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The Use of A Geographically Weighted Regression Model to Analyze Predictors of The Rice Supply in Bojonegoro

Denny Nurdiansyah[1*], Mochamad Nizar Palefi Ma'ady[2], Alif Yuanita Kartini[1], Ummi Agustin Yuliana[1]

[1]Statistics Study Program, Universitas Nahdlatul Ulama Sunan Giri, Indonesia
[2]Department of Information Systems, Telkom University, Surabaya Campus, Indonesia

**Email Correspondence:* denny.nur@unugiri.ac.id

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ABSTRACT

The research goal would be to understand all potential influences on the amount of rice available within every sub-district in the Bojonegoro district. Geographically weighted regression (GWR), a technique used for this study, uses kernels: adaptive bisquare, fixed bisquare, adaptive gaussian, and fixed gaussian. The state office for food security and farming inside the Bojonegoro district provided secondary statistics for the 2018 year that included information on the population, the harvested area, the rice production, and the rice supply. The outcomes from the kernel-fixed gaussian elected model using AIC minimum criteria for the GWR model. The implementation's conclusion is due to the impact of variety in locations. The next research recommendation is a time-series spatial study of the rice problem.

1. Introduction

According to law number 18 in the 2012 year related food, food security has the understanding as a condition food met by a state to individuals, which indicated food by providing adequate quantity and quality and healthy, evenly for life productive, and sustainable (Pemerintah, 2012). Food agriculture organization (FAO) said that four aspects are the main pillar in providing food security are food availability affordability, access to food, food price stability, and food utilization (Pratama et al., 2019). Where in the pursuit of food security, food availability to the quantity and the quality of initial capital can be sufficient to ensure affordability, access, price stability, and food utilization (Susanto et al.,

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2020).

According to Food Security and Vulnerability Atlas (FSVA), the Bojonegoro district is on food security better with a score of the food index (IKP) of 81,21. In addition, the district that ranked fourth highest in east java in contributed rice production made the Bojonegoro regency one of the main producers of rice unseeded in the province of east java (Darsan & Dawud, 2021). But, the achievement that has been acquired does not guarantee that every region of the district has the resilience of good food. In fact, from 28 in Bojonegoro district, there are still 9 districts that enter into a group with the condition of food security as well as poor; they were Balen, Baureno, Gondang, Kepohbaru, Malo, Ngasem, Ngraho, Sekar, and Sumberejo (Supardi et al., 2020). This indicates that still needs to be an increase in food security, especially in terms of even distribution of food in the Bojonegoro district.

Rice as a commodity prime food has high consumption, supply needs to be maintained which could give impact on economic conditions. (Cahya et al., 2018). Based on agency data food security and agriculture Bojonegoro district (2022) mentioned the availability of rice in Bojonegoro district from 2017 to 2020 was decreasing. The availability of rice in the Bojonegoro district from 2017 until 2018 decreased by 58.526 tons. Meanwhile, in the year 2018 to 2019, the availability of rice decreased by 43.716 tons. And from 2019 to 2020, the availability of rice in the Bojonegoro district decreased by 55.281 tons. It provides information that the decline in the availability of rice is the most significant happened in 2018.

In realizing food security through the food availability of rice in the Bojonegoro district can be prefixed to know the predictor variables are anything to exert an influence upon the availability of rice. Based on research conducted by Wijoyo et al. (2020) related to the availability of rice in east java multiple linear regression modeling shows that the harvest is a significant positive impact on the availability of rice. Aside from the issue of the harvested area the availability of rice is relatively determined by the increase or decrease in rice production. This is following research by Ilyas et al. (2020) related to the availability of rice in Indonesia by the method of analysis the pathway that produces rice production had a significant impact on the availability of rice in Indonesia. Another factor that can affect the availability of rice is the population. Pujiati et al. (2020) suggested that the increasing number of people can influence food availability. Based on research conducted by Utami et al. (2019) The dynamic panel approach shows that the number of people of influence has a significant impact on the ratio of the availability of rice in east java.

Bojonegoro district is a district with several sub-district enough which is 28 in which every area has the characteristics of different. Hence, equity food rice in the Bojonegoro district is when factors affect the availability of rice in every region sub-district known. To anticipate problems that should be implemented in an analysis is the availability of rice in The Bojonegoro district by taking into consideration the influence of geographical location or by using a geographically weighted regression (GWR) model. This is important for a pattern of relationships in terms that can be observed. Nisa (2022) suggested that the analysis with a spatial approach like GWR is applicable if the data involved in the study detected the effect of spatial. Putu et al. (2020) said that affect spatial can be divided into two of them the correlation across the residual (dependencies) spatial and the diversity between the (heterogeneity spatial) testing a heterogeneity spatial involving Breusch Pagan test.

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Lu et al. (2017) defined GWR as one local technique used to form a model of relations varying in terms. The researchers before many researchers have used of GWR model research conducted by Li et al. (2019) about the urban analysis in China, Tizona et al. (2017) in modeling dengue fever in east Borneo, Cholid et al. (2019) about a case of baby stunting, Yang et al. (2018) about modeling house cost in the Dalian city in the China, Pratiwi et al. (2019) related Life Expectation Score in the central Java, dan Azies (2019) about the death score of the baby in the east Java. This study used modeling GWR that seeks to capture the impact on the availability of rice in the Bojonegoro district and sub-district.

Research is expected to help the government of Bojonegoro district determines policy in the pursuit of security and equity food for every sub-districts in Bojonegoro district. Hence, the researchers attempted to submit the title research "The Use Of A Geographically Weighted Regression Model To Analyze Predictors Of The Rice Supply In Bojonegoro".

2. Method

2.1. Research Design

In this study design, applied research is quantitative research involving the Geographically Weighted Regression (GWR) method. The weightings of used consist of four function kernels spatial, namely Adaptive Bisquare, Fixed Bisquare, Adaptive Gaussian, and Fixed Gaussian. In an implementation, the tool used is R-Studio software version 4.1.2 with the criteria for selecting the best model of the Akaike Information Criterion (AIC) minimum.

2.2. Population and Sample

The population research is the availability of rice and the predictor variable in the Bojonegoro district, while data on who would be the sample is the rice supply, harvested area, the rice production, and the population in the Bojonegoro district in 2018. The study locations will be carried out in the local food security and agriculture office in the Bojonegoro regency within four months, where research begins between October and April 2022.

2.3. Sampling Technique

The sampling technique applied is purposive sampling, where data is taken from a database adapted to needs or. research objectives. As in the implementation of a case study in this study, sample data associated with the rice supply and its predictor variables was obtained from the office of food security and agriculture in Bojonegoro district.

2.4. Research Subject

In this study, the data used is secondary data originating from the food and agriculture Bojonegoro district of data and data regarding the rice supply and factors that influence it in every region in Bojonegoro district 2018 year totaling 28 unit observation or in a ratio measurement. The variables contained in this study are presented in Table 1 as follows:

Table 1. Definition of Research Variables

Variable	Variable Name	Description
Respon	The Rice Supply (ton)	The number of reserved rice at each sub-

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Variable	Variable Name	Description
	(Y)	district is under the supervision dept of agriculture and food security in the Bojonegoro district.
Predictor	The Harvested Area (Ha) (X_1)	The number of reserved rice at each sub-district is under the supervision dept of agriculture and food security in the Bojonegoro district.
	The Rice Production (ton) (X_2)	Agricultural products from commodities rice in each sub-district in the Bojonegoro district.
	The Population (head) (X_3)	The number of people who settled in every district in the Bojonegoro district.

This research used the rice supply variable with predictor variables like harvested area, rice production, and population. In addition, this research also involved two variables relating to the geographical variable u are defined as latitude and v as longitude.

2.5. Technique of Data Analysis

The analysis that there are procedures in this research will be used to analyze variable predictor that affects the rice supply in Bojonegoro by considering the influence of spatial uses in the GWR method using R-Studio software. The following step is to analyze the data used in this research:

1. Performing data modeling starts with entering observation data.
2. Undertook the identification of data characteristics on the rice supply and variable predictor influence.
3. Testing for spatial effects which in this paper only tests for spatial heterogeneity using the Breusch Pagan statistical test. If the spatial heterogeneity effect is not found, the global regression model or multiple linear regression model is used in step 4; If the spatial heterogeneity effect is met, the local regression model or GWR model is used in step 6.
4. Do modeling the rice supply with the multiple linear regression (MLR) model with the following procedure:
   a. Detect multicollinearity symptoms.
   b. Perform multiple linear regression model estimation.
   c. Performing parameter significance testing with F test and t test.
   d. Testing the assumptions of normality, heteroscedasticity, and autocorrelation; then if the test passes then proceed to step 7, but if it is not fulfilled then continue to step 5.
5. Do modeling the rice supply with the multiple linear regression (MLR) model based bootstrapping with the following procedure::
   a. Specifying a bootstrap sample of usually 100.
   b. Taking a repeated sample by replacing 100 observations from the sample data set, run the regression model and save the coefficients obtained. In the end, we will have 100 pairs of coefficients or parameters of the regression model.
   c. Creating confidence intervals for each parameter of the regression model.

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d. Checking the significance of model parameters is done with parameters that are significant if they are within the confidence interval then continue to step 7.

6. Do modeling the rice supply with the geographically weighted regression (GWR) model the following:
   a. Do a reckoning of the Euclidean distances between the observations.
   b. Do the bandwidth levels by considering the minimum on cross-validation (CV).
   c. Choosing the best function of weight kernels to vote by considering the AIC (Akaike information criterion).
   d. Doing the calculating value and estimation of the GWR model parameters with the kernels' functioning.
   e. Testing the method to see the contrast between MLR and GWR methods.
   f. Testing the partial significance of this fact to parameter model GWR with the best weight functions.
7. Present the output of the regression model and measuring goodness-of-fit measures.
8. Provide an interpretation of the regression model regarding the relationship patterns of the research variables that contribute to food security and agriculture in Bojonegoro Regency.

2.6. Flow Chart

The procedure of the analysis contained in the research is described in the form of a flow chart like Figure 1, following in:

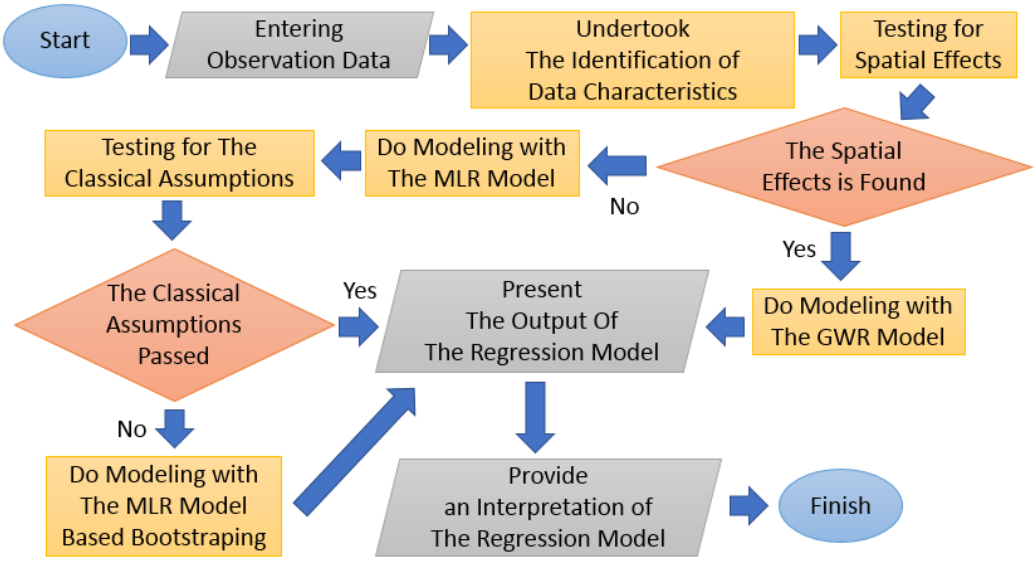

Figure 1. Flow Chart for The Procedure of Data Analysis.

