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Exploration of high school students' sentiments and emotions towards mathematics: Linked to learning outcomes

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Abstract

Mathematics research often focuses only on students' learning outcomes without considering their emotional aspects. This study aims to describe the tendency of students' sentiment toward mathematics in general and partially based on mathematics learning outcome groups, namely high, medium, and low. In addition, a mood analysis was conducted using Ekman's Basic Emotion classification. Data collection techniques are questionnaires and documentation. The questionnaire contains open questions about students' opinions on mathematics and closed to queries for student demographics. Documentation is done by collecting test scores from student grade books. This study used a descriptive method with data in the form of 72 comments from grade XI high school students in Bandung City, which were analyzed using the Orange Application Sentiment Analysis. The results of the study showed that (1) student sentiment was generally dominated by positive sentiment at 72.22%, (2) positive sentiment also dominated the groups of students with high, medium, and low learning outcomes, with a percentage of more than 68%, and (3) the results of the classification of emotions based on Ekman's Basic Emotion indicated that "joy" was the most dominant emotion, while "anger" had the lowest frequency of occurrence. This study provides new insights regarding students' emotional aspects in mathematics learning, which can be used to improve teaching strategies.

Keywords: high school students sentiment analysis; mathematics learning outcomes; Ekman's emotion

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I. Introduction

Mathematics is one of the most important subjects in education. As a basic science that is the foundation for understanding various other disciplines, mathematics has a strategic role in forming logical, critical, and creative thinking skills. In addition, mathematical skills are needed to solve problems in everyday life and are part of the demands of the development of science and technology. However, many research results show that students' opinions about mathematics tend to be less positive. For example, a study by Gecici and Bayirli (2022) stated that most students feel that mathematics is a difficult, boring, and scary subject. Fitroh and Sari (2018) revealed that

mathematics is a subject that is considered difficult and frightening, which decreases students' enthusiasm.

Based on research conducted after the Covid pandemic era regarding student responses to mathematics learning, which is explained by describing 1) the Acceptance of mathematics learning materials, 2) the Understanding of mathematics subject matter, and 3) The assessment of mathematics lesson material obtained by students who always answered was 0%, meaning that there were no students who were always able to accept and understand mathematics learning. The percentage of students who answered frequently was just under 4% (Sari & Harini, 2015). Another study by Gecici and Bayirli (2022) revealed that unpleasant learning experiences, monotonous learning methods, and the lack of relevance of the material to everyday life often influence students' negative impressions. This condition affects students' motivation to learn mathematics, ultimately impacting their learning outcomes.

Positive responses are very important in learning mathematics. Students will be more motivated to learn mathematics if they have a positive response because a positive response will help them understand the concept or material. Students get a stimulus that encourages the belief that they can complete the task. This stimulus makes them more relaxed and open to learning new things. This positive response also significantly improves student learning outcomes (Oktavia & Hidayati, 2022).

Students' responses to mathematics play an important role because they can affect students' learning outcomes; this is in line with the results of research conducted by Komariah and Nuruddin (2023). Mathematics learning outcomes measure the success of the mathematics learning process. According to research by Sugihartono and Kasyadi (2022), students with a positive response to mathematics will see everything positively; their moods will not change easily when facing bad circumstances.

In addition, students tend to have higher self-confidence in mastering the material, which impacts learning outcomes. Other studies conducted by Sari & Harini (2015) and Fathia et al. (2021) showed a strong relationship between a positive attitude towards mathematics and better learning outcomes. Therefore, creating a positive perception of mathematics is one of the key factors in improving the quality of mathematics learning in schools. High school students' responses to mathematics are often of concern to researchers. According to research by Sari dan Nugroho (2022), most high school students consider mathematics challenging but difficult to master. Meanwhile, research by Pasehah et al. (2020) revealed that several factors, such as the level of understanding of the material, teacher support, and the learning environment in the classroom, influence high school students' perceptions of mathematics. The results of these studies indicate variations in students' views on mathematics, which need to be studied more deeply to understand the factors that influence them.

This study aims to explore more deeply the views of high school students towards mathematics and the mood of students in Ekman's classification. In addition, this study also focuses on describing students' views based on mathematics learning outcomes, which are divided into 3 categories: high, medium, and low. Thus, the results of this study are expected to provide a comprehensive picture of students' views on mathematics, which can be used as a consideration to improve the quality of mathematics learning in schools.

