



Enhancing students' numeracy literacy in human heredity material through a brain-based learning model

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Article Information	Abstract
Keyword: Brain-based learning; Numeracy literacy; Human heredity material; Students' literacy Kata Kunci: Pembelajaran berbasis otak; Literasi numerasi; Materi hereditas pada manusia; Literasi peserta didik History: Received : 03/06/2024 Revised : 26/06/2024 Accepted : 28/06/2024 Published : 30/06/2024	In this digital era, data and information in biology are increasingly presented in quantitative form that must be processed and interpreted. To deal with this, students' numeracy literacy becomes essential to train. This study aims to reveal an increase in students' numeracy literacy by implementing the brain-based learning model. This study used a quasi-experimental method with a pretest-posttest non-equivalent group design. The sample consisted of 28 students in the experimental class and 30 students in the control class who had been selected by random sampling. The instruments used were question sheets with various types, such as the Minimum Competency Assessment (MCA) questions. The findings of this study indicate that the experimental class has a higher N-Gain Score, which is 0.71 with high criteria, while in the control class, it is 0.60 with a moderate category. The better N-Gain Score can also be seen from each numeracy literacy indicator's analysis. This indicates that the brain-based learning model improves students' numeracy literacy more effectively. Based on these findings, further research can conduct a long-term study of applying the brain-based learning model to students' numeracy literacy to understand the sustainability of the improvements. <i>Abstrak. Di era digital ini, data dan informasi dalam ilmu biologi semakin banyak disajikan dalam bentuk kuantitatif yang harus diproses dan diinterpretasikan. Dalam rangka menghadapi hal tersebut, literasi numerasi siswa menjadi hal yang penting untuk dilatih. Tujuan penelitian ini adalah untuk mengungkap adanya peningkatan literasi numerasi siswa melalui implementasi Model Brain Based Learning. Penelitian ini menggunakan metode eksperimen semu dengan desain pretest posttest non-equivalent group design. Sampel terdiri dari 28 siswa pada kelas eksperimen dan 30 orang siswa kelas kontrol yang telah dipilih secara random sampling. Instrumen yang digunakan adalah lembar soal dengan berbagai tipe seperti pada soal Asesmen Kompetensi Minimum (AKM). Temuan penelitian ini menunjukkan bahwa kelas eksperimen memiliki N-Gain Score yang lebih tinggi, yaitu sebesar 0.71 dengan kriteria tinggi, sedangkan pada kelas kontrol sebesar 0.60 dengan kategori sedang. Perolehan N-Gain Score yang lebih baik juga terlihat dari analisis setiap indikator literasi numerasi yang diteliti. Hal ini menandakan bahwa model Brain Based Learning lebih efektif dalam meningkatkan literasi numerasi siswa. Berdasarkan temuan tersebut, penelitian berikutnya dapat melakukan analisis jangka panjang dari penerapan Model Brain Based Learning terhadap literasi numerasi siswa untuk memahami keberlanjutan peningkatan yang dicapai.</i>

A. Introduction

Numeracy literacy is one of the skills the government emphasizes to be trained in the educational aspect in the 21st century (Han et al., 2017). Numeracy literacy is not only about the ability to calculate or use numbers but also the ability to understand, analyse, and apply mathematical concepts in various contexts of everyday life (Rosalina & Suhardi, 2020). In this digital era, numeracy literacy is becoming increasingly important because of the large amount of data and information individuals must process and interpret. Therefore, integrating numeracy literacy in the education curriculum is expected to improve students' ability to think critically, solve problems, and make the right decisions based on existing data (Kintoko et al., 2021; Rizki et al., 2022). In addition, numeracy literacy also plays a role in preparing students to face challenges in the increasingly complex and technology-based world of work (Aisah et al., 2021). Thus, strengthening numeracy literacy in schools is a strategic step to improve the quality of human resources and the nation's competitiveness on a broader global scale.