3. Results and Discussion

3.1. Results

Before conducting more advanced analysis, statistical descriptive first to see how a general picture of data from each variable would check. The amount of data the observations that have been involved in this study, as many as 28 observations where data those with extensive data harvested area (X_1), the rice production

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(X_2), the population (X_3), and the rice supply (Y) on any sub-districts in the Bojonegoro district in 2018. Table 2 served as a summary of the findings and descriptive statistics of any variable research.

Table 2. Descriptive Statistics of The Rice Supply Data in Bojonegoro District

	Min	Median	Mean	Max	Variance
Y	2,223	13,744	17,249	42,029	142,439,724
X_1	687	4,244	5,328	12,981	13,588,551
X_2	0	20,799	29,663	74,326	509,141,512
X_3	11,451	45,595	46,836	85,972	483,543,649

Table 2 it can be seen information related information on the descriptive statistics variable research of the lowest value (minimum), the middle value (median), the average (mean), the highest (maximum), and the variance. Next, Figure 2 will be given a picture in visual in a map thematic to see the scatter data on the rice supply in the Bojonegoro district, where the area division is classified into five categories.

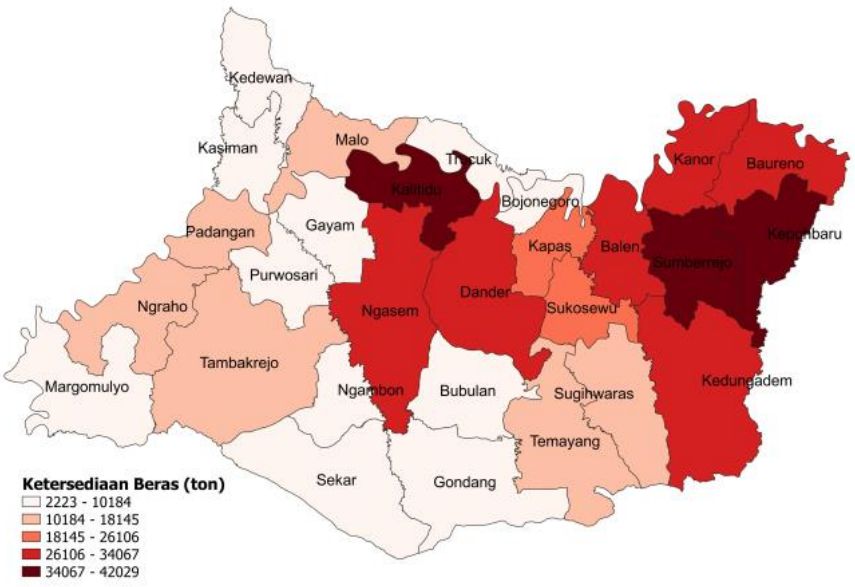

Figure 2. The scatter data on the rice supply in the Bojonegoro district

After obtaining the results statistics descriptive of variables, research next represented the result of spatial effect testing was first. The spatial effects which in this paper only tests for spatial heterogeneity using the Breusch Pagan statistical test.

Table 3. The results of spatial heterogeneity test

Breusch Pagan test	Statistic	p-value
	13.655	0.0034*

*The significance for α by 5%.

Based on the results of testing heterogeneity spatial in Table 3, the benchmark for consideration in decision-making was valued p-value ≤ α but failed to receive H_0, or it can say that variant in every region is heterogeneous.

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So, data will be processing rice availability in the Bojonegoro district with the GWR.

Following in Table 4 served the value of an optimum bandwidth, each with its function of the kernel of the results with a method of GWR modeling.

Table 4. The optimum bandwidth on each function kernels

Function Kernels	Value of CV Minimum	Bandwidth
Fixed Gaussian	12.4100	0.0571
Fixed Bisquare	13.9995	0.2236
Adaptive Gaussian	22.6543	0.2143
Adaptive Bisquare	23.3796	0.8571

After obtaining the optimum bandwidth value in each kernel function, the next step that you can do is to determine the weight kernels function best by taking into account the Akaike information criterion (AIC) in each kernel function. Following Table 5 will be presented the AIC value on each kernel function.

Table 5. The AIC value in each kernel function

Model	Kernel Function	AIC
GWR	Fixed Gaussian	-22.9673
GWR	Fixed Bisquare	17.3486
GWR	Adaptive Gaussian	27.0710
GWR	Adaptive Bisquare	26.9919

Based on the results outlined in Table 5, obtained information was that the kernel function has the best function kernels in that it has a value of the AIC minimum.

After obtaining the best kernel function, the tested conformity model was to see if the GWR model is better than a linear regression or global regression model. Table 13 will be displayed the result of testing conformity GWR model.

Table 6. The results of the conformity GWR model

Model	df	SSE	F-statistic	P-value
MLR	3.5894	8.9766		
GWR	24	0.3379	26.569	0.0048*

*The significance for α by 5%.

From Table 12 known p-value is 0.0048. A standard significance of 5 % stated that the p-value ≤ a with α by 5%, which we can conclude failed to receive H0, meaning there is a significant difference between the global regression and GWR.

From the implementation of the GWR model obtained, the predictor variables significantly influence the availability of rice at each sub-districts, and the form of modeling where from test results significance in partial 28 equation produce different models the next one represented into Table 7.

Table 7. The GWR model in each sub-district.

Sub-District	Significant Predictor	GWR model
Balen	-	$\hat{y} = 0.5608 + 0.7859X_1 + 0.2968X_2 + 0.0191X_3$
Baureno	-	$\hat{y} = 2.9107 + 1.0454X_1 + 0.2102X_2 – 0.2543X_3$

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Sub-District	Significant Predictor	GWR model
Bojonegoro	X_2	$\hat{y} = 0.7575 - 2.5595X_1 + 0.7220X_2{*}+0.0548X_3$
Bubulan	X_1	$\hat{y} = -0.0804 + 2.8918X_1{*} - 0.0464X_2+0.0912X_3$
Dander	-	$\hat{y} = 0.2490 + 1.5345X_1 + 0.1985X_2 + 0.0418X_3$
Gayam	X_2	$\hat{y} = 0.2075 + 0.1723X_1 + 0.6571X_2{*} - 0.0577X_3$
Gondang	-	$\hat{y} = -0.0067 + 3.1918X_1 +0.0003X_2+0.0061X_3$
Kalitidu	X_2	$\hat{y} = -0.0381 - 0.6358X_1 + 0.7536X_2{*}+0.0515X_3$
Kanor	-	$\hat{y} = 2.6753 + 0.8242X_1 + 0.2601X_2 - 0.2319X_3$
Kapas	X_2	$\hat{y} = 0.8217 - 2.5668X_1 + 0.7290X_2{*}+0.0548X_3$
Kasiman	X_3	$\hat{y} = -0.4618 + 0.7769X_1 - 0.0557X_2+0.4206X_3{*}$
Kedewan	X_3	$\hat{y} = -2.3899 + 4.4150X_1 - 0.5907X_2+0.9667X_3{*}$
Kedungadem	-	$\hat{y} = -0.0170 + 2.7520X_1 +0.0719X_2+0.0133X_3$
Kepohbaru	-	$\hat{y} = 1.3495 + 0.0955X_1 + 0.4721X_2 - 0.1083X_3$
Malo	X_2. X_3	$\hat{y} = -1.3146 - 3.3093X_1 + 0.7642X_2{*}+0.7330X_3{*}$
Margomulyo	-	$\hat{y} = 0.0423 + 1.6472X_1 + 0.1764X_2 + 0.0486X_3$
Ngambon	X_1	$\hat{y} = 0.0250 + 3.0947X_1{*} + 0.0429X_2 - 0.0128X_3$
Ngasem	X_2. X_3	$\hat{y} = 0.3262 + 2.1385X_1 + 0.3735X_2{*}-0.1609X_3{*}$
Ngraho	-	$\hat{y} = 0.2063 - 1.0776X_1 + 0.4314X_2 + 0.1383X_3$
Padangan	-	$\hat{y} = 0.1359 + 1.4341X_1 - 0.0354X_2 + 0.1689X_3$
Purwosari	-	$\hat{y} = -0.1655 + 0.6277X_1 + 0.2697X_2 + 0.2003X_3$
Sekar	-	$\hat{y} = 0.0005 + 3.2364X_1 + 0.0008X_2 - 0.0003X_3$
Sugihwaras	-	$\hat{y} = -0.1164 + 1.6701X_1 + 0.1737X_2 + 0.0893X_3$
Sukosewu	-	$\hat{y} = 0.0963 - 0.0098X_1 + 0.3797X_2 + 0.1156X_3$
Sumberrejo	-	$\hat{y} = 0.4515 + 1.2956X_1 + 0.2641X_2 + 0.0067X_3$
Tambakrejo	X_1	$\hat{y} = 0.0130 + 3.1586X_1{*} + 0.0082X_2 + 0.0015X_3$
Temayang	-	$\hat{y} = -0.0836 + 1.7568X_1 + 0.1412X_2 + 0.0896X_3$
Trucuk	X_2. X_3	$\hat{y} = -0.4169 - 0.5481X_1 + 0.7493X_2{*}+0.1305X_3{*}$

*The significance for α by 5%.

Next, based on the results in Table 7, the variables' significant impact on the availability of rice in each sub-districts in district 5 is grouped into a group that has the same criteria that visualization in Figure 3.

Figure 3. Grouping sub-district in Bojonegoro district based on the results of the partial test with the GWR method

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3.2. Discussion

Table 2 shows that value variants in each variable observation have great value, meaning that data from each variable is quite varied. In the meantime, in Figure 1 can be seen that distribution points the availability of rice in the Bojonegoro district is very low, by category low, are, high, and very high in the area did not cluster a particular area.

Based on Table 3, the test results involving heterogeneity spatial with the Breusch-Pagan test showed that a variant in every region is heterogeneous. So that could go forward data processing the availability of rice in the Bojonegoro regency with a method of geographically weighted regression (GWR).

As shown in Table 4, the implementation GWR model involving four kernels obtained the value of the bandwidth optimum for each kernel function. The value of the bandwidth optimum was determined by looking at numbers cross-validation (CV) minimum. Next, based on Table 5 obtained information, the model of best criteria is a GWR model involving the function of the fixed gaussian kernel function due to has Akaike information criterion (AIC) minimum. Where the bandwidth obtained with the process of the fixed gaussian kernel is 0,0571 who has the sense that a point included in a radius of 0,0571 has been designated the influence of optimal parameter in developing model at every location.

Table 6 indicates the exam results conformity model intended to see if the GWR model involving the function of the fixed gaussian kernel is better than a linear regression or global regression model. Where obtained test results were the conclusion that there is a significant difference between global regression models and GWR has the sense that the GWR model, by involving the function of the fixed gaussian kernel better if compared with global regression models.