II. Research Method

The method used in this study is descriptive. Descriptive methods are used to create a systematic, factual, and accurate picture or description of students' views on mathematics. Furthermore, this study also aims to determine students' negative, positive, and neutral sentiments toward mathematics. This research was conducted in several stages:

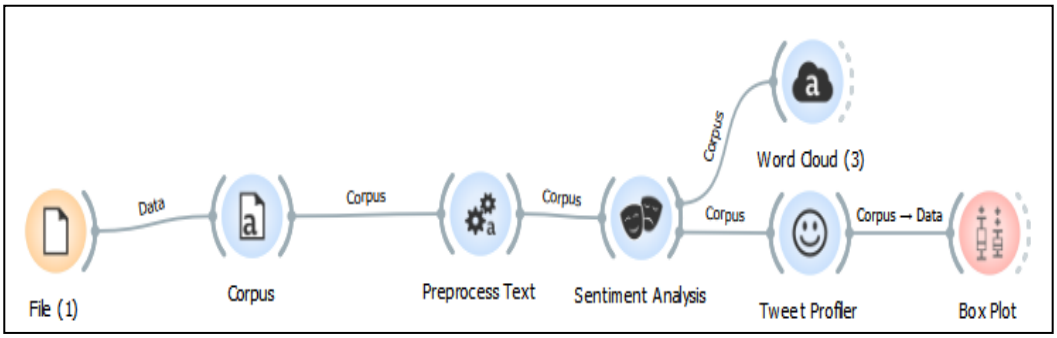
1) Data collection, using Google Forms, by asking students questions about their opinions on mathematics. The data collected were 72 opinions from 72 students. 2) Preprocessing, cleaning, case folding, tokenizing, stemming, filtering, and translating were carried out at this stage. 3) Processing, all 72 student opinions were analyzed to determine the direction of student sentiment. Sentiment analysis is natural language processing, which aims to classify data into text form. With the help of sentiment analysis, previously unstructured information can be transformed into more structured data. Student opinions can be analyzed manually one by one, but many reviews will be faster using a sentiment analysis system by performing classification techniques. The classification used in this analysis uses the sentiment analysis widget in the Orange application (Effendy, 2015; Maulana et al., 2023; Salsabila, 2022; Giang & Tran, 2021).

To be more comprehensive, this study also describes students' responses to mathematics based on mathematics learning outcomes, namely students' test scores, which are divided into 3 categories: high, medium, and low (Sari & Harini, 2015).

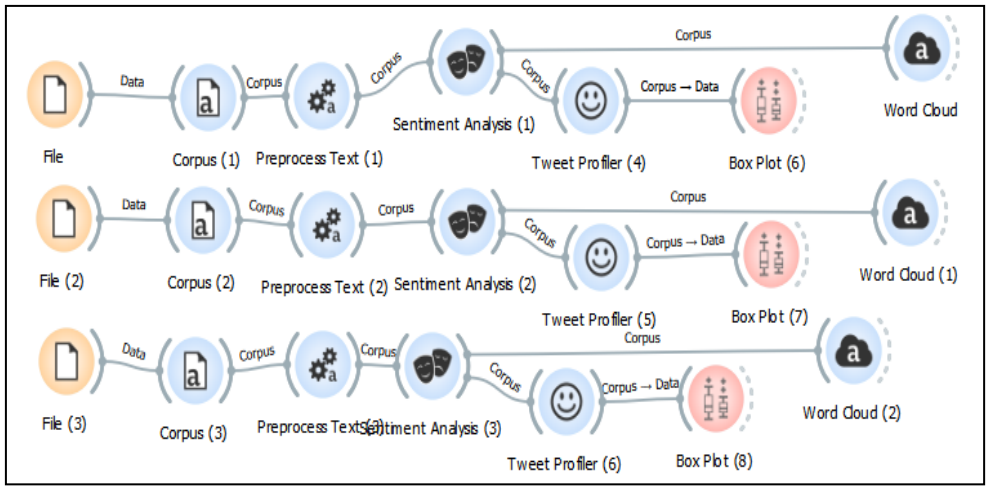
Table 1. Student learning outcomes

Category	Point	Number of Students	Percentage
High	$100 \geq x \geq 80$	32	44.44
Medium	$80 > x \geq 60$	18	25.00
Low	$60 > x \geq 0$	23	31.94

This study also analyzed students' moods about mathematics based on the comments submitted. Students' moods were determined using Ekman's Basic Emotion classification (Abidin, 2022). The widget records used in the data analysis of this study are presented as follows.



(a) Analysis of overall student sentiment and mood



(b) Analysis of student sentiment and mood based on mathematics learning outcomes

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III. Results and Discussion

In this section, the author presents the results of his research. The points presented in this section emphasize the scientific conclusions obtained rather than conveying a very detailed description of the myriad of data held.

This study collected data from student opinions on mathematics from high school students in Bandung City through Google Forms. Many data were successfully obtained, including as many as 72 opinions. Furthermore, data preprocessing was carried out starting from the stages: 1) Cleaning, namely deleting attributes in the data such as symbols, numbers, hashtags, URLs, and emojis; 2) Case folding, a process that changes letters in data, a stage to separate or break text into parts of words called tokens; 3) Stemming, a stage to take words that are considered important or remove words that are considered not to have important meaning for research.