Referring to the 2022 PISA study results, student numeracy literacy in Indonesia is still categorized as low. Indonesia is ranked 67th, 71st, and 70th out of 81 countries evaluated for science, reading, and mathematics, respectively (OECD, 2023). This shows that efforts to improve numeracy literacy in Indonesia need attention and encouragement for improvement so that these problems can be resolved immediately. According to Diyarko & Waluyo (2016), one factor causing Indonesian students' low numeracy literacy is the need for more habituation to solve problems related to numeracy literacy. To measure students' basic competencies in reading and numeracy literacy as part of efforts to improve the quality of national education, the government has implemented the MCA launched by the Ministry of Education and Culture of the Republic of Indonesia (Teresia, 2021).

Numeracy literacy is critical because it allows students to effectively understand and work with numbers, which is essential in various aspects of life and academic disciplines (Megawati & Sutarto, 2021). Especially in modern biology today, concepts in biological science are no longer only based on qualitative aspects but have become more quantitative and interdisciplinary (Nuraeni et al., 2015). Based on the results of interviews conducted with biology teachers at several public and private high schools with A accreditation in Bandung City, it was stated that many students still experience difficulties in numeracy literacy, especially in complex subjects involving numbers and calculations such as genetics. This difficulty indicates the need for innovative teaching methods to improve students' understanding and retention of these challenging topics.

One of the promising learning models to overcome this problem is the Brain-Based Learning model. Based on neuroscience, Brain-Based Learning utilizes knowledge about how the brain learns naturally and offers a learning concept to strengthen students' brain potential (Jensen, 2008). The principles of Brain-Based Learning include creating a safe learning environment (Dwiputra et al., 2023), integrating active and enjoyable learning strategies, and connecting new information with existing knowledge (Haghighi, 2012; Mastoni et al., 2019; Setyaningtyas & Harun, 2020). These principles are designed to make learning more engaging and effective, improving students' academic performance.

Several previous studies have shown that Brain-Based Learning creates learning experiences that encourage thinking skills, create a comfortable learning environment, and create active and meaningful situations for students (Mastoni et al., 2019; Putri et al., 2019; Setyaningtyas & Harun, 2020). Other studies have shown positive results in mathematics learning through the application of the Brain-Based Learning model, including increased student learning outcomes, critical thinking skills (Susanti et al., 2019), problem-solving (Damayanti & Sukestiyarno, 2014). The positive results from implementing the Brain-Based Learning model are also expected to provide good results in biology learning integrated with numeracy.

The Brain-Based Learning model offers significant potential in biology education, especially human heredity. Heredity in humans is a basic topic in biology that discusses the transmission of genetic traits from parents to offspring. However, several things could be improved in studying this topic. Genetics involves complex concepts that often cause students difficulty understanding (Diana & Rachamatulloh, 2017). In addition, the assumption of students that learning genetics is not exciting and boring causes students' interest in learning to decrease (Cimer, 2012). This makes the topic ideal for applying innovative teaching strategies through learning with the Brain-Based Learning model.

Integrating the Brain-Based Learning model offers significant advantages for enhancing student numeracy literacy in biology education, particularly regarding human heredity. Heredity, which deals with the transmission of genetic traits from parents to offspring, often presents complex concepts that can be challenging for students to grasp (Diana & Rachamatulloh, 2017). Additionally, students may perceive genetics as uninteresting and tedious, leading to decreased motivation to learn (Cimer, 2012). The Brain-Based Learning model leverages understanding how the brain learns best, which can be particularly effective in teaching such intricate topics. By incorporating strategies that align with the brain's natural learning processes, such as using

visual aids, interactive activities, and real-life examples, teachers can make the subject more engaging and comprehensible (Dwiputra et al., 2023). This approach not only aids in understanding complex genetic concepts but also enhances students' numeracy literacy by helping them interpret and analyse genetic data, probabilities, and patterns in inheritance.

