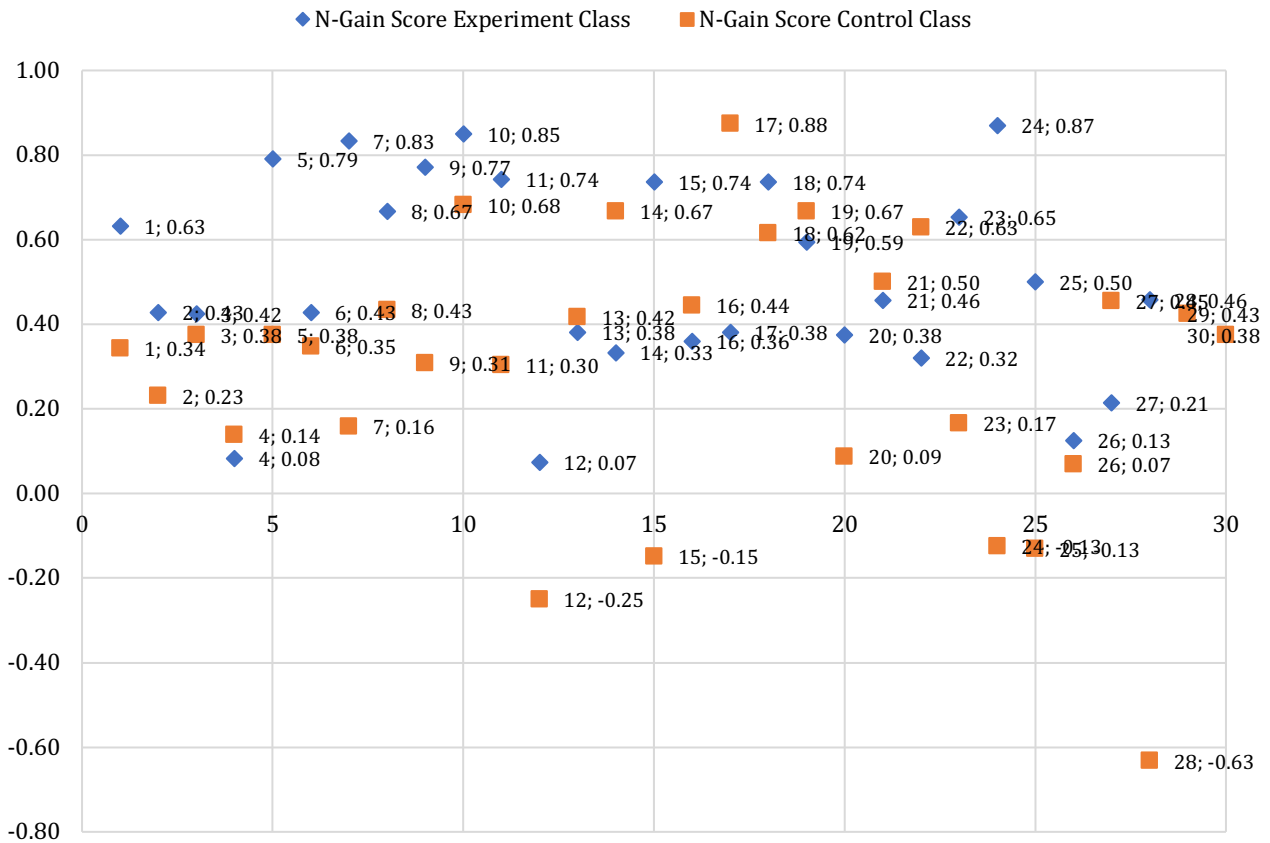


Figure 2. Distribution of N-Gain Score of Students' Biological Mathematical Attitudes

Table 4

Comparison of N-Gain Score per Aspect of Biological Mathematical Attitude

Mathematical-Biological Attitude Aspects	Experiment		Control	
	N-Gain Score	N-Gain Index Criteria	N-Gain Score	N-Gain Index Criteria
1: Interest	0.54	Medium	0.40	Medium
2: Utility Value	0.49	Medium	0.25	Low
3: Perceived Cost	0.40	Medium	0.31	Medium