Ketemu = happy	Bertemu sama dengan happy
Matematika itu menyenangkan, tapi memusingkan juga:)	Matematika itu menyenangkan, tetapi memusingkan juga
semoga masuk ke otak aamin	Semoga masuk ke otak. Amin
Seruuuu	Seru
senang walau tidak mengerti'	Senang walau tidak mengerti
sulit tapi jika kita bisa memecahkan rumus & soal yang di berikan, itu sangat seru dan memiliki kesan tersendiri	Sulit tetapi jika kita bisa memecahkan rumus dan soal yang di berikan, itu sangat seru dan memiliki kesan tersendiri
ingin lebih bisa dalam perhitungan belajar	Ingin lebih bisa dalam perhitungan belajar
matematika seru tapi mungkin karna saya kurang mengerti rumus2 dari smp karna kesalahan saya sendiri yang tidak mendengarkan guru membuat saya tidak terlalu senang dengan matpel tersebut. tapi jika belajar dan mengulang rumus2 nya mungkin suatu saat akan menyukainya	Matematika seru tetapi mungkin karena saya kurang mengerti rumus-rumus dari SMP karena kesalahan saya sendiri yang tidak mendengarkan guru membuat saya tidak terlalu senang dengan mata pelajaran matematika. Tetapi jika belajar dan mengulang rumus-rumus matematika mungkin suatu saat akan menyukainya

Figure 1. Preprocessing data

Figure one shows data that has gone through a cleaning stage so that symbols, URLs, hashtags, numbers, and emojis are gone. 4) Translating: Students' opinions about mathematics are translated from Indonesian to English.

Respon	Responds
Matematika sebenarnya gampang kalau mengerti rumusnya, tetapi dalam menghafal rumus tersebut yang susah	Mathematics is actually easy if you understand the formulas, but memorizing those formulas is the difficult part.
Menantang tetapi kadang seru	Challenging but sometimes fun
Matematika merupakan pelajaran yang sedikit rumit tetapi menyenangkan	Mathematics is a subject that is a bit complicated but enjoyable.
Matematika itu terlihat indah, jika yang melihatnya adalah orang yang mencintai matematika.	Mathematics looks beautiful if the one looking at it is someone who loves mathematics.
Matematika seru, tapi saat ulangan merasa sangat susah soalnya dan susah mengingat rumus	Math is fun, but during exams, the problems feel very difficult and it's hard to remember the formulas.
Seru dan menarik	Exciting and interesting
Sulit tetapi jika kita bisa memecahkan rumus dan soal yang di berikan, itu sangat seru dan memiliki kesan tersendiri	Difficult, but if we can solve the formulas and problems given, it's very exciting and leaves a unique impression.
Ingin lebih bisa dalam perhitungan belajar	Want to be better at calculations in learning.
Seru, kuncinya bermain logika dan menghafal rumus	Fun, the key is playing with logic and memorizing formulas.
Lumayan senang matematika	I quite enjoy math

Figure 2. Translating data

The sentiment analysis model in this study focuses on popularity classification, namely classifying textual comments into "positive," "negative," or "neutral." Subjective classification, namely verifying the subjectivity and objectivity of a comment or detecting irony, is not included in this analysis. The results of student sentiment classification based on their textual comments about mathematics are presented in Figure 3.

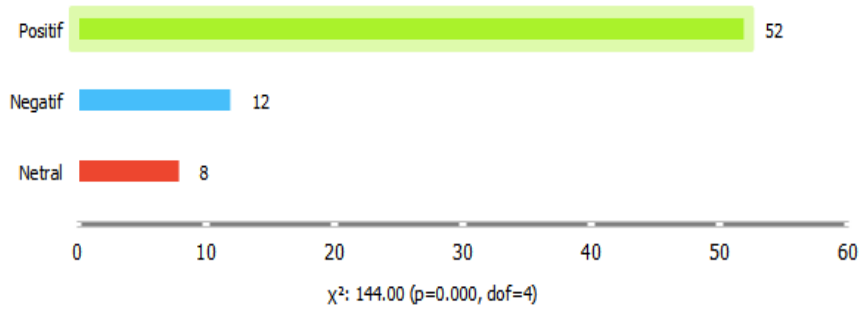

Figure 3. Student sentiment frequency

Based on the bar chart in Figure 3, it is known that 72.22% of students showed sentiments that were in the positive classification. The majority of sentiments expressed by students were positive. This was followed by negative sentiment, with a percentage of 16.67, and the least neutral sentiment, only 11.11%. The value of $\chi^2 = 144$ shows the Chi-Square test results, which measure how well the observed sentiment distribution is distributed. The large values of χ^2 and p-value = 0, 00 indicate that the sentiment distribution between groups is statistically significantly different.

This finding is more specific than that reported by Jalal (2022), who found that 50% of students perceive mathematics as a fairly difficult subject. Findings on more specific mathematics topics, such as fractions, were reported by Wardana & Damayani (2017) that students' perception achievements in fraction learning are still relatively low. Partially, the classification of sentiment based on students' mathematics learning outcomes is divided into high, medium, and low, as presented in Table 2.