Next, based on the parameters, partial testing in Table 7 obtained 28 different equation models different in the model of the rice supply at every area in the Bojonegoro district. Where from the testing in partially formed five groups by the same criteria just in Figure 2, which provides information that group 1 with variable significant broad crop consisting of three sub-district (Bubulan, Ngambon, and Tambakrejo), Group 2 has significant rice production consisting of 4 sub-districts (Gayam, Kalitidu, and Kapas), group 3 has a considerable population comprised of 2 sub-districts (Kasiman and Kedewan), group 4 has significant rice production and a population consisting of 3 sub-districts (Malo, Ngasem, and Trucuk), as well as on every team in which every predictor variable did not influence significantly consisting of 16 sub-districts (Balen, Baureno, Dander, Gondang, Kanor, Kedungadem, Kepohbaru, Margomulyo, Ngraho, Padangan, Purwosari, Sekar, Sugihwaras, Sukosewu, Sumberrejo, and Temayang).

4. Conclusions

Based on the minimum Akaike information criterion (AIC) value, the results of the GWR model with fixed gaussian kernel function weighting is a model with a measure for the best model in rice availability in Bojonegoro Regency. From The GWR modeling, the rice supply in each sub-district is influenced by different factors due to the diversity effect.

The suggestion given in this research is to use observation data from the last few years so that it can provide more information about the current rice

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supply in Bojonegoro Regency. The suggested method is a time series spatial study. Future research can add other predictor variables such as rice consumption, rice import volume, and others.

Author Contributions

The first and second authors contribute to the creation of scientific articles, as well as managing papers for the publication process. The third author contributes to the processing and analysis of research data. The fourth author contributed to data collection.

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Declaration of Competing Interest

The authors report that there are no potential conflicts of interest in the preparation of this scientific article.

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Exploring Student Algebraic Thinking to Solve TIMSS Problems in Terms of Accommodator Learning Styles

Lutfiyya Fajar Zahiroh[1], Masduki Masduki[1*]

[1]Department of Mathematics Education, University of Muhammadiyah Surakarta, Surakarta, Indonesia

**Email Correspondence:* masduki@ums.ac.id

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ABSTRACT

This study aims to explore students' algebraic thinking skills in solving Trends International Mathematics and Science Study (TIMSS) problems in terms of accommodator learning styles. The research design used is a case study with a qualitative analysis approach. The results showed that accommodating subjects were able to meet the indicators of algebraic thinking, namely generalization, abstraction, analytical thinking, dynamic thinking, and modeling. However, the lack of accuracy in performing calculation operations causes the answers obtained by the subject to be less precise on abstraction, analytical thinking, and dynamic thinking problems. The characteristics of subjects with accommodator learning styles who are more likely to use intuition in solving problems influence students' ability to solve problems related to algebraic thinking.

1. Introduction

Algebraic thinking is the process of reasoning algebraic symbols on the relationship between a quantity and something unknown and is related to abstraction and the development of variable concepts (Amerom, 2002). Algebraic thinking can also be interpreted as the ability to form conclusions in general, change or modify, and understand thoroughly the concept and solve algebra problems involving numbers or symbols with the aim of making it easier for students to learn algebra at school (Kieran, 2004). Carraher et al., (2006) describes algebraic thinking as a system of thinking that involves numbers and high-level reasoning skills to form conclusions aimed at creating relationships between algebraic concepts and algebraic problems. Based on some of these

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understandings, it can be concluded that algebraic thinking is a process of reasoning algebraic symbols, thinking involving numbers and the ability to form conclusions. Therefore, algebraic thinking is a thinking process that involves reasoning algebraic symbols or numbers to form conclusions in general, changing or modifying those aimed at solving algebraic problems.

Several experts have investigated the components associated with algebraic thinking. Lew (2004) states that the components of algebraic thinking include generalization, abstraction, analytical thinking, dynamic thinking, modeling and organizing. At the generalization stage, students are expected to be able to explain patterns or formulate general symbols. Then, at the abstraction stage, students are expected to be able to analyze mathematical objects and relationships based on generalizations. At the stage of analytical thinking, students are expected to solve problems to determine unknown quantities. Furthermore, at the dynamic thinking stage, students are expected to be able to manipulate mathematical objects. At the modeling stage, students are expected to represent problems in the form of mathematical models. Then, at the organizing stage, students are expected to be able to use logical strategies to solve algebra problems. Kieran (2004) and Istikomah et al., (2020) states that algebraic thinking has three components that students must have: generational, transformational and global meta-level. Generational can be defined as an algebraic object expressed in an equation. Transformation can be defined as a change in the form of an expression or equation based on rules. Then, the global meta-level is an ability that involves algebra in solving a problem related to algebra or not. In this study, researchers used the formulation of the components of algebraic thinking according to Lew (2004) to investigate students' algebraic thinking skills. Formulation of the components of algebraic thinking from Lew (2004) more details making it easier for researchers to reveal students' algebraic thinking skills.

Patton and Santos (2012) states that algebraic thinking is a thinking ability that requires students to be able to operate a quantity that in reality is unknown. In this case, algebraic thinking can encourage students to think logically to solve algebra problems in learning mathematics and everyday life problems. Nurhayati et al., (2017) states that algebraic thinking is a logical way of thinking that is needed in learning mathematics to solve problems related to algebra. Then, algebraic thinking is an indispensable ability for students to explore solving mathematical problems involving algebraic concepts such as geometric transformation materials, matrices, linear equations and inequalities, linear programs, algebra (Hardianti et al., 2020). Algebraic thinking is also related to the ability to think critically which is one of the indispensable thinking skills in the 21st century which requires every student to have skills in the learning process such as 4C skills namely Communication, Critical Thinking, Collaboration, and Creativity (Mutohhari et al., 2021). Through educators, 4C skills can be used to prepare learners who are responsive and able to face global competition (PeranginAngin et al., 2021). By having the ability to think algebraically, students are trained to think critically, creatively, reason and think abstractly, so that students are able to become problem solvers reliably.

Students' algebraic thinking ability in solving problems is influenced by several factors, one of which is learning style. One learning style that involves student experience is Kolb's learning style. Kolb and Kolb (2005) classifies four types of learning styles which include accommodator, assimilator, diverger and

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converter learning styles. Gooden et al., (2009) explained that the accommodator type of learning style is a combination of Concrete Experience (CE) and Active Experiment (AE), namely the ability to engage in new experiences, depend on others for information, and easily act according to intuition. Then, Pratiwi et al., (2011) revealing the type of assimilator learning style is a combination of Abstract Conceptualization (AC) and Reflective Observation (RO), namely the ability to create various theoretical models, inductive reasoning, and combine various information that has been obtained. Next, Richmond and Cummings (2005) explained that the divergent type of learning style combines the ability of Concrete Experience (CE) and Reflective Observation (RO), which is to view concrete situations through various perspectives, imaginative and have a good ability to process information into alternative ideas. As for Daimaturrohmatin and Rufiana (2019) states that the type of converter learning style is a combination of Abstract Conceptualization (AC) and Active Experimentation (AE), namely the tendency to be able to make decisions and solve problems efficiently and can find practical from an idea or idea.

Research on algebraic thinking has been done before by several researchers. Indraswari et al., (2018) researching the algebraic reasoning ability of high school students in solving algebra problems based on learning styles shows that on generalization indicators students with visual and kinesthetic learning styles determine the general rules of equations used to solve problems using algebraic symbols. While students with auditorial learning styles use a sentence. Then, Azahra and Masriyah (2022) the study of high school students' algebraic thinking skills in solving algebraic problems in terms of visual, auditory and kinesthetic learning styles showed that the three learning style subjects performed six algebraic thinking indicators from the stages of generalization, abstraction, analytical thinking, dynamic thinking, modeling and organization. Students with visual and kinesthetic learning styles determine the general rules of equations used to solve problems using algebraic symbols. While students with auditorial learning styles express explanations verbally (words).

Next, Amri and Arsid (2022) the research on the creative thinking ability of high school students in terms of learning styles in algebra material shows that students with visual learning styles are at the third level of creative thinking ability because they can meet the indicators of fluency and flexibility. This also occurs in students with kinesthetic learning styles but there is a lack of accuracy. While students with auditorial learning styles are at the first level of creative thinking ability because they are only able to meet the fluency indicator. Harti and Agoestanto (2019) examining the algebraic thinking skills of high school students in terms of critical thinking skills in problem-based learning showed that students' critical thinking and algebraic thinking skills in problem-based learning reached minimal criteria. Students belonging to the high critical thinking group have high global generational and meta-level abilities, while medium to high transformational abilities. Then, students in the middle critical thinking group have generational, transformational and meta-level global abilities tend to be moderate. Furthermore, students belonging to the low critical thinking group have low generational and transformational abilities, while global meta-level abilities are low to moderate.

The studies that have been done do not appear to examine the relationship between Kolb's learning style and students' algebraic thinking skills. In other

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words, there has been no research that discusses specifically about students' algebraic thinking skills in solving math problems in terms of Kolb's learning style. Based on this description, the research question that arises is how students' algebraic thinking skills in solving mathematical problems are viewed from the accommodator learning style. Therefore, this study aims to reveal students' algebraic thinking skills in solving mathematical problems in terms of accommodator learning styles. The results of this study are useful for teachers to design learning strategies and problems that can develop students' algebraic thinking skills in accordance with accommodator learning styles.

2. Method

The research design used is a case study with a qualitative approach. This study involved 64 grade VIII students in one of the private junior high schools in Surakarta, Central Java, Indonesia. The instruments used in this study were algebraic thinking test questions, KLSI questionnaires, and interview guidelines. The components or indicators of algebraic thinking to be analyzed consist of 5 components, namely generalization, abstraction, analytical thinking, dynamic thinking and modeling. Researchers compiled ten questions adopted from the TIMSS questions for grade VIII (Provasnik, 2013). Each component of algebraic thinking according to (Lew, 2004) are represented by two questions. Before being used, the questions were first validated by 3 mathematics learning experts. Based on the validation results, the researcher set eight questions by eliminating 1 question in the generalization and dynamic thinking components. Next, researchers conducted a test of questions on 20 students who were not research subjects. Based on the results of the trial, researchers made improvements to the problems used for data collection. Then, to classify students' learning styles, researchers used the KLSI instrument (Kolb and Kolb, 2005). Furthermore, to uncover students' algebraic thought processes in depth, researchers used interview guidelines. Before use, interview guidelines are first validated by expert validators.

In this study, five questions were analyzed consisting of 1 question each on the components of generalization, abstraction, analytical thinking, dynamic thinking and modeling. The questions to be analyzed are presented in Table 1. Generalization problems aim to investigate students' ability to solve problems using number patterns or number series. Abstraction problems aim to investigate students' ability to use symbols related to mathematical concepts and properties. Then, analytical thinking problems aim to reveal students' ability to determine the value of an equation and inequality problem. Furthermore, dynamic thinking problems aim to reveal students' ability to solve problems using direct proportionality. Meanwhile, modeling problems aim to investigate students' ability to represent problems into mathematical models.

Table 1. Examples of Algebraic Thinking Test Questions

No	Question Type	Question
1	Generalization	Several pieces of tiles are arranged into a square shape as follows: The 3 × 3 square shape consists of 8 Gray tiles and 1 Black tile. The 4 × 4 square shape consists of 12 Gray tiles and 4 Black tiles. The table below shows the number of tiles arranged into square shapes of various sizes. Complete the

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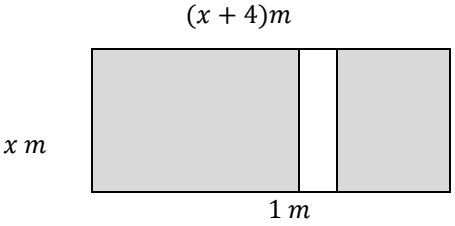
No	Question Type	Question
		table below to find out the number of tile pieces that make up the square!