Based on the results of a literature review by Azzahra & Dwiputra (2023), there has yet to be any research conducted on implementing the Brain Based Learning model in grade XII of high school, especially in biology subjects. This study aims to reveal the implementation of the Brain-Based Learning model to improve the numeracy literacy of grade XII high school students on the topic of heredity in humans. Integrating the Brain-Based Learning strategy into the teaching of this topic can improve students' understanding and application of numerical concepts related to genetics. The results of this study are expected to provide valuable insights into the effectiveness of the Brain-Based Learning model in improving numeracy literacy and offer practical recommendations for educators to adopt more brain-friendly teaching methods in their classrooms.

B. Material and method

This study uses a quasi-experimental method that analyses the effect of the brain-based learning model on students' numeracy literacy skills on the material of heredity in humans and then compares it with other groups using conventional learning. The research design used is the Pretest Posttest Non-Equivalent Group Design which refers to Wiersma (1995). This research design is presented in Table 1.

Table 1 Pretest posttest nonequivalent control group design research design

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

Description:

O1 = Pretest to reveal students' numeracy literacy skills and mathematical-biological attitudes

O2 = Posttest to reveal students' numeracy literacy skills and mathematical-biological attitudes

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

X2 = Treatment in the form of implementing conventional learning

The population in this study were grade XII high school students at a private school with A accreditation in Bandung City who were studying Human Heredity material in the 2023/2024 academic year. The research sample was determined by random sampling; samples were taken randomly from two classes from the existing classes to be drawn. The first draw for the experimental class, Class XII IPA 2,

consisted of 28 students who were given learning treatment with the Brain-Based Learning model. The second draw for the control class, namely class XII IPA 1, consists of 30 students who were given treatment with conventional learning, namely using the lecture method, followed by the Drill and Practice Method to solve problems on heredity in humans.

The instrument used to assess students' numeracy literacy skills is a question sheet with various questions, namely multiple choice, matching, true/false, short answer, and essay, as in MCA questions (Kemendikbud, 2021). This series of diverse questions evaluate students' understanding and application of mathematical concepts, data interpretation, and problem-solving in the context of human heredity. By requiring calculations of genetic probability, data analysis from Punnett squares and pedigrees, and genetic principles, this instrument measures students' ability to apply numeracy skills to real-world biology learning.

C. Results and discussion

The Brain-Based Learning model implemented in the experimental class follows seven stages of learning according to Jensen (2008): pre-exposure; preparation; initiation and acquisition; elaboration; incubation and memory insertion; verification and checking; and celebrations and integration. A comparison of the average pretest and posttest scores of students' numeracy literacy in the experimental and control classes is presented in Figure 1.

Based on the diagram in Figure 1, it is known that the average score of the initial achievement (pretest) of students in the experimental class is lower than the control class. After the learning, the experimental class implementing the Brain-Based Learning Model had a higher average score than the control class implementing conventional learning. The data on students' numeracy literacy achievement were then analysed statistically to determine whether the average achievement scores of the two sample classes were significantly different.

The results of the prerequisite test using IBM SPSS™ software on the normality of the pretest and posttest scores showed that the data were not normally distributed. In contrast, the homogeneity test showed that all data had homogeneous variance. Because of this, the non-parametric Mann-Whitney U-test was used as a hypothesis test to determine the significance of the data obtained through the pretest and posttest.

The average difference test on the pretest data showed insignificant results, indicated by the Asymp Sig (2-tailed) value 0.579. These data indicate that the numeracy literacy of students in the experimental class and the control class before being given treatment did not show a significant difference. After being given treatment, there was a substantial difference between the posttest scores of the

experimental class and the control class numeracy literacy as evidenced by the Asymp Sig. (2-tailed) <0.05 , which was 0.003. From these results, it can be concluded that learning by implementing the Brain-Based Learning Model affects students' numeracy literacy in learning human heredity material. According to Meltzer (2002), in a study using an experimental group and a control class, the N-Gain Score test can be used when there is a significant

difference between the average post-test score of the experimental group and the post-test score of the control group through a mean difference test. The N-Gain Score analysis determines how effective the Brain-Based Learning model intervention is in the experimental class compared to learning in the control class on students' numeracy literacy. The difference in N-Gain Score from the two sample classes is presented in Table 2.