Table 2. Percentage of Students' Polarity Classification on Mathematics

Group	Sentiment		
	Positive	Neutral	Negative
High	68.75	12.5	18.75
Medium	72.22	5.56	22.22
Low	78.26	13.04	8.70

Based on the table above, students with high, medium, and low learning outcomes tend to show a positive sentiment. This is in line with the results of research conducted by Rosyadi et al. (2023), who found that students' perceptions of their mathematics learning achievements towards limited face-to-face learning tend to be positive.

Likewise, the results of Karuniawati's (2021) research on the perceptions of grade XI students in mathematics learning with the topic of geometric transformation. Students' positive perceptions reached 65 percent. Further studies were conducted to see sentiment based on high school students' comments presented through word clouds, as presented in Figure 4.

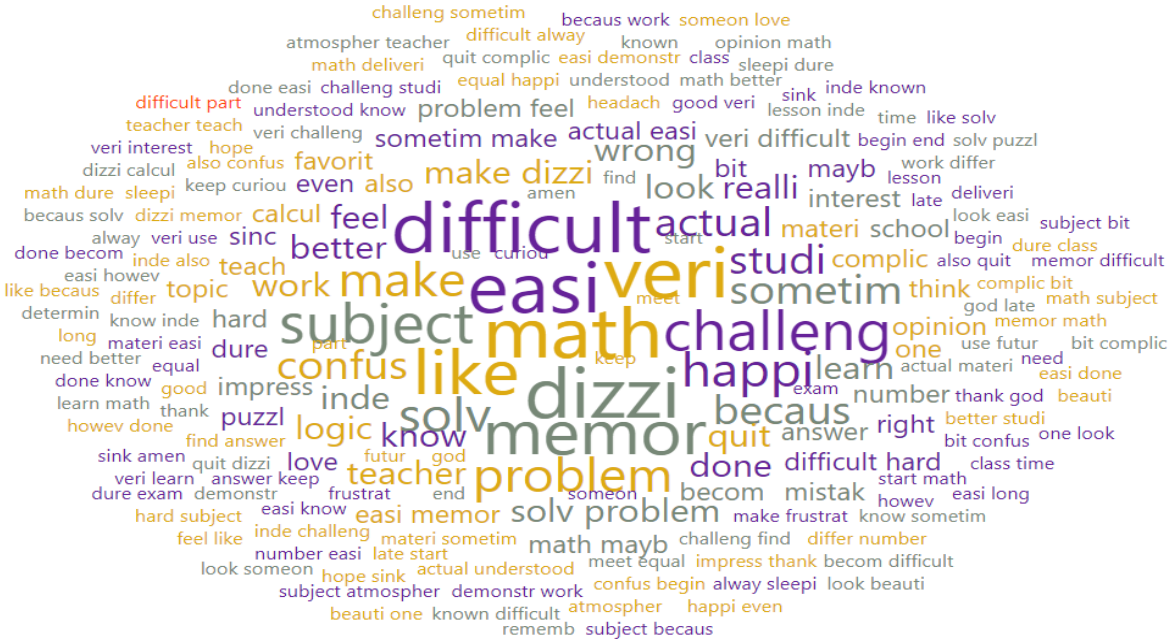

Figure 4. World cloud student sentiment towards mathematics

The dominant keywords that appear in students' textual responses about mathematics are shown by words in the word cloud with large font sizes. Based on Figure 4, it can be seen that

the most dominant keywords stated by students about mathematics are "math," "very," "easy," "like, "challenge," "subject," "make," "happy," "dizzy," "difficult," "memory," "solve," and "problem." Eight of the thirteen most dominant words that appear in the students are included in the classification of positive words that also show students' positive sentiments towards mathematics. The choice of dominant positive keywords of students, which can be interpreted as "math," "very," "easy," "like," "challenge," "subject," "make," and "happy," indicate that most students consider mathematics easy to understand, many students like mathematics, students feel challenged to learn mathematics.

Words such as "dizzy," "difficult," "memory," "solve," and "problem," which are also dominant in the keywords of students' textual comments, indicate that there are still students who think that mathematics is confusing, students find it difficult to learn mathematics, there are formulas that must be memorized, and students are unable to solve mathematical problems. However, negative words' frequency is lower than positive words. Furthermore, a partial analysis was conducted from the word cloud that appeared in each group of students based on their mathematics learning outcomes.

Figure 5. World cloud student sentiment in the high mathematics learning outcome group

Figure 5 shows a word cloud of keywords of textual comments of students in the high mathematics learning achievement group, with the dominant words appearing being "understand," "fun," "enjoy," "formula," "exit," "difficult," "actual," "memory," "easy," "like," and "solve." Seven of the eleven most dominant words appearing by students are included in the classification of positive words, showing students' positive sentiments towards mathematics. The choice of dominant positive keywords by students indicates that most students understand mathematics, feel happy with mathematics, and consider mathematics easy to understand and interesting to learn. Words such as "formula," "difficult," "memory," and "solve" are also dominant in the keywords of students' textual comments.