Shape	Number of Black Tiles	Number of Gray Tiles	Total Tiles
3 × 3	1	8	9
4 × 4	4	12	16
5 × 5	9	16	25
6 × 6	16		
7 × 7	25		

2 Abstraction — Take a look at the rectangle image below!



If the width of the unshaded area is 1m, then determine the equation showing the area of the shaded area (m²)!

3 Analytical Thinking — Solve the following inequality!

$9x - 6 < 4x + 4$

4 Dynamic Thinking — Take a look at the table below!

Bush Height (cm)	Shadow Length (cm)
20	16
40	32
60	48
80	64

The table above shows the shadow lengths of four bushes of different heights at 10 a.m. If the height of the bush is 50 cm, then determine the length of the shadow of the bush!

5 Modeling — The table below shows the temperature at various times of the day!

Time	06.00	09.00	12.00	15.00	18.00
Temperature (°C)	12	17	14	18	15

Draw a graph showing the corresponding information in the table above.

Furthermore, based on the results of the KLSI questionnaire algebra thinking test to 64 students, recapitulation data was obtained as presented in Table 2.

Table 2. Recapitulation of Student Learning Styles

No	Learning Style	Number of Students
1	Accommodator	32
2	Assimilators	6
3	Diverger	7
4	Converters	19

Based on the data in Table 2, most subjects have accommodator learning style characteristics. Therefore, in this paper the researcher focuses on the

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analysis of subjects who have an accommodator learning style. Researchers selected 2 subjects in the accommodator learning style category with the criteria of having relatively similar algebraic thinking test scores. To facilitate data analysis, both subjects were assigned S1 and S2 codes.

Data analysis is carried out by first conducting document analysis, namely analysis of students' answers in solving algebraic thinking test questions. The focus of the analysis is on the steps of solving the problem and the strategy used to solve the problem. In document analysis, researchers use assessment rubrics as presented in Table 3.

Table 3. Assessment Rubric

No	Judging Criteria	Score
1	Incorrect solution steps or unable to answer the question	0
2	The solution step is partially correct and the answer is incorrect.	1
3	Correct solution steps but incorrect answers.	2
4	Solution steps and answers are correct	3

Furthermore, researchers conducted interviews to reveal more deeply the steps and strategies of solving students in solving algebraic thinking test questions. The interview is intended to validate the student's answers in the document i.e. the student's answer sheet.

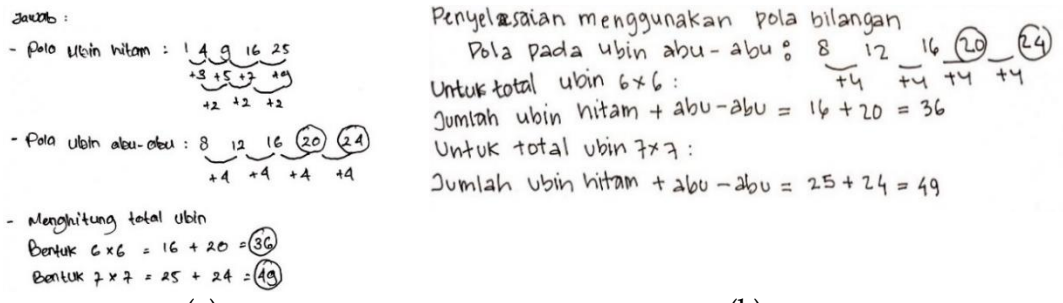
3. Results and Discussion

3.1 Results

The following are presented the results of document analysis and interviews of both subjects with accommodator learning styles in solving generalization problems, abstractions, analytical thinking, dynamic thinking, and modeling.

3.1.1 Analysis Question Number 1

Question number 1 is used to investigate students' generalization ability, which is a process that aims to find a pattern or shape in a given set of objects. Based on the test results, S1 and S2 subjects can solve questions using the right solving steps and get the right answers as well. The subject's answer in solving question number 1 is presented in the picture below.



(a) (b)

Figure 1. Answer to question number 1: (a) S1, (b) S2

Based on Figure 1, S1 and S2 solve the generalization problem in almost the same way. S1 first determines the difference in black tile patterns on each square shape, which is 3, 5, 7, and 9. Then, S1 determines the difference between gray

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tiles on 3 x 3, 4 x 4, and 5 x 5 square shapes which is 4. Based on the pattern obtained, S1 can determine the number of gray tiles for 6 x 6 and 7 x 7 square shapes i.e. 20 and 24. Next, S1 determines the total tiles in a square shape whose value is still unknown, namely 6 x 6 and 7 x 7 by adding black tiles and gray tiles, which are 36 and 49 tiles. The same is done by S2 by first determining the difference in gray tiles on 3 x 3, 4 x 4, and 5 x 5 shape squares to determine the number of gray tiles on 6 x 6 and 7 x 7 square shapes. Then S2 determines the total tiles by summing the sum of the number of black tiles and gray tiles on the corresponding square shape. The understanding of the two subjects related to generalization is supported by the results of the researchers' interviews with S1 and S2.

Researchers : How can you find the number pattern on the number of gray tiles and the total tiles?
S1 : I created a number pattern on the black tiles first. The numbers 1 to 4 have a difference of 3, from 4 to 9 have a difference of 5, and so on. Furthermore, the first number pattern does not yet have the same difference, so I made another number pattern from the number 3 to 5 which has a difference of 2, 5 to 7 has the same difference of 2 and so on.
S2 : The number of gray tiles in the first column is 8, then I compare it with the second column, which is 12 and has a difference of 4, then in column 3, which is 16, which has a difference of 4, so I already know the difference is 4, so column 4 I fill in with 16 + 4 and the result is 20, then use the same method in column 5, which is 20 + 4, the result is 24.

Researchers : What about gray tile patterns and tile totals?
S1 : I figured out the difference myself. From 8 to 12 has a difference of 4, then 12 to 16 also has a difference of 4, and so on. So that the values 20 and 24 are obtained. Then, for the total tiles are summed only from the black and gray tiles. 16 + 20 the result is 36.
S2 : I sum it up to find the total 6 x 6 tiles with the number of black and gray tiles, so 16 +20 = 36, then for the total 7 x 7 tiles which is 25+24 = 49.

Based on the interview results, S1 and S2 can explain the solution steps to determine the number of gray tiles and the total tiles that are still unknown in 6 x 6 and 7 x 7 square shapes using the number pattern in the previous square shape. Thus, it can be concluded that both subjects are able to satisfy the indicator of algebraic thinking on the generalization component, that is, being able to use number patterns to generalize the next pattern. Then, both subjects solve the problem using a way that the subject understands himself and does not refer to a specific formula. This corresponds to the characteristics of the subject's accommodating learning style that tends to use one's own experience or understanding in solving problems.

3.1.2 Analysis Question Number 2

Question number 2 is used to investigate students' abstraction abilities, namely

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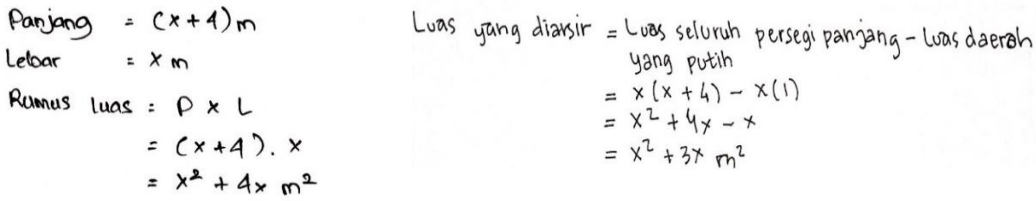
the process of abstracting mathematical objects and relationships between mathematical objects. Based on the test results, S1 has not been able to solve the problem using the right solving steps and has not been able to get the right answer either. Conversely, S2 is able to solve problems using the right solving steps and get the right answers as well. The answers of the two subjects in solving question number 2 are presented in Figure 2.



(a) (b)

Figure 2. Number question answer 2: (a) S1, (b) S2

Based on Figure 2, S1 and S2 solve abstraction problems in almost the same way. S1 first writes the formula of the area of the rectangle. Next, S1 substitutes the length and width values into the rectangular area formula so that the rectangular area $x^2 + 4x$ m² is obtained. However, S1 made the mistake of not paying attention to the area of the area that was not shaded to calculate the area of the shaded area. The same strategy is also carried out by S2 to solve question number 2. S2 writes that the shaded area can be found using a formula in the form of subtraction from the area of the entire rectangle minus the area that is not shaded. Then, S2 determines the area of the shaded area, namely the area of the rectangular area, which is x (x + 4) minus the area of the unshaded area which is x so that $x^2 + 3x$ is obtained. The understanding of the two subjects related to solving abstraction problems is presented in the following interview results.

Researchers : How do you find the area of shaded area?
S1 : I think the length (x + 4) m and width x m can be multiplied according to the rectangular formula whose result is $x^2 + 4x$ m².
S2 : I use the rectangular formula, so to find the shaded area can use the formula of the area of the entire rectangle subtracted by the area of the unshaded area. The length of the first is x + 4. The width of the first is x. Then, the length of the second is x and the width of the second is 1 m. Next, substitute it in the rectangular formula. The calculation is x (x) becomes x^2 plus x (4) becomes 4x and subtracts x (1) to x. So the result is $x^2 + 3x$ m².

Researchers : What about non-shaded areas?
S1 : I don't count.

Based on the results of the interview, both subjects can explain how to determine the solution of the problem. However, the steps to solve the S1 problem are still not right because they do not calculate the area that is not shaded. While S2 is able to utilize the area of the area that is not shaded to determine the area of the shaded area. Thus, both subjects have fulfilled the indicators of algebraic thinking in the abstraction component, namely being able to abstract mathematical objects and relationships between mathematical objects.

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However, the lack of accuracy of S1 that does not take into account the area that is not shaded causes the answers obtained to be less precise.

3.1.3 Analysis Question Number 3

Question number 3 is used to investigate students' ability to think analytically, which is to apply inverse operations in solving problems. Based on the test results, S1 subjects can solve questions using the right solving steps and get the right answers as well. Meanwhile, S2 subjects can solve questions using the right question solving steps but the answers obtained are not correct. The subject's answer in solving question number 3 is presented in Figure 3.

(a) (b)

Figure 3. Answer to question number 3: (a) S1, (b) S2

Based on Figure 3, S1 and S2 use different solving steps to solve problem number 3 related to analytical thinking. S1 solves the problem by collecting terms containing variables in the left field and terms containing constants in the right field. S1 uses an inverse operation, where the 4x term on the right segment is moved to the left segment so that the sign changes to -4x. Then, the constant -6 in the left segment is performed inverse operation to +6 in the right segment. Using algebraic manipulations obtained values x < 2. Meanwhile, S2 uses the completion step by collecting all the tribes on the left segment. However, S2 made the mistake of changing the +6 sign to -6 even though no inverse operation was performed. This results in improper completion of S2. The understanding of the two subjects related to the steps to solve question number 3 is presented in the results of the researcher's interview with S1 and S2.