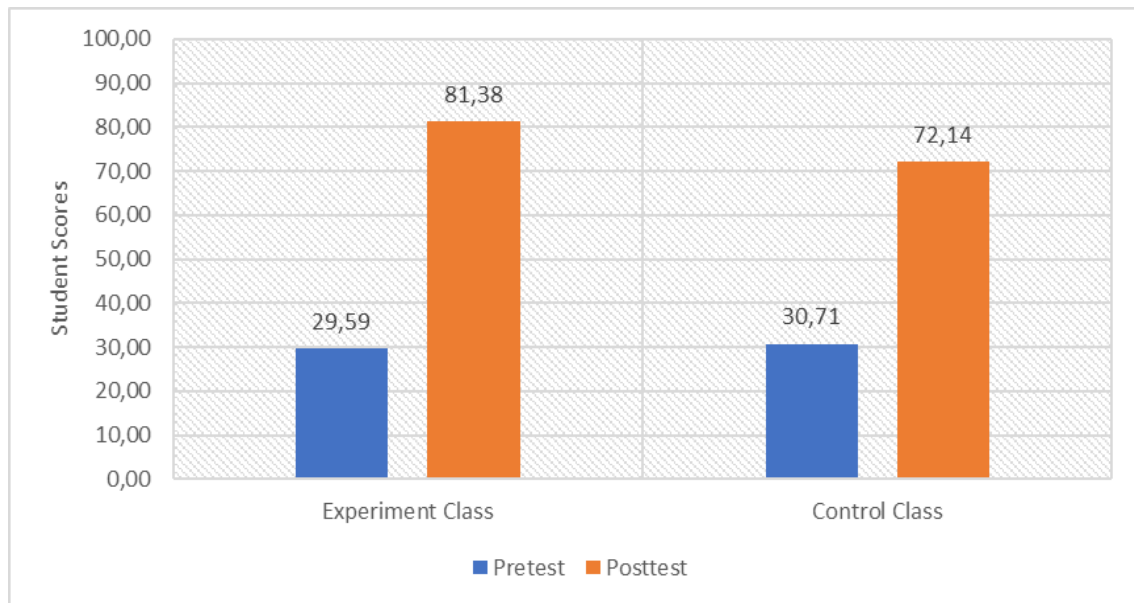


Figure 1 Comparison of average pretest and posttest scores of sample classes

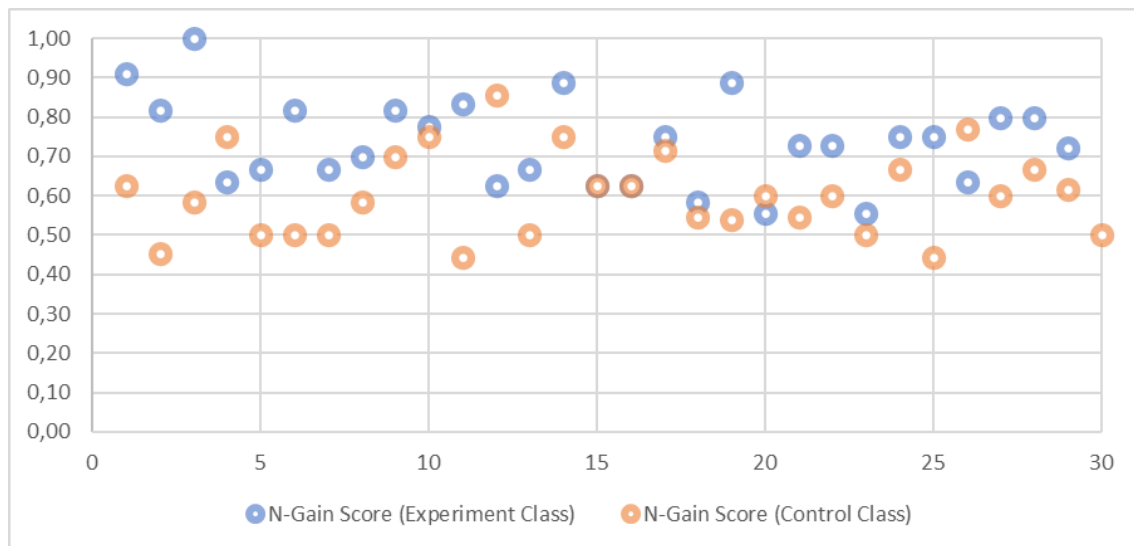


Figure 2 Distribution of students' N-Gain scores

Table 2 N-Gain score of students' numeracy literacy

Group	N	N-Gain score average	N-Gain index criteria
Experiment	28	0.74	High
Control	30	0.60	Medium

Meanwhile, Figure 2 shows the distribution of students' N-Gain Scores in the sample class. Based on the data in Table 2 and the distribution of students' N-Gain Score in Figure 2, the experimental class has several students with better N-Gain Score values than the control class. This indicates that the Brain-Based Learning model improves students' understanding

and numeracy literacy skills more effectively. Furthermore, the N-Gain value of each numeracy literacy indicator is calculated to compare how effective the Brain-Based Learning model intervention and the conventional learning model that has been implemented. Numeracy literacy indicators according to Han et al. (2017) include (1) using various numbers and symbols related to basic mathematics to solve problems in various contexts of everyday life, (2) analysing information displayed in various forms (graphs, tables, charts, diagrams and so on), and (3) interpreting the results of the analysis to predict and make decisions. The results of the N-Gain Score calculation is presented in Table 3.

Table 3 Comparison of N-Gain values per numeracy literacy indicator

Literacy numeracy indicators	Experimental class		Control class	
	N-Gain score	N-Gain index criteria	N-Gain score	N-Gain index criteria
Using	0.88	High	0.78	High
Analysing	0.75	High	0.53	Medium
Interpreting	0.63	Medium	0.56	Medium