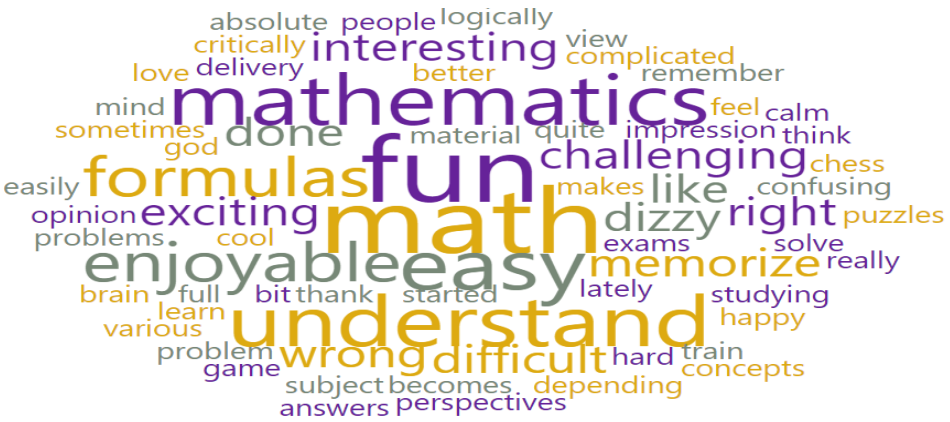

Figure 6. World cloud student sentiment in the medium mathematics learning outcome group

In Figure 6, the keywords with the highest frequency in a row are "math" 8 times and "fun" 6 times. This means that students consider mathematics a fun subject.

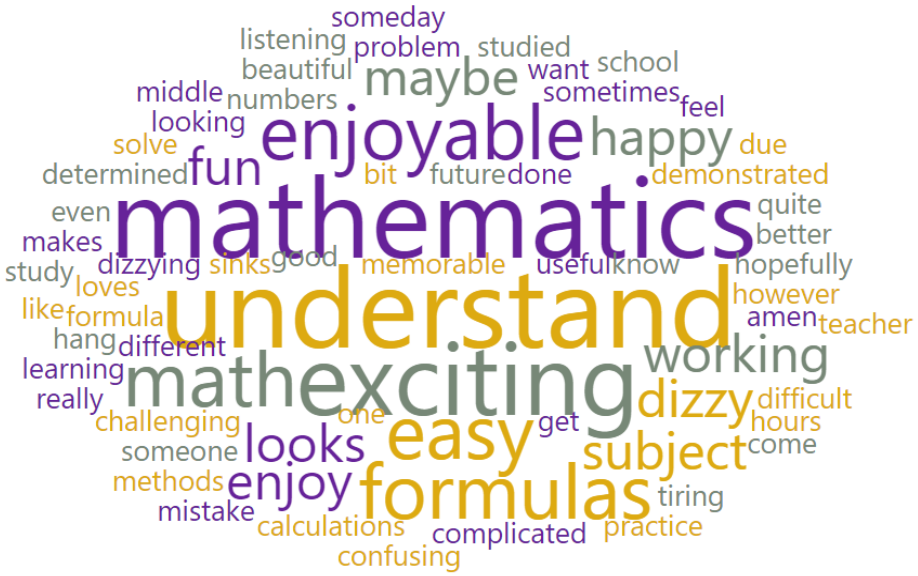

Figure 7. World cloud sentiment of students in the low mathematics learning outcome group

Figure 7 shows a word cloud of keywords of textual comments of low-group students. The dominant words that appear are "understand," "mathematics," "exciting," "easy," "enjoyable," "math," and "formula." Four of the seven most dominant words appear by students, showing positive sentiments of students toward mathematics. The words with the highest frequency of appearance are "understand" and "mathematics, " indicating that students think mathematics is easy to understand.

The next analysis is carried out to determine students' moods through class emotions classification. After conducting sentiment analysis, the sentiment analysis widget is then connected to the tweet profiler widget so that the sentiment analysis results can be used to determine students' moods. The emotions used in the tweet profiler are Ekman's Basic Emotions classification. This simple model focuses on universal basic emotions, making it easy to analyze general emotions. The emotion categories are Joy, Sadness, Anger, Fear, Disgust, and Surprise. The results of the emotion analysis are as follows:

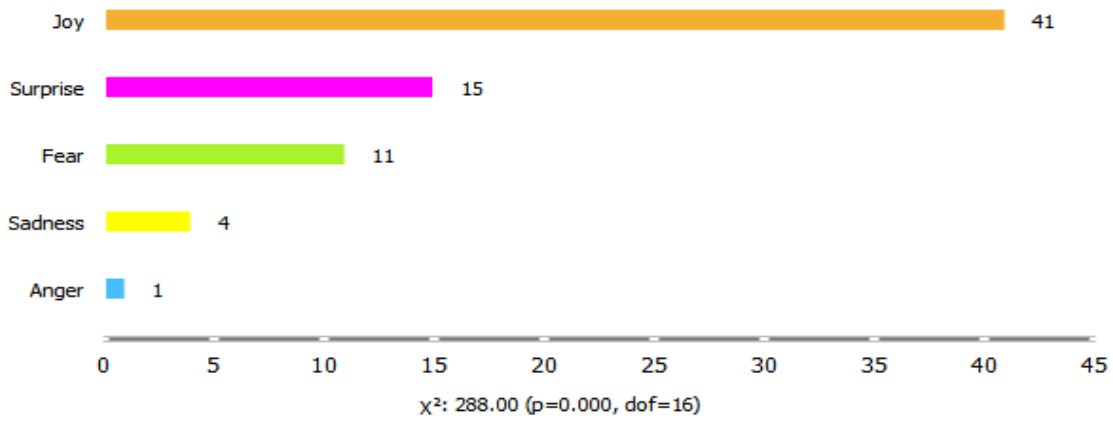

Figure 8. Analysis of student emotions

The graph of sentiment analysis results on mathematics using the Ekman method shows that the emotion "joy" dominates with the highest frequency value, which is 41. This shows that most high school students' responses contain positive sentiments and describe a happy or optimistic atmosphere. The frequency of "surprise" as many as 15 is in second place, which can indicate a significant amount of surprise or astonishment. The emotion "fear" is in third place with a frequency of 11, which indicates that only a few have feelings of fear or discomfort. Meanwhile, the emotion "sadness" has a low frequency of only 4. "Anger" only appears once, and the frequency is the lowest among other emotions, indicating that only a few students feel angry. These results illustrate that happiness is the dominant emotion in the collected responses analyzed. This indicates that the response is positive. Furthermore, the results of the emotion analysis based on the sentiment category are presented in Figure 9.

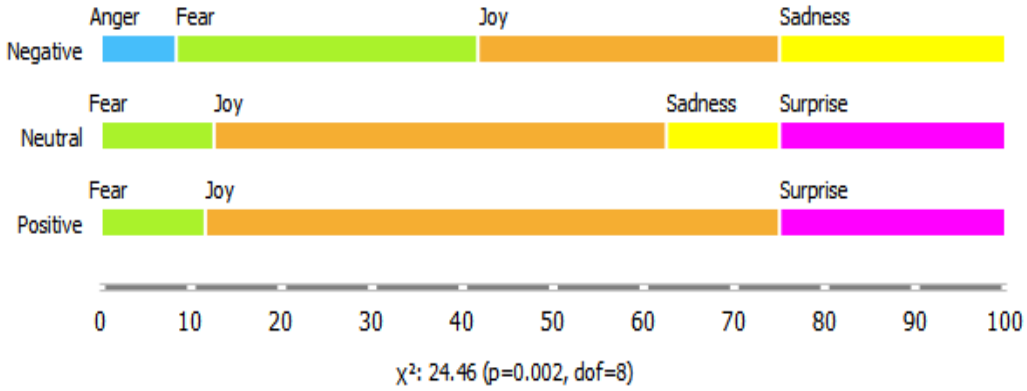

Figure 9. Classification of emotions in each type of sentiment

Based on Figure 9, fear, sadness, and joy are the most dominant emotions in the negative sentiment category. This shows that negative feelings do not entirely color students' negative responses because they show the emotion of joy at the highest frequency. However, negative , which reflects that some responses are slightly negative, but there is still a balance with other emotions are more dominant in negative sentiment. This means that feelings of fear and sadness drive students. The emotion of joy is more prominent in the neutral sentiment category, followed by surprise. At the same time, fear and sadness have a smaller portion feelings. The emotion category in positive sentiment is dominated by joy followed by

surprise emotion, while fear appears only in small frequency. This means that students' positive responses are driven by strong happiness accompanied by elements of surprise. Overall, this graph reflects that students' responses to stimuli are more dominantly positive, marked by the emergence of happiness emotions in each category. Further analysis was conducted to see the sentiment tendency in each emotion category. The results of the analysis are presented in Figure 10.