The comparative data in [Table 4](#) highlights the effectiveness of the Brain-Based Learning (BBL) model in enhancing students' biological mathematical attitudes across various aspects. The experimental class consistently achieved medium criteria for all aspects of attitudes, whereas the control class showed only medium criteria for interest and perceived cost but low criteria for utility value. This suggests that the BBL model promotes a more comprehensive improvement in attitudes compared to conventional learning. The higher and more evenly distributed N-Gain Score values in the experimental class indicate that the BBL model not only supports overall attitude development but also benefits students across a range of initial abilities.

These findings align with previous research showing that BBL creates an inclusive learning environment by integrating cognitive engagement and emotional well-being, which are critical for fostering positive attitudes (Mekarina & Ningsih, 2017; Riskiningtyas & Wangid, 2019). The absence of negative N-Gain Scores in the experimental class further reinforces the model's ability to effectively address students' diverse needs and reduce barriers to learning, such as anxiety or low initial motivation. By contrast, the presence of students in the control class with negative scores suggests that conventional methods may not adequately support all learners. This highlights the potential of BBL to cultivate a growth-oriented mindset and improve students' attitudes toward integrated mathematics and biology learning.

The effectiveness of the Brain Based Learning model can be seen from the acquisition of higher N-Gain Score values seen from each aspect of biological mathematical attitudes measured. This finding

indicates that the implementation of the Brain-Based Learning model shows good results in improving students' biological mathematical attitudes in a positive direction. The implementation of the Brain Based Learning model in improving each aspect of students' biological mathematical attitudes is described as follows.

Interest Aspect

Through an integrative approach based on neuroscience principles, this study explores how the Brain-Based Learning model can influence aspects of students' interest in biology subjects that contain quantitative data. In preparation syntax, the teacher explains the learning material briefly through the Canva presentation media. This brief explanation from the teacher provides an overview and context of what will be learned so that students feel more prepared and enthusiastic to follow the next learning process. This shows that a short but clear initial explanation is very effective in arousing student interest and readiness. This preparation stage creates curiosity or pleasure in students.

At each meeting, the teacher delivers material concisely and engagingly to provide students with foundational knowledge. Visually appealing and informative presentations spark curiosity and help establish a strong initial understanding (Prabowo et al., 2022). Following the presentation, the teacher encourages students to participate in brief discussions to delve deeper into the topics presented. These discussions aim to activate prior knowledge and connect it with new concepts. Additionally, students are regularly assigned numeracy literacy exercises, which are completed either individually (initiation and acquisition syntax) or in groups (elaboration syntax). These tasks, designed with contextual problems relevant to students' daily lives, nurture their interest and enthusiasm for learning. Research has shown that the Brain-Based Learning model can enhance key factors in successful learning, such as motivation, self-efficacy, and academic achievement (Mekarina & Ningsih, 2017; Sani et al., 2019).

The Brain-Based Learning model further fosters a love of learning by emphasizing a comfortable, enjoyable, and emotionally engaging environment tailored to students' cognitive abilities (Riskiningtyas & Wangid, 2019; Wijayanti et al., 2021; Yudha et al., 2020). This approach helps students easily absorb material and build their self-efficacy. For many, mathematics-related tasks can evoke anxiety due to numbers and mathematical symbols. However, by creating a supportive and non-judgmental learning environment, the Brain-Based Learning model effectively reduces this anxiety, enabling students to approach learning with confidence and positivity.

The incubation and memory insertion syntax in the Brain Based Learning model provides students with a short break. This stage is accompanied by games and relaxation facilitated by the teacher. In this study, the teacher played soft musical instruments to create a relaxed atmosphere. Lidiastuti et al. (2019) in their study that playing classical music can stimulate and energize the creative and motivational areas of the brain. Music can activate the flow of memory stored in the corpus callosum. Tang's (2017) study explained that the brains of some students who showed positive emotional attitudes and low stress functioned better when compared to students who had good feelings about and fatigue.