Table 3 shows comparative data on the N-Gain values per numeracy literacy indicator in both sample classes. The experimental class showed better results than the control class. The magnitude of the N-Gain Score evidences this for indicators 1, 2, and 3, respectively, namely high-high-medium, while the control class has high-medium-medium criteria. This finding indicates that applying the Brain-Based Learning model in the experimental class significantly improves students' numeracy literacy.

The first indicator of numeracy literacy has a slightly higher N-Gain Score in the experimental class than the control class. These better results can be caused by the Brain-Based Learning Model learning method, which better facilitates students integrating numeracy literacy through the worksheet containing more contextual human heredity material assignments based on existing problems and accompanied by accurate statistical data. This learning provides a deeper and more meaningful understanding for students. This is in line with research by Widiani et al. (2017) which also presents contextual problems in implementing the Brain-Based Learning Model, and the results have a positive influence in helping students improve their creative thinking skills.

Dewi & Masrukan (2018); Susanti et al. (2019) explained that the application of the Brain-Based Learning model provides an opportunity to create a learning process that involves students' brains actively and comprehensively and frees students to build their knowledge of diverse and contextual learning situations. In addition, learning with the Brain-Based Learning Model is accompanied by

relaxation and simple games that help students remember and understand the material. This method is by neuroscientific theory which states that brain activity that involves pleasure and relaxation can improve cognitive abilities and long-term memory (Sari & Mariani, 2023; Lee & Juan, 2013). Relaxation and simple games help reduce stress and increase focus so students are better prepared to receive and process information.