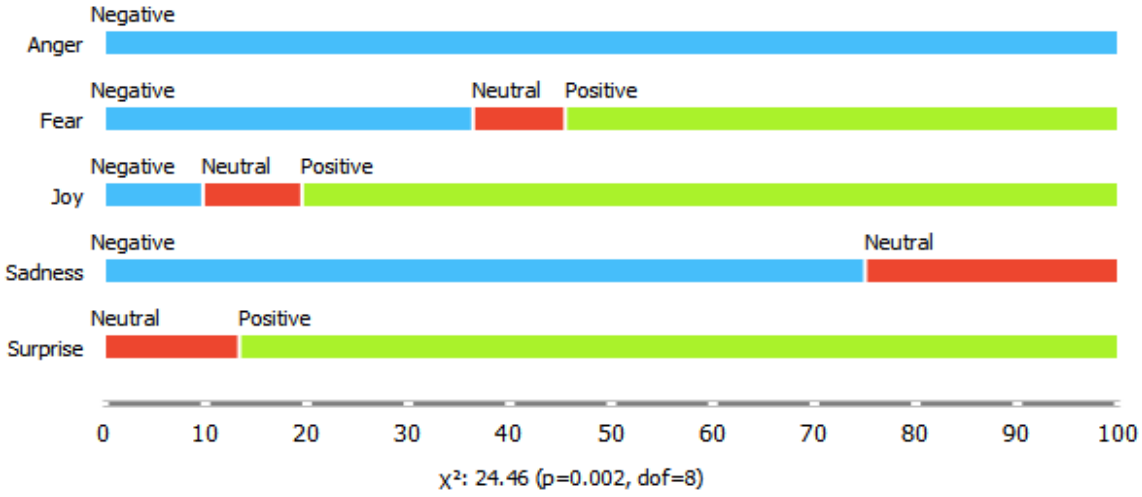

Figure 10. Sentiment tendency in each category in student comments

Based on Figure 10, negative sentiment brings up all categories of emotions, with the most dominant categories appearing as Anger, Sadness, and fear. Meanwhile, positive sentiment does not bring up emotions of anger and sadness, with the strongest emotions being surprise and joy. To bring up positive sentiment characterized by students' positive views of mathematics, it is necessary to provide students with experiences that present excitement and benefits in learning mathematics (Bernard & Sunaryo, 2020).

In addition, it is very important to condition mathematics learning to be carried out in a fun way. Mathematics teachers can adopt a more active, creative, and fun learning approach. Involving students in discussions, games, or mathematics projects relevant to everyday life can help reduce fear and increase students' interest in mathematics subjects (Lestari et al., 2024). The learning challenges must also be considered to minimize experiences that make students anxious and afraid and experience failure, resulting in students having emotions of sadness, fear, and even anger. Emphasized that teachers need to make changes and be more creative and innovative in learning in order to improve the negative nuances of mathematics learning.

Furthermore, topic modeling was conducted using textual data from students' comments on mathematics using Latent Dirichlet Allocation (LDA). This generative method represents a list of words from a data set that are similar or related to a particular topic group. Topic modeling is a text-mining technique to determine hidden topics in a collection of texts. Words that often appear together are then categorized into one topic. The limitation of the analysis into 2 main topics in this study was carried out to emphasize the findings of the direction of sentiment from textual comments expressed by students.

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Topic	Topic keywords
1	easy, math, challenging, sometimes, formulas, difficult, done, wrong, enjoy, like
2	formulas, dizzy, difficult, happy, subject, like, math, confusing, makes, quite

Figure 11. LDA topics

Based on Figure 11, topic 1 is more dominated by words that indicate that mathematics is easy and challenging; students enjoy learning mathematics and like mathematics. However, it was also found in topic one that students have difficulty understanding the formula and make mistakes when working on mathematics problems. While topic 2 is more dominated by negative words, such as difficulty making mathematical formulas, students feel dizzy and confused, even to the point that students are quiet. However, positive feelings were also found in the students, namely happiness and liking mathematics. A visual depiction of topic one is presented in Figure 12, and topic two is portrayed in Figure 13.