Researchers : What do you do to solve the inequality problem??
S1 : I moved the variable number x in the left field. Then, a number that is not variable in the right field. Furthermore, 9x minus 4x is 5x, then 6 plus 4 is 10. Then, to find the value of x I divide the number 10 divided by 5, 5 I move it on the right segment so that the result of x is 2 or x less than 2.
S2 : I moved 4x +4 to the left segment so that the right segment is less than 0 and easy to calculate. So 9x is subtracted by 4x which is 5x, while -6 is subtracted by 4 which is -10. Next I moved -10 on the right segment to 10. Then I move the number 5 to the right segment or 10 minus 5, the result is 5. So the value of x is less than 5.

Based on the results of the interview, S1 and S2 can explain the solution steps to obtain x value from a form of inequality. S1 explains that solving a form of inequality can be done by grouping terms that contain variables and constants in the same field so that calculation operations can be carried out. Meanwhile, S2

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moves all tribes in the right segment to the left segment with the aim that the left segment is 0 so that it is easier to solve. However, S2 is less careful by changing the constant sign so that the solution obtained is not right. Thus, both subjects already meet the indicator of algebraic thinking on the component of analytical thinking that is, understanding the use of inverse operations to solve problems. The lack of accuracy of S2 in the calculation operation causes the answers obtained to be less precise.

3.1.4 Analysis of Question Number 4

Question number 4 is used to investigate students' ability to think dynamically, namely students' ability to solve problems using comparisons. Based on the test results, S1 can solve the problem using the right solving steps and get the right answer as well. In contrast, S2 is unable to solve the problem. The answer S1 in solving question number 4 is presented in Figure 4.

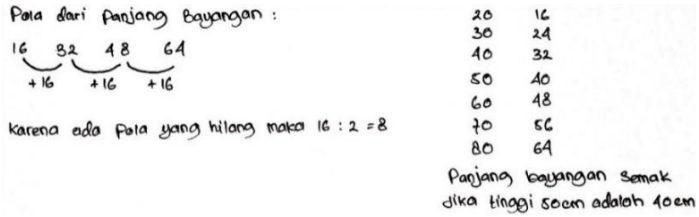

Figure 4. Answer S1 question number 4

Based on Figure 4, S1 solves the problem using a number pattern that relates the height of a bush to the length of its shadow. S1 is able to identify the difference in shadow length from the height of the bush presented in the table, which is 16. Because the bush height in the problem has a difference of 20, S1 uses the concept of comparison to determine the height of the shadow when it is known that the bush height is 50 cm. S1 divides the difference in shadow height by 16 by 2 so that 8 is obtained. Then S1 concludes that if the bush height difference is 10, the shadow height difference is 8. Based on the identification results, S1 constructs a number pattern that relates the height of the bush if the difference is 10 and the height of the shadow. S1 found that if the height of the bush is 50 cm long, the shadow is 40 cm. S1's understanding regarding solving question number 4 is presented in the following interview excerpts.

Researchers : How do you solve this problem?
S1 : I answer it using trial and error, I try to use the number pattern method. I first saw the number pattern in the length of the shadow of the bush there were numbers 16, 32, 48, 64 so that it had a difference of 16. Then, I divide 16 by 2 because at the height of the bush there is a missing pattern. So if sorted the height of the bush is 20, 30, 40, 50, 60, 70, 80 and the length of the shadow has a difference of 8. So 16 + 8 the result is 24. 24 + 8 the result is 32, and so on.

Based on the results of the interview, S1 can explain how to determine the length of the shadow of the bush if the height of the bush is 50 cm. S1 explains that to solve this problem you can use a number pattern in the length of the

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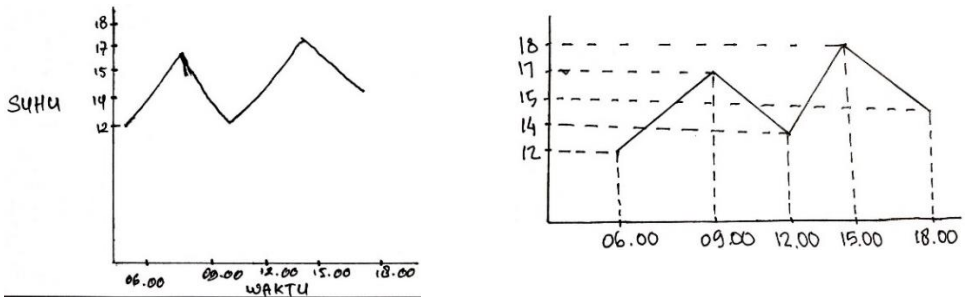
shadow of the bush. The solution of dynamic thinking problem number 4 on the accommodator subject can be seen through the use of direct proportionality to solve the problem. The completion steps that S1 writes are based on the results of trial and error that the subject understands himself. Thus, S1 is able to meet the indicator of algebraic thinking ability in the dynamic thinking component, which is able to use comparisons to solve problems. Subject-solving strategies that use trial and error show the characteristics of the subject, learning styles accommodators who tend to favor experimentation or experimentation in solving problems.

3.1.5 Analysis Question Number 5

Question number 5 is used to investigate students' ability to solve modeling problems, namely the ability to represent complex situations using mathematical expressions, interpret situations with mathematical models, and draw conclusions from a mathematical problem solving. Based on the test results, S1 wrote down the completion steps that were done partially correct and the answers obtained were not correct. Meanwhile, S2 is able to answer using the right completion steps and get the right answer as well. The subject's answer in solving question number 5 is presented in Figure 5.



(a) (b)

Figure 5. Answer to question number 5: (a) S1, (b) S2

Based on Figure 5, S1 and S2 are able to solve modeling problems in relatively the same way. Both subjects drew graphs based on the information available in the problem, which is a graph that states the relationship between time and temperature changes. This shows that both subjects are able to represent mathematical problems in the form of data in the form of tables into graphic forms so that they are easier to understand. The understanding of both subjects related to modeling was also shown in the interview results as follows.

Researchers : How to make a graph that matches the data in the problem? Then what is the conclusion?

S1 : I draw part of the time on a horizontal line and I determine the line based on the results of asking with friends, namely 06.00, 09.00, 12.00, 15.00, and 18.00. Then, I draw a vertical line that is the temperature part with the numbers 12, 17, 14, 18, and 15. Furthermore, time is connected with the right temperature, for example 06.00 with a temperature of 12° and so on. So the conclusion is that the lowest temperature is at 12° at 06.00 and the highest temperature is 18° at 15.00. But when I draw it doesn't use

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a ruler so the lines connected are not right.

S2 : I draw the time part on the horizontal line, there are 6:00 a.m., 9:00 a.m., 12:00 p.m., 3:00 p.m., and 6:00 p.m. Then, drawing a vertical line in the temperature section, there are numbers 12, 17, 14, 18, and 15. Next, the time and temperature pairs are connected according to those in the table. At 06.00 the temperature pair is 12°, at 09.00 the temperature pair is 17°, and so on. From the meeting point is drawn from each other to form a graph. In conclusion, in my opinion, the lowest temperature is at 12° hours 06.00, the highest temperature is 18° hours 15.00. Low temperature means cold, High temperature means hot.

Based on the results of the interview and the analysis of the answers to question number 5, it can be concluded that both subjects were able to meet the indicators of algebraic thinking in the modeling component. Both subjects are able to represent the information contained in the problem into another form, namely graphs. Then, both subjects can also make inferences from the graphs that have been compiled.

3.2 Discussion

Accommodator subjects demonstrate the ability to solve algebraic thinking problems related to the components of generalization, abstraction, analytical thinking, dynamic thinking and modeling. In the generalization component, the subject is able to use known number patterns to generalize to unknown patterns. In the abstraction component, the subject is able to abstract mathematical objects and use relationships between mathematical objects to solve problems. Furthermore, in the analytical thinking component, the subject is able to use inverse operations to solve inequality-related problems. In the dynamic thinking component, the subject is able to use comparisons to solve problems. In the modeling component, the subject is able to represent the information contained in the problem into another form, namely graphs. However, the lack of accuracy in performing calculation operations causes the answers obtained by one of the subjects to be less precise on problems related to abstraction, analytical thinking, and dynamic thinking. This is in line with research Winarso and Toheri (2021) which concludes that accommodator subjects sometimes make mistakes in solving mathematical problems. In addition, the results of the study Rahmah et al., (2022) also indicates that the subject accommodator encountered an error in the process of troubleshooting.

The problem-solving steps of both subjects can be attributed to accommodator learning style characteristics that are characteristic of a combination of concrete experiences or feelings and active experiments or real activities. Accommodating subjects tend to discover knowledge through direct experience in the real world and transform their experience in experiments or experiments. This is in line with research Itasari et al., (2021) which states that students with an accommodating learning style in solving a problem will be directly involved in concrete situations and use intuition or feelings more than logic. Then, Sudria et al., (2018) states that subjects with accommodative learning styles in solving problems need more intensive guidance compared to other learning style subjects.

The findings of this study show that students' learning styles have an impact

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on students' ability to solve problems. Every individual has a different learning style. Therefore, differences in student learning styles need to be recognized and facilitated by educators or teachers with different learning strategies. This is necessary so that students with diverse learning styles get learning treatment that is in accordance with the characteristics of their learning styles. The application of learning strategies that are able to facilitate the diversity of student characteristics, such as learning styles, can encourage student success in learning, especially in solving mathematical problems.

4. Conclusions

Accommodating subjects are able to fulfill five components of algebraic thinking, namely generalization, abstraction, analytical thinking, dynamic thinking and modeling. In the generalization component, the subject is able to use known number patterns to generalize to unknown patterns. In the abstraction component, the subject is able to abstract mathematical objects and use relationships between mathematical objects to solve problems. Furthermore, in the analytical thinking component, the subject is able to use inverse operations to solve inequality-related problems. In the dynamic thinking component, the subject is able to use comparisons to solve problems. In the modeling component, the subject is able to represent the information contained in the problem into another form, namely graphs. The lack of accuracy of the subject in the calculation operation causes some of the answers given to be incorrect, especially in problems related to abstraction, analytical thinking, and dynamic thinking. This is influenced by the characteristics of accommodator learning styles that sometimes make mistakes in solving a problem. Accommodating subjects in solving problems tend to use intuition, interest in experiments and real experience, sometimes causing a lack of accuracy in answering questions. Thus, learning style is one of the factors that affect students' ability to solve problems.

Author Contributions

Lutfiyya Fajar Zahiroh: conceptualization, designing research methods, collecting data, analyzing data, conducting discussions, drafting articles. Masduki: conceptualization, formulating the research focus, designing research methods, analyzing data, conducting discussions, revision the article.

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Declaration of Competing Interest

No potential conflicts of interest were reported by the authors.

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Rahmah, K., Inganah, S., Darmayanti, R., Sugianto, R., & Ningsih, E. F. (2022). *NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0 Analysis of Mathematics Problem Solving Ability of Junior High School Students Based on APOS Theory Viewed from the Type of Kolb Learning Style*, 5(2), 109-122.