The second numeracy literacy indicator showed a better improvement in the experimental class compared to the control class, with the most significant difference in the N-Gain Score, which was 0.22. This significant improvement can be caused by the Brain-Based Learning Model, which is more effective in helping students understand and analyse complex information. Using various forms of visual representation such as graphs, tables, diagrams, and diagrams in brain-based learning helps students associate mathematical concepts with real situations, making it easier to analyse and understand information. This is supported by research by Mohd et al. (2022); Carifio & Perla (2009) which revealed that numerical information presented in various forms (diagrams, graphs, and so on) can improve students' understanding of concepts.

In addition, learning environments designed according to the Brain-Based Learning Model are often more interactive and involve various activities that stimulate all the senses, so students are more actively engaged in the learning process (Husna et al., 2018). Activities like this improve students' analytical skills because they are involved in meaningful and relevant learning (Mertha et al., 2019). This approach also allows for more constructive and direct feedback so that students can immediately identify errors or mistakes in their analysis and correct them. Aulia et al. (2021); Nilawati et al. (2019) also did the same thing in their research, namely in the syntax incubation and memory insertion, students were given feedback or reinforcement on the conclusions that had been made so that they could improve communication, retention, and student learning outcomes.

Meanwhile, the third indicator of numeracy literacy has almost the same N-Gain score between the two classes, namely with moderate criteria. The experimental class has a slightly higher score, 0.63, while the control class is 0.56. The achievement of this N-Gain value shows that although there is a slight difference between the two classes, the increase in the skill of interpreting quantitative information is relatively even in both groups. This almost the same achievement is likely due to several factors. First, the skill of interpreting quantitative data may be more dependent on the understanding of basic mathematical and statistical concepts that students already have before the learning intervention. In this case, both the Brain-Based Learning model and

conventional learning methods likely provide equal emphasis on strengthening these basic concepts, so that the final results are similar.

Second, this indicator may take longer to show significant differences between learning methods. According to Lai et al. (2021); Syaekhu (2021), interpreting quantitative information and using it for prediction and decision-making is a complex skill and often requires repeated practice and experience. Good reasoning skills support strong interpretive skills. On the other hand, effective reasoning usually depends on accurate data interpretation. Furthermore, Sani (2021) also explained that in conducting reasoning, students' abilities are needed to analyse data and information, draw conclusions, and expand their understanding of new situations. These new situations may be previously unknown situations or more complex contexts. This means that more time and practice are needed to train students' reasoning. Both learning methods may produce similar improvements in the short term, but the more interactive and contextual Brain-Based Learning approach may show more apparent advantages in the long term.

Although the difference is insignificant, the higher N-Gain value in the experimental class indicates the potential superiority of the Brain-Based Learning Model in the long term. With its focus on learning by the way the brain naturally works, this method can be better at helping students internalize the skills of interpreting quantitative information, especially if given more time and applied consistently.

Although this third indicator shows almost the same increase in both classes, this result does not reduce the superiority of the Brain-Based Learning Model seen in the previous indicators. Implementing the Brain-Based Learning Model still shows significant potential in improving students' numeracy literacy and analytical skills, which can be a basis for educators to consider this model an effective alternative to learning.

Learning using the Brain Based Learning Model is carried out for three meetings assisted by a worksheet to facilitate students in numeracy literacy which contains tasks in various MCA questions. By including tasks in the form of questions involving the analysis of genetic data, such as family trees or genetic ratios, the instrument trains students' ability to interpret and draw conclusions from numerical information. The worksheet systematically contains learning stages by following the seven Brain Based Learning Model steps.

In the "pre-exposure" stage, the teacher presents a concept map that allows students to build a conceptual map in their minds. Using concept maps to describe the relationship between genetic concepts, such as genes, alleles, dominant, and recessive, helps students better visualize and understand the information structure. Research by Saleh & Mazlan

(2019); Maneval et al. (2011) revealed that using concept maps stimulates students' minds to continue exploring information and understand lessons better while they are involved in learning activities. Using concept maps results in deeper learning and has a major positive effect on memory, knowledge outcomes, and attitudes towards learning.