After taking a short break, students were asked to repeat important concepts from the material studied at each meeting. In this study, the repetition of material at meeting I was assisted by the use of genetic flashcards, which allowed students to group between autosomal-linked traits and provide explanations related to these traits. The genetics flashcards used offer an interactive and visual learning approach, which can increase student engagement in the learning process. This method allows students to study in groups so they can exchange knowledge and explain concepts to each other, which can deepen their understanding. In addition, the use of genetics flashcards helps in strengthening students' long-term memory of the material being studied. The process of grouping and explaining repeatedly with the help of genetics flashcards helps students to internalize information better.

In the second meeting of the incubation and memory insertion syntax, the teacher played a video comparing human traits, and students were asked to guess the traits classically according to the questions given. This method utilizes the power of visualization to help students understand the differences and similarities of genetic traits in a fun way. This learning activity encourages students to connect the information they have learned with real examples of human genetic traits that they see in the video and compare the traits with themselves. Furthermore, in the third meeting, students reviewed the material independently through a video about human blood type prepared by the teacher. Through repetition and the use of visual aids such as videos, students can connect verbal information with visual

and numerical representations, thereby strengthening their numeracy literacy skills. This is something that can encourage students' interest in participating in biology learning based on numeracy literacy.

Utility Value Aspect

Learning human heredity material is integrated with mathematical concepts such as probability and statistics to predict inheritance patterns. Thus, students not only understand biological concepts in depth but also improve their numeracy skills. This approach can improve students' biological mathematical attitudes, especially in the utility value aspect because students directly relate the relevance of mathematics in understanding real biological phenomena. In addition, this method encourages students to develop analytical and critical skills, as well as fosters greater curiosity about biology subjects. By combining these two disciplines, students can experience more comprehensive and meaningful learning, which in turn increases their motivation and academic performance.

The Brain-Based Learning model emphasizes the use of various relevant and contextual learning strategies to help students relate mathematical concepts to their daily experiences (Sani et al., 2019). This can increase the utility value felt by students, especially from human heredity material. At the initiation and acquisition stage, students are invited to apply the basic knowledge that has been previously obtained through working on numeracy literacy tasks independently. The teacher acts as a facilitator who provides guidance and feedback while students work on this independent task. By providing a supportive and motivating environment, the teacher helps students overcome the difficulties they face, such as determining the magnitude of the probability of offspring from a certain cross. In learning, the teacher tries to create a supportive classroom environment where students feel safe to ask questions and make mistakes. Hasna & Wathon (2018) explain that this supportive environment is important to facilitate effective learning. The initiation and acquisition stages are very important for building a strong foundation in students' understanding of more complex inheritance concepts.

Next, in the syntax elaboration, students discuss in groups. The learning followed by students simulates genetic crossing so that it can help students understand probability and statistics in the context of inheritance. Through discussion, students can share their understanding, ideas, and perspectives on the material that has been learned. To improve numeracy literacy, the tasks given require students to create or present heredity data in the form of diagrams, such as punnett squares or family trees, helping students understand and analyze inheritance patterns visually. This elaboration stage is designed to deepen students' understanding through the application of concepts in more complex and real situations (Jensen, 2008). At this stage, students work on literacy tasks in groups to help students better understand the material being studied. Through a student-centered approach, learning becomes more meaningful and relevant to students, thereby building aspects of utility value in students.

Learning with the brain-based learning model ensures that students not only gain knowledge passively but also actively explore, integrate, and apply new information. This is supported by Jensen (2008), who states that learning that involves collaboration and group discussion is in line with the principles of Brain-Based Learning, which emphasizes the importance of a learning environment that supports social interaction, active involvement, and rich and meaningful learning experiences.