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Analysis of Mathematics Problem Solving Ability in View of Extrovert-Introvert Personality Types

Vebiola Ardiani[1*], Haryati Ahda Nasution[1]

[1]Pendidikan Matematika, Universitas Muslim Nusantara Al-Washliyah Medan

**Email Correspondence:* vebiolaardiani@umnaw.ac.id

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ABSTRACT

This study was conducted to analyze mathematical problem solving in terms of opportunities in terms of extrovert-introvert personality types in class X of SMKN 1 Patumbak. Researchers took samples, namely class X Rpl students of SMK Negeri 1 Patumbak with a total of 35 students. Sampling is taken by purposive sampling technique, also known as consideration sampling, which is a sampling technique from the population on certain considerations. Instruments and data collection techniques were carried out, namely by distributing questionnaires, conducting interviews, and providing test instruments. From the tests conducted, it is known that students who have extroverted personalities are more enthusiastic in working on questions than students with introverted personalities. From these results it is known that students who have introverted personalities can write down answers, but are less able to explain the answers. Meanwhile, students with extroverted personalities tend to be more confident, both in writing answers and explaining answers.

1. Introduction

Elmarfia & Yohanes, (2020) stated the reasons for the need for students to learn mathematics, namely because: (1) it is always used in other aspects of life, (2) all fields of study require appropriate mathematical skills, (3) it is a strong, short and effective means of communication. clear, (4) can be used to present information in various ways, (5) improves logical thinking skills, accuracy and spatial awareness, and (6) provides satisfaction in solving challenging problems.

Wahyuni et al., (2022) stated that Mathematics is also material taught at the

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educational level, from elementary school to high school and even in tertiary institutions. According to Siregar in (Rita Nauli, Ida Karnasih, Madyunus Salayan 2018) stated 5 reasons for the need to study mathematics because mathematics is; (1) a means of clear and logical thinking, (2) a means of solving daily life problems, (3) a means of relating patterns and generalizing experiences, (4) a means of developing creativity and (5) a means of increasing awareness to cultural development.

This is the teacher's desire to know the students' thinking process in solving a problem in mathematics learning. The importance of solving mathematical problems is reflected in Branca's opinion (Sulastri et al., 2021) , namely that it is one of the important goals in learning mathematics. In fact, the problem-solving process is the heart of mathematics, so to improve problem-solving abilities, skills are needed in compiling problem-solving steps.

Problem solving is a competency that students must have. Zuniana & Rahaju (2019) stated that in SPLDV probem solving, students experienced difficulties including students not being able to state what they knew and asking about the problems given, students not being able to create mathematical models, students not being careful when solving problems. So using algebraic operations incorrectly, students don't know how to look again correctly and what needs to be looked at again.

In the process of mathematics learning activities, a question or problem is a question that must be worked on by students. Therefore, when facing mathematics questions, students must plan in advance the series of commands that will be used. Karimah in (Rozalina & Nurdalilah, 2022) , concluded that problem solving is a reasoning ability that every person must have which will be very useful in solving problems in everyday life. Branca and NCTM Hendriana, Rohaeti, and Sumarno in (Ramadhani, 2020) concluded that problem solving has three meanings, namely: problem solving as a goal, as a process and as an appearance.

In reality, currently there are still many students in Indonesia who have low levels of thinking processes in solving mathematical problems (Habibatul Izzah & Azizah, 2019) . This is proven by the results of PISA (*Program for International Student Assessment*) released in 2019 which prove that the average ability of students in Indonesia in Mathematics and Science subjects is classified as very low (Mustakim, 2020) . Several factors that cause students' low problem solving abilities are also because the learning process is more focused on developing and testing students' memory (Saputri & Febriani, 2017) .

When students solve problems, students not only apply the various knowledge and abilities they already have, but students can find the right combination of rules and regulations so that they control their thinking process. Anwar & Amin (Lia, 2022) state that in solving mathematical problems, students carry out a logical thinking process in order to solve the problem.

One solution that can train students' abilities in solving mathematical problems is in solving according to Polya (Muslim, 2015) . Important steps or stages that students must take in solving problems according to Polya (in Hidayat & Sariningsih, 2018). These include (1) understanding the problem, (2) preparing a plan, (3) implementing the plan, and (4) looking back. One stage to the next in solving the problem supports each other to produce problem solving from related problems. Students play a role in understanding each step of problem solving so that students' thinking processes run well (Sulastri et al.,

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2021) .

In the process of learning activities there may be various types of personalities whose learning patterns are not easy to equalize. Because each personality type has its own way of solving the problems it faces, personality types consist of *extroverts and introverts* . Students who have extroverted personalities tend to be active in activities, have high self-confidence, interact well, actively ask and answer questions, think objectively. Meanwhile, students or children who have introverted personalities tend to be more passive. Less active in asking and answering, their self-confidence is slightly lower, they think subjectively (Listia et al., 2022) .

From the results of observations at State Vocational High School 1 Patumbak, the researcher obtained the results of an interview with the Mathematics teacher, Mrs. Dina as a class , then students also do not understand the rules for solving them, and there are still many students who systematically take steps in solving problems. Learning is also still carried out by means of lectures without testing the students' personality abilities. Students also do not have the courage to show themselves to work on mathematics problems, some students have to be appointed by their teacher first to work on mathematics problems, so that students' thinking processes for solving learning mathematics problems are still weak.

According to Ahda (2018), the actual difficulty of students based on understanding in completing mathematics tests is being able to understand the meaning of each word in the test given. In this way, the researchers conducted research on the process of students' mathematical problem solving abilities in opportunity material in terms of *extrovert-introvert personality types* in class X students at State Vocational School 1 Patumbak.

Based on this statement, the problem formulation is "how is the ability to solve mathematical problems in opportunity material in terms of the *extrovert-introvert personality type* in class X State Vocational School 1 Patumbak?"

The aim of this research is "to determine the ability to solve mathematical problems on opportunity material in terms of *extrovert-introvert personality types* in class X State Vocational School 1 Patumbak."

2. Method

This research is included in qualitative research with a descriptive approach. Nirmayani (2021) states that qualitative research is a way of knowing (something) where a researcher collects, organizes and interprets information obtained from humans using the eyes or ears as a filter. The characteristics of qualitative research are 1) It is carried out in natural conditions, directly to the data source and the researcher is the key instrument. 2) Qualitative research is more descriptive. The data collected is in the form of words or images, so there is no emphasis on numbers (Gumilang, 2016) .

In this research, the researcher involved participants, namely students in class X RPL State Vocational School 1 Patumbak with a total of 35 students . To understand students' *problem solving, instruments are used, namely questionnaires, interviews, documentation and tests.*

This instrument was created to estimate the dimensions of Extraversion which has a total of 24 questions, Neuroticism which has a total of 24 questions and lying which has a total of 9 questions. Personality tests are carried out by

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giving respondents a set of questions or written statements to answer.

The formula for finding students' problem solving ability scores is:

$$Nilai = \frac{Skor\ yang\ Diperoleh}{Skor\ Maksimal} \times 100 \quad (1)$$

The following are the descriptive statistical calculations that will be used by researchers in the following Table 1.

Table 1. Descriptive Statistical Calculation

Score	Levels
0 - 39%	Very low
40 - 54%	Low
55 - 64%	Enough
65 - 79%	Tall
80 - 100%	Very Tall

The data analysis carried out was data reduction. This is done to be able to summarize, as well as focus on what is important, discarding what is not needed in the research process. Next, the summarized data is presented. The data presented was obtained from interviews. The final step is drawing conclusions. The activity of drawing conclusions in this research is by describing the results of data presentation with indicators of problem solving steps that have been achieved by students, then analyzing them into problem solving steps according to Polya. So that conclusions will be obtained from the presentation of the data.

3. Results and Discussion

Based on the research that has been carried out, 4 subjects were chosen as follows:

a. The researcher used class X 2 RPL at SMK Negeri 1 Patumbak as a sample consisting of 35 students.
b. The personality results of extroverted and introverted students were obtained from the EPI personality questionnaire, which consisted of 24 questions. The personality questionnaire was given to students in class X 2 RPL SMK Negeri 1 Patumbak, totaling 35 students.

Table 2. Classification of Student Personality Motives

Student Code	Total Value	Personality type
S2	≥ 12	extrovert
S6	≥ 12	extrovert
S3	≥ 12	extrovert
S7	≥ 12	extrovert
S4	≥ 12	extrovert
S11	≥ 13	extrovert
S12	≥ 12	extrovert
S13	≥ 13	extrovert
S14	≥ 14	extrovert
S16	≥ 15	extrovert
S18	≥ 12	extrovert
S19	≥ 12	extrovert
S23	≥ 13	extrovert
S24	≥ 12	extrovert
S29	≥ 12	extrovert

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Student Code	Total Value	Personality type
Number of Students		15 Learners
S1	≤ 10	introvert
S5	≤ 10	introvert
S8	≤ 10	introvert
S9	≤ 07	introvert
S10	≤ 11	introvert
S15	≤ 10	introvert
S17	≤ 09	introvert
S20	≤ 11	introvert
S21	≤ 11	introvert
S22	≤ 10	introvert
S25	≤ 09	introvert
S26	≤ 10	introvert
S27	≤ 07	introvert
S28	≤ 08	introvert
S30	≤ 11	introvert
S31	≤ 08	introvert
S32	≤ 10	introvert
S33	≤ 09	introvert
S34	≤ 10	introvert
S35	≤ 07	introvert
Number of Students		20 Learners

From the table above it can be seen from the total number of students in class X-2 RPL Patumbak 1 State Vocational High School for the academic year 2022-2023 which has a total of 35 students 15 who have extroverted personalities and the remaining 20 students who have introverted personalities.

c. The posttest was carried out by 4 students, 2 as extroverts and 2 as introverts, where 1 student with a high level of thinking had an Extrovert personality type and 1 student with a weak level of thinking had an Extrovert personality type, then 1 student with a very high level of personality had a variety of introverted personalities and 1 student with a medium level of thinking who has a variety of introverted personalities.

Table 3. Problem Solving Ability Based on Variety of Student Personalities

Category	Number of Students	No absence	
		extrovert	introvert
Very high	3		33,09,15
Tall	14	12,02,14,24,16,18	22,35,30,27,25,05,28,20
Currently	9	23,03,04,07	01,08,32,34,10
Low	7	06,19,29,11,13	26,17
Very low	2	29	26

Based on the test results, it was obtained that 3 introvert students were in the very high category, 6 extrovert students and 8 introvert students were in the high category, 4 extrovert students and 5 introvert students were in the medium category, 5 extrovert students and 2 introvert students were in the medium category. low and finally 1 extrovert student and 1 introvert student are in the very low category.

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d. Based on the results of the problem-solving ability test and the results of the interview tests carried out by the students, it can be concluded that students who have a variety of introverted personalities in the first stage are able to write down material and state what is known and asked in questions correctly, then in the second stage the problem-solving ability The problem is to create a well-designed problem solving plan for all questions. Then in the third stage, students with various introverted personalities were not able to re-check the results of the answers they got even though the final results they got were correct. Based on the results of the post-test on problem-solving abilities and interview tests carried out by students, it can be concluded that not all students who have a variety of extroverted personalities can answer all questions correctly and easily.
e. The presentation of the research results was carried out on data on the classification of extrovert and introvert personality types. Next, the data is described according to the stages of mathematical problem solving according to Polya, namely understanding the problem, preparing a solution plan, implementing the solution plan, and re-examining the results of problem solving. The ability to solve problems is seen from each step in solving the problem. The data in this research are the results of written tests and interviews with 2 subjects.