The "preparation" stage allows teachers to create curiosity or pleasure in students. For this reason, the presentation is made as interesting as possible and the material is presented concisely as basic knowledge for students. Visually appealing and informative presentations aim to pique students' curiosity and build a solid foundation of initial understanding (Prabowo et al., 2022). After the presentation, the teacher invites students to participate in a short discussion to dig deeper into the topic presented. This discussion aims to activate students' prior knowledge and connect it to new material. Through this preparation stage, it is hoped that students will be more prepared and motivated to follow the next stages of learning, so that the learning process becomes more effective and enjoyable.

In the "initiation and acquisition" stage, students can apply the basic knowledge acquired through independent work on numeracy literacy tasks. Research by Diana & Sukestiyarno (2019) revealed that independent learning can improve students' critical thinking skills. In this study, students were trained to solve simple calculation problems and make connections between concepts that have been learned. The teacher acts as a facilitator who provides guidance and feedback while students work on this independent task. The Initiation and Acquisition stage is essential for building a strong foundation in students' understanding of more complex inheritance concepts. Through a student-centered approach, learning becomes more meaningful and relevant to students.

Syntax "elaboration" provides opportunities for students to discuss in groups. To improve numeracy literacy, the tasks required students to create or present heredity data in graphs and diagrams, such as Punnett squares or family trees, helping students understand and analyse inheritance patterns visually. Students are encouraged to connect new knowledge with previous experiences or knowledge, thus creating a more holistic and contextual understanding. Learning becomes more meaningful because students memorize information and understand the material's relevance and practical application.

The "incubation and memory insertion" stage gives students a short break. Jensen (2008) explains that at this stage students are given time and space to reflect, absorb, and let new ideas or information settle in their minds. In addition, this stage can also be accompanied by games and relaxation facilitated by the teacher. In this study, the teacher played music to

create a calm atmosphere and invited students to stretch. After a short break, students were asked to repeat essential concepts from the studied material. Repetition of the material was assisted by the use of genetic flashcards, which allowed students to group examples of genetic disorders and provide explanations related to these traits. The process of grouping and explaining, which was carried out repeatedly with the help of this learning media helped students to internalize information and strengthen students' long-term memory of the material being studied better.

In the "verification and checking" stage, the teacher checked students' understanding of the material that had been studied. The teacher checked students' understanding through interactive quizzes using the Quizizz and Wordwall platforms. This platform allows students to answer questions in real-time and receive immediate feedback, which helps strengthen their understanding of the material (Prasetya, 2021; Surahmawan et al, 2021). Checking understanding through various verification methods aims to ensure that teachers can ensure that students truly understand essential concepts in the material on human heredity. In addition, this effort also contributes to improving students' numeracy literacy. 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 real-world applications.

In the "celebrations and integration" stage, involving students' emotions through fun activities is essential. Positive emotions can increase students' motivation, engagement, and long-term memory of the material studied. In this study, the awards given were in the form of praise and small prizes to recognize students' efforts and achievements. Celebrating success helps strengthen students' self-confidence and gives them a real sense of accomplishment (Hanaris, 2023; Heri, 2019), encouraging them to continue trying and studying hard.

D. Conclusion

Implementing the Brain-Based Learning Model to improve students' numeracy literacy showed positive results. This is evidenced by the N-Gain Score obtained by students in the experimental class, which was 0.74 with high criteria, while in the control class, it was 0.60 with a moderate category. The N-Gain Score obtained for each numeracy literacy indicator studied also showed better results in the class that implemented the Brain-Based Learning Model than the control class that implemented the conventional learning model. In the experimental class, the N-Gain score was 0.88, 0.75, 0.63 (criteria: high-high-moderate), while the control class had an N-Gain Score of 0.78, 0.53, 0.56 (criteria: high-moderate-

moderate). These results indicate that applying the Brain-Based Learning model in the experimental class significantly improves students' numeracy literacy. Based on these findings, further research can conduct a long-term analysis of the application of the Brain-Based Learning Model to students' numeracy literacy to understand the sustainability of the improvements achieved.

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