Perceived Cost Aspect

The Brain-Based Learning model emphasizes the importance of a pleasant and supportive learning atmosphere, which can reduce the perceived costs or barriers felt by students. According to Insani et al. (2023), when students feel comfortable and supported in the learning process, they tend to be more open to receiving and understanding the material. Sousa & Tomlinson (2011) also stated that the brain-based approach integrates emotional involvement, nutrition, a comfortable environment, music, movement, meaning-making, and the absence of threats for maximum student participation and achievement.

According to Dewi et al. (2022), methods such as problem-solving in small groups or educational games can make learning mathematics more enjoyable and less scary. For this reason, independent learning followed by group discussions are carried out in learning with this Brain Based Learning model. With active involvement in discussions and problem-solving, students will become accustomed to the collaborative and analytical approaches needed to solve real problems. This learning activity can help students better understand the concept of heredity and apply mathematical knowledge in a biological context.

In learning human heredity material, for example, students participate in gamete pairing simulation activities (meeting III) or genetic flashcard games (meeting I) involving the concept of heredity in pairing genetic traits linked to autosomes. This helps them internalize concepts through direct experience and group discussions involving collaborative activities that allow students to share ideas with classmates. Lidiastuti et al. (2019) explained that the Brain-Based Learning model has the potential to influence student development in terms of student discipline, challenges, and collaboration. This not only enriches conceptual understanding but also improves the social aspect of learning, which can indirectly influence students' positive attitudes towards the lesson.

Checking student understanding, especially in syntax verification and checking, is made as interesting as possible to reduce the burden felt by students (perceived cost), namely by using the Quizizz application, videos, and Wordwall as media in checking student understanding. The media has an evaluation display that contains images and is accompanied by music so that students are more relaxed. Interactive and adaptive evaluation methods can be an effective solution to overcome the pressure felt by students in learning. Interaction with interactive media also helps students understand the numerical concepts involved in heredity, such as the probability of inheritance of traits and genetic pattern analysis. According to Susanti (2021), by utilizing interesting technology and media, students are more motivated to learn and more easily understand the relationship between theoretical concepts and their applications in real contexts.

The celebrations and integration stage instills a sense of love for learning in students, especially in the material of heredity in humans by involving students' emotions. Positive emotions can increase students' motivation, involvement, and long-term memory of the material being studied (Supradewi, 2010). When students feel happy and appreciated, they tend to be more enthusiastic and motivated to learn further. In this study, teachers gave awards and celebrated the successes achieved by students during the learning process. Awards in the form of praise and small gifts to recognize students' efforts and achievements. Awards or celebrations with applause and praise are included in emotional learning that involves the prefrontal cortex. The prefrontal cortex works when happy and comfortable (Handayani & Corebima, 2017). Celebrating success helps strengthen students' self-confidence and gives them a real sense of accomplishment (Hanaris, 2023; Heri, 2019), which in turn encourages them to continue trying and studying hard.

Overall, the Brain Based Learning model not only instills a love of learning and increases motivation, but also encourages students to develop and apply their numeracy literacy in real contexts. This is very important in learning heredity material in humans, where a strong understanding of data, statistics, and numerical analysis is essential to understanding genetic concepts.

CONCLUSION

Based on the findings on students' biological mathematical attitudes, it is proven that the Brain Based Learning model provides better results in improving students' biological mathematical attitudes. The better N-Gain Score in the experimental class indicates that the Brain Based Learning model can provide a learning situation that increases the interest and utility value aspects of integrated mathematics biology learning, and decreases the perceived cost aspect of students. The Brain-Based Learning model can be developed for implementation at lower levels of high school, namely classes X and XI. In practice, the routine implementation of Brain Based Learning can be an alternative innovative and effective learning model to improve students' biological mathematical attitudes. The use of this model can help teachers design more interesting and interactive learning so that students are more motivated and actively involved in the learning process. This model also allows teachers to identify areas where students experience difficulties and provide more targeted assistance.

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