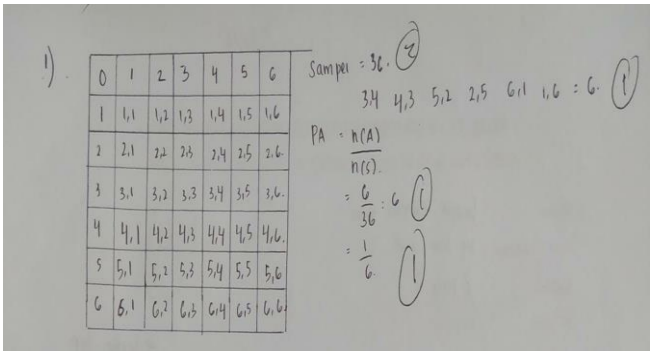

Figure 1. Answer to SH 14 Question Number 1

The extrovert personality type has the characteristics of being happy with people, confident, active, happy working in groups, easy to get along with and speaks after thinking. Based on the results of the SH 14 written test, question number 1 with the extrovert personality type, the subject was able to write what he knew and was correct, but some of the writing requested was not correct. Based on the results of the interview above, information was obtained:

1) Understanding the Problem
   Based on the results of the interview, the subject was able to state what he knew and asked the question correctly as in the answer to question P. Then from the statement the subject was also able to identify several concepts related to solving the question asked even though there were still answers that were not correct.
2) Develop a problem solving plan
   Based on the results of the interview above, the subject can state initial conclusions, and can draw conclusions correctly based on the results of the investigation that has been carried out and is confident in the conclusions he has made.

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3) Implement a problem solving plan
   In question P, the subject only understands how to solve it, namely by discussing it with his/her seatmate.
4) Check the solution results again
   In question P, the subject is sure of the answer and checks the answer he wrote again.

The following are the results of interviews that researchers conducted with students for question number 1 with the Extrovert personality type as follows:

Q : What do you know about probability question number 1?
SH 14 : What is known is that there are 36 samples, then 7 dice appear, there are 6 samples, sis.
Q : What are the questions asked about opportunities? Explain?
SH 14 : What is the probability of the event that the number on the dice turns 7?
Q : Do you find difficulty in understanding the elements of opportunity questions? explain?
SH 14 : Yes, I have difficulty understanding the meaning of the first die, which is not a multiple of 5, sis.
Q : What is your strategy for solving this opportunity problem?
SH 14 : My strategy in working on questions is by discussing it with my classmates, Sis.
Q : Do you think the solution steps you took were correct?
SH 14 : Yes, sis.
Q : Did you check your answer again?
SH 14 : Yes sis.
Q : Did you get this solution in another way?
SH 14 : Yes sis, but I'm still confused

The following is a presentation of mathematical problem solving data for the personality type of introverted students.

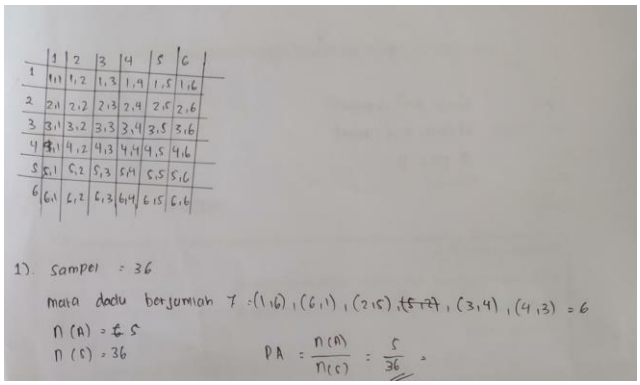

Figure 2. Answer to SH 09 Question Number 1

Based on the results of the interview above, information was obtained:

1) Understanding the Problem
   Based on the results of the interview, the subject was able to state what he knew and asked questions correctly as in the answer to question P. Then

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from the subject's statement he was also able to identify several concepts related to solving the questions asked. Then the subject also checked the answer again whether it was correct or not, from the final result the researcher saw that the subject was able to answer the question with the correct steps and the final result was correct too.

2) Develop a problem solving plan
   Based on the results of the interview above, the subject can state initial conclusions, and can draw conclusions correctly based on the results of the investigation that has been carried out and is confident in the conclusions he has made .
3) Implement a problem solving plan
   In question P, the subject can understand how to solve it, namely by understanding the material that the researcher has previously provided.
4) Check again
   In question P, the subject is sure of the answer and checks again that the answer he wrote is correct.

The following are the results of interviews that researchers conducted with students for question number 1 with the Introvert personality type as follows:

Q	: What do you know about probability question number 1?
SH 09	: What I know from question number 1 is that there are 36 samples, then in the question of how 7 dice appear there are 6 samples, sis.
Q	: What are the questions asked about opportunities? Explain?
SH 09	: What is asked in question number 1 is what is the probability that the number of dice will be 7? Then by showing the first dice that is not a multiple of 5, I can determine n(A), sis.
Q	: Do you find difficulty in understanding the elements of opportunity questions? explain?
SH 09	: Yes, I found a little difficulty in answering question number 1.
Q	: What is your strategy for solving this opportunity problem?
SH 09	: My strategy in working on questions is by understanding the material notes that you have given me, Sis.
Q	: Do you think the solution steps you took were correct?
SH 09	: I think so, sis.
Q	: Did you check your answer again?
SH 09	: Yes sis.
Q	: Did you get this solution in another way?
SH 09	: Yes sis

4. Conclusion

Based on the results that have been obtained, it can be concluded that students with mathematical problem solving in the opportunity material, in terms of extrovert personality types, are more enthusiastic in taking tests than students with introverted personalities. From the research results, it was found that students who have introverted personalities can write answers, but are less able to explain the answers. Meanwhile, students with extroverted personalities tend to be more confident, both in writing answers and explaining their answers.

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Author Contributions
Authors have sufficiently contributed to the study, and agreed with the results and conclusions.

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Declaration of Competing Interest
No conflict of interest is declared by authors.

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Development of E-Module Based on Mathematical Literacy Skill in Statistical Materials

Shindy Amelia Efendi[1], Yulia Haryono[1], Anna Cesaria[1*]

[1]Mathematics Education, Sains and Technology, Universitas PGRI Sumatera Barat, Indonesia

**Email Correspondence:* annacesaria13@gmail.com

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ABSTRACT

This research aims to produce an E-Module with math literacy-based questions that are valid and practical for 10th-grade statistics in SMA Negeri 3 Padang. The type of research conducted is development research using the ADDIE development model. Data analysis techniques include interview analysis, E-Module validation analysis, and E-Module practicality analysis. The results of the research show that mathematics learning using the E-Module, which facilitates mathematical literacy questions, is both valid and practical. Based on the data analysis, it was found that the developed E-Module had a validity score of 92.31%, categorized as highly valid. The final practicality score for teachers was 85%, categorized as highly practical, and the final practicality score for students was 88.26%, also categorized as highly practical.

1. Introduction

Mathematics is a fundamental subject that plays a crucial role in human life and the advancement of science and technology (STEM). It serves as the foundation for all fields of knowledge dealing with abstract concepts. Therefore, the presentation of mathematical materials in education is often linked to everyday life, with the aim of enabling students to discover concepts and develop their mathematical skills based on their experiences and existing knowledge (Agustina, 2019). Learning mathematics is one of the means to foster scientific and logical thinking and is essential in efforts to enhance the quality of human resources (Maghfiroh & Rohayati, 2020).

The concept of a free curriculum becomes intriguing in the context of technological advancements and skills needed in the 21st century. Students are

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required to acquire various 21st-century skills, abbreviated as 4C: critical thinking and problem solving, creativity, communication skills, and the ability to work collaboratively (Andiani et al., 2020). One of the fundamental aspects considered in the development of a free curriculum is mathematical literacy. The goal is to help students develop mathematical ideas in their everyday lives and solve contextual problems, making mathematics education more meaningful for students.

The results of mathematical literacy skills among students at SMA N 3 Padang in the topic of statistics are generally considered low and moderate. This is because most students fall into levels 2 and 3. Level 2 represents basic mathematical abilities, including communication, mathematization, and representation. Level 3 includes advanced mathematical skills such as communication, mathematization, representation, reasoning, and the use of mathematical tools. There are still some students at level 1, indicating limited mathematical abilities focused on communication and representation. However, some students have reached level 4, where they have fulfilled all basic mathematical skills, including communication, mathematization, representation, reasoning, problem-solving strategies, the use of operations and symbolic language, formal language, technical language, and the use of mathematical tools (Afrilina et al., 2022).

The low level of students' mathematical literacy skills is due to learning obstacles that occur in students (Jelvindo et al., 2022). Learning obstacles are divided into three factors: mental readiness to learn (obstacle of ontogenic origin), teacher education and teaching system (obstacle of didactical origin), and limited student knowledge (obstacle of epistemological origin) (Cesaria dan Herman, 2019).

The level of mathematical literacy among students at SMAN 3 Padang shows consistent results between the studies conducted (Jelvindo et al., 2022) and (Afrilina et al., 2022). The learning barriers identified among students with varying levels of mathematical literacy include ontogenic obstacles, where students at literacy levels 1 to 4 commonly struggle due to a lack of understanding of prerequisite materials. Didactical obstacles are also prevalent among students with mathematical literacy levels 1 to 4, as they often face challenges associated with incomplete coverage of the curriculum by their teachers. Additionally, epistemological obstacles are frequently observed in students with mathematical literacy levels 1 to 4, as they tend to struggle with incomplete conceptual comprehension of the subject matter (Jelvindo et al., 2022).

However, there are several issues identified in the learning process. One key problem is that the focus is not placed on understanding the correct concepts and problem-solving methods; rather, it often centers solely on obtaining the correct answers. This issue can be attributed to students' limited grasp of mathematical concepts, a tendency to rush through assignments, difficulty determining the principles or formulas to apply, and a habit of not providing detailed responses to questions. As a result, students frequently struggle when presented with different problems by their teachers. Additionally, students are not accustomed to solving mathematical problems by applying standard mathematical problem-solving processes, which could guide them in effectively addressing mathematical challenges.

Another challenge is that students often encounter confusion when

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reading data presented in the form of diagrams, tables, and graphs during statistics lessons. This is largely due to inadequacies in the learning materials provided to students. While students are required to have only one printed curriculum book, some students with strong mathematical abilities possess two different printed curriculum books. Consequently, other students rely solely on the printed curriculum book and explanations from their teachers. According to students, the printed curriculum book is difficult to understand because it lacks completeness in its content and uses formal language. Furthermore, the Learning Activity Sheets (LKPD) provided to students only cover specific subtopics and lack comprehensive explanations. These challenges highlight the need for improved teaching methods and learning materials in the statistics curriculum to enhance students' understanding and proficiency in mathematical literacy.

The concept of "merdeka belajar" aims to improve educational access and services through infrastructure improvements and technology-based education. The use of learning media as a support for the learning process is one of the advantages of technology in education. Learning media is a tool used to convey and deliver messages to users in order for them to engage in planned learning processes efficiently and effectively. This generates a favorable learning environment, allowing students to grasp the subject more quickly and pique their interest in further study (Purba & Harahap, 2022).

One of the most effective, efficient, and student-centric media is the E-Module. Modules are considered self-directed learning tools because they come with instructions for independent learning. This means that students can engage in learning activities on their own without the direct presence of an instructor. Based on research conducted (Yunus et al., 2022), the development of E-Modules enhances students' self-directed learning and leads to effective learning outcomes even before formal interventions are introduced.