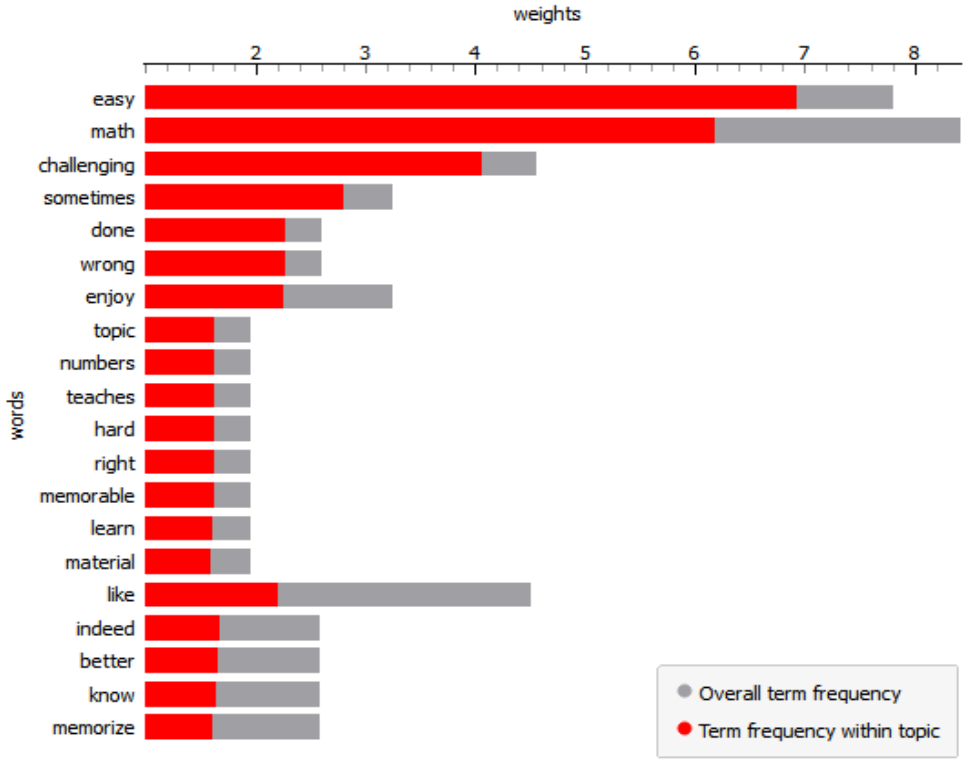

Figure 12. LDA visual topic 1

Figures 12 and 13 show an overview of the keywords of the two main topics classified based on students' textual comments about mathematics. Topic 1 starts with easy, math, challenging, and sometimes. Topic 1 is dominated by positive sentiment in mathematics, with more occurrences of positive category words in this topic.

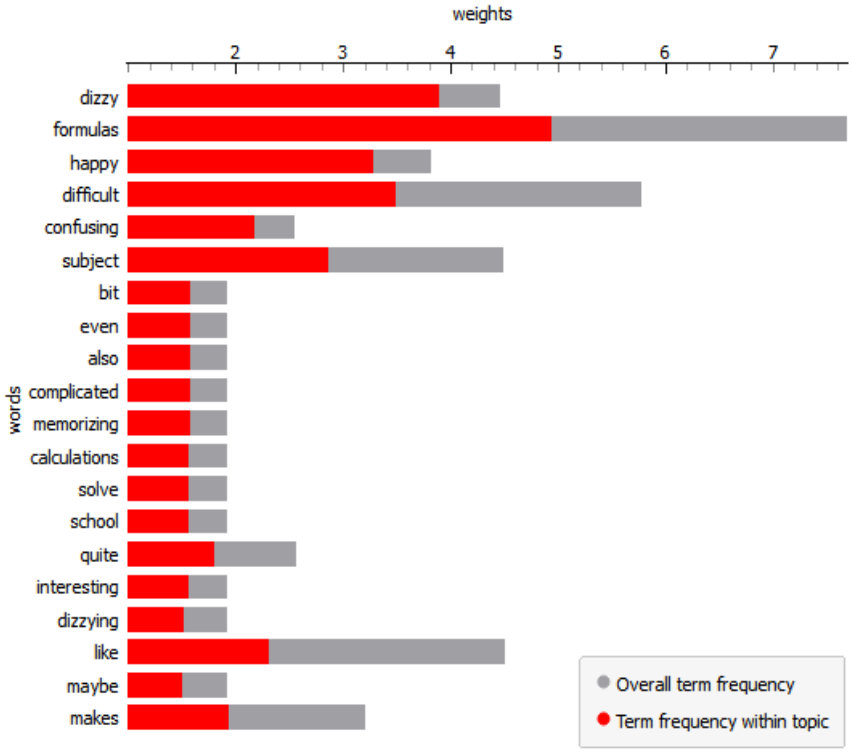

Figure 13. LDA visual topic 2

Topic 2 starts with the main keywords dizzy, formulas, difficult, happy, subject, and confusing. Four words have long bars where the four words are closely related to students' perceptions of mathematics as confusing, having many formulas, difficult to understand, and making students dizzy. However, in topic 2, the word happy also has a long bar indicating that students still have positive sentiments about mathematics. This analysis strengthens the findings of the dominant sentiments raised by high school students as positive sentiments. This is to the results of the study by Rosyadi et al. (2023), which states that students' perceptions of face-to-face mathematics learning are limited to all category groups based on their mathematics learning achievement, all of whom tend to have positive perceptions.

IV. Conclusion

Based on the results of the analysis of textual comments of high school students about mathematics, several conclusions can be drawn, namely: 1) High school students' sentiments are dominated by positive sentiments (percentage achievement of 72.22%), with the three most keywords expressed in students' opinions about mathematics "understand," "fun," "enjoy." 2) The sentiments shown by students in the high, medium, and low learning outcome groups are dominated by positive sentiments (percentage achievements of the three groups are more than or equal to 68.75%). 3) Ekman's Basic Emotions classification results show that "joy" is students' most dominant emotion in textual comments about mathematics. Meanwhile, "anger" is the emotion with the least occurrence in student comments about mathematics.

The findings of this study are expected to provide a basis for selecting research interventions and mathematics learning strategies with a positive paradigm because the results show the dominance of positive sentiments toward mathematics. Good practices in mathematics learning that make students feel challenged and at the same time feel pleasure in mathematics, as well as patterns of the emergence of other positive sentiments, should be studied more at various levels of education.

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