Recognizing the issues at hand, the researcher was motivated to develop electronic instructional materials known as E-Modules. There are various software options available for creating E-Modules, and one of them is Flip PDF Professional. Flip PDF Professional is reliable software designed to convert PDF files into digital flip publications, making them visually appealing and resembling a physical book. Flip PDF Professional offers several advantages, including its user-friendly interface and the ease of operating the final product it generates. It can be published offline, allowing it to run on computers, and it can also be uploaded online, enabling access on smartphones. This accessibility makes Flip PDF Professional a viable option for individuals who may not be familiar with HTML programming languages (Seruni et al., 2019).

The research conducted aligns with previous studies on developing E-Modules using *Flip PDF Professional*, as demonstrated (Meliana et al., 2022). However, this research expands on that by utilizing nearly all the features available in Flip PDF Professional. Consequently, the E-Modules developed in this study incorporate audio, video, quizzes, and interactive elements, making them even more engaging. Moreover, accessing and using these E-Modules is not complicated, as they are published online and can be accessed on both smartphones and computers with a reliable internet connection.

Based on the background mentioned above, the author is considering the development of teaching material that can be used in a valid and practical

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learning process. This material will take the form of an E-Module development that facilitates mathematical literacy-based questions.

2. Method

This research was conducted at SMAN 3 Padang and aimed to develop an E-Module based on mathematical literacy skills for the subject of statistics. The research subjects included 12 students in phase E for small group testing. Phase E represents the level of competence of each student in the context of an independent curriculum designed for 10th-grade students in high school or equivalent (SMA/SMK). The research methodology used in this study is research and development (R&D), employing the ADDIE development model. The ADDIE model consists of five stages, which are:

2.1. Analyze

In this stage, the research team conducts two activities: field studies and literature reviews (Rayanto & Sugianti, 2020). Field studies involve examining issues in the learning process, learning objectives, student capabilities, student characteristics, teaching implementation, and learning outcomes. Literature reviews involve relevant studies, the analysis of textbooks, and the analysis of student worksheets (LKPD). After collecting data, self-evaluation is performed to refine the analysis results.

2.2. Design

Self-evaluation and refinement of the framework design involve creating a storyboard and initial interface using the analyzed software and providing mathematical literacy-based questions. In the product design phase, the process begins with creating the cover and introduction using Canva. Subsequently, various components like learning activities, summaries, bibliographies, glossaries, and biographies are developed using Microsoft Word. Additionally, supplementary elements, such as quizzes and feedback presentations, instructional videos, and interactive buttons, are incorporated using the Flip PDF Professional application before the digital publication in PDF format. During this stage, the development of assessment instruments for validation sheets is also carried out, which are reviewed by experts.

2.3. Development

Further development is based on the initial design, which includes creating practical instruments and validating the development results through expert reviews, including content validators, subject teachers, and media validators. This revision process ensures that the final product is valid. The output product is in the form of HTML5 or Flash files.

2.4. Implementation (Implementasi)

After validation, the implementation phase tests the practicality of the product. Limited testing is conducted with students and teachers to determine its practicality.

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2.5. Evaluation (Evaluasi)

Evaluation in this research is primarily formative, focusing on improving the development product through validation and practicality testing.

The data types in this study include qualitative and quantitative data. Qualitative data in this research are derived from field observations and interviews conducted with teachers and students, while quantitative data are collected from validation sheets and practicality questionnaires. Data analysis techniques for assessing validity and practicality involve the use of a Likert scale. The validity of the data obtained from the validators is calculated using the following formula:

$$Validity\ value = \frac{Number\ of\ scores}{Maximum\ score} \times 100\% \quad (1)$$

The level of validity of the E-Module developed is interpreted using the following criteria in Table 1 below.

Table 1. E-Module Validity Category

Precentage (%)	Criteria
$0 \leq NV \leq 20$	Invalid
$20 < NV \leq 40$	Not valid
$40 < NV \leq 60$	Fairly valid
$60 < NV \leq 80$	Valid
$80 < NV \leq 100$	Very valid

Source: modified from (Riduwan, 2010)

The selection of research subjects is based on the students' level of ability, as categorized in Table 2 below.

Table 2. Category Of Practical Subjects

Value range	Category
$80 \leq x \leq 100$	High
$55 < x < 80$	Average
$0 \leq x < 50$	Low

Source: (Rezky et al., 2022)

The practicality of the E-Module, as assessed by practitioners, is determined by calculating the practicality level of the E-Module using the following formula:

$$Practicality\ value = \frac{Number\ of\ scores}{Maximum\ score} \times 100\% \quad (2)$$

The level of practicality of the E-Module being developed is interpreted using the criteria in Table 3 below.

Table 3. Category Practicality E-Module

Precentage (%)	Criteria
$0 \leq NP \leq 20$	Not practical
$20 < NP \leq 40$	Not practical
$40 < NP \leq 60$	Quite practical

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Precentage (%)	Criteria
$60 < NP \leq 80$	Practical
$80 < NP \leq 100$	Very practical

Source: modified from (Riduwan, 2010)

3. Result and Discussion

The final product is the development of electronic-based teaching material, namely the E-Module, which facilitates mathematical literacy-based questions for the topic of statistics. The software used is Flip PDF Professional, which contains content such as a cover, an introduction, learning activities, supporting activities, summaries, final evaluations, and a conclusion. The research development process follows the ADDIE stages, adapted from (Tegeh et al., 2014) and (Puspasari & Suryaningsih, 2019). The results and discussions of the research are described below.

In the **Analysis** phase, efforts are made to obtain information about the issues present in the field through a literature review. Based on the field analysis, which includes the analysis of student characteristics, observation analysis of the learning process, and interviews, it was found that students had difficulty understanding problems, lacked a solid grasp of concepts, rushed through assignments, and struggled to determine problem-solving strategies. Additionally, students often had the misconception that mathematics had no relevance to their everyday lives.

As for the literature analysis, it was found that the teaching materials used by educators in schools included print textbooks and participant worksheets (LKPD). In LKPD, problems were presented directly without accompanying materials to assist participants. Meanwhile, in the textbooks, there were mathematical literacy-based questions, but they lacked variety, and not all of them related to real-life situations. Additionally, based on the analysis of textbooks and LKPD, it can be concluded that the statistics teaching materials are aligned with the Competence Standards (CP). However, the material structure provided does not yet align with the Academic Process Standards (ATP).

This aligns with relevant research findings that the mathematical literacy skills of students at SMA N 3 Padang, specifically in the topic of statistics, are still considered low and moderate, as most students are predominantly at levels 2 and 3. The low level of mathematical literacy skills in students is attributed to learning barriers. Learning barriers identified in students based on their mathematical literacy abilities include ontogenic barriers, which affect students with mathematical literacy levels ranging from 1 to 4, generally because students do not understand prerequisite materials. Didactic barriers are encountered by students with mathematical literacy levels ranging from 1 to 4, primarily because the material taught by teachers is incomplete. Epistemological barriers are also found in students with mathematical literacy levels ranging from 1 to 4, mainly because their understanding of the concepts is incomplete (Afrilina et al., 2022) and (Jelvindo et al., 2022).

Based on the data mentioned above, the researcher decided to develop an E-Module that facilitates mathematical literacy-based questions to make the learning process easier for students. This E-Module with mathematical literacy-based questions presents content related to everyday life, enabling students to easily understand the material. Moreover, it's highly accessible as it can be used

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on students' smartphones, making it convenient to carry and access from anywhere.

In the **Design** phase, the researcher prepares reference books related to statistics and mathematical literacy-based questions, constructs the framework for the E-Module, determines the initial interface design, explores the needs, and designs the layout. The instructional material product in question combines text, images, and videos. Some supporting applications used in the design process include Canva and Word, while Flip PDF Professional is used in the publication process to incorporate instructional videos, evaluations, and interactive buttons. The teaching material created is tailored to meet the needs and curriculum requirements.

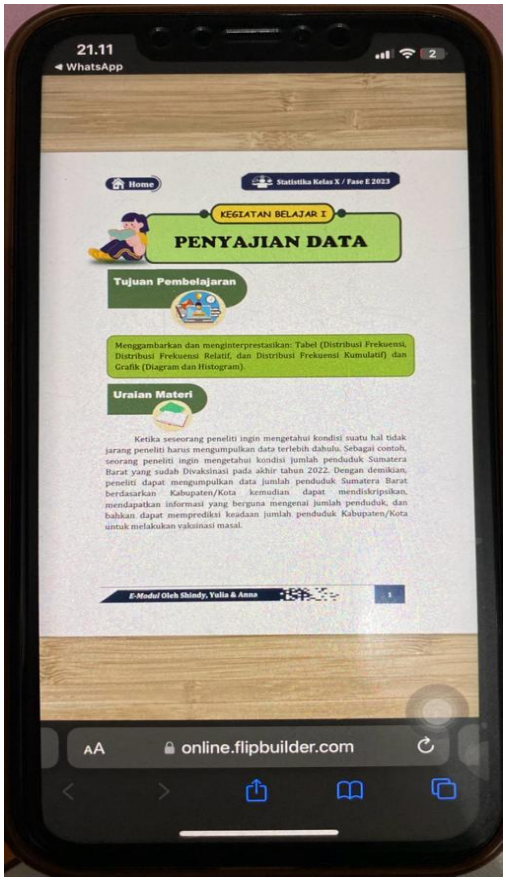

Figure 1. E-Module Design with Flip PDF Professional

Translate:

Learning Activity 1
Data Presentation

Purpose of learning
Describes and interprets: tables (frequency distribution, relative frequency distribution, and cumulative frequency distribution) and graphs (diagram and histogram).

Material Description

When a researcher wants to understand the condition of something, it is often necessary to collect data. For example, a researcher might want to know the number of people in West Sumatra who have been vaccinated by the end of 2022. In this case, the researcher can gather data on the population of West Sumatra based on districts or cities. This data can then be used to describe and obtain useful information about the population. Additionally, it can be used to make predictions about the population in different districts or cities to plan for mass vaccination efforts. Data collection is a fundamental step in the research process, allowing researchers to gather the information they need to analyze, interpret, and draw conclusions about a particular phenomenon or situation.

Figure 1 illustrates the E-Module created using Flip PDF Professional, featuring an introductory description of the material that guides students in mathematical literacy within their daily lives. This E-Module, which facilitates mathematical literacy-based questions, is designed with procedures for solving mathematical literacy questions. It aims to simplify students' independent work

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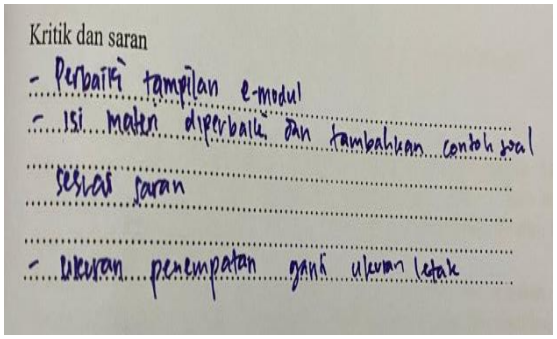
on mathematical literacy questions and enhance the learning process in schools.

In the **Development** phase, the E-Module is created using Flip PDF Professional software and published in HTML format for online access. This allows the Module to be opened on both computers and smartphones. The process of using Flip PDF Professional and operating the final product is not difficult, and it can be used even by those who are not familiar with HTML programming, as stated by (Seruni et al., 2019) . The resulting product will undergo validation by content validators, user validators, and media validators. After validation, any necessary adjustments to the E-Module will be made based on the feedback and suggestions provided by the validators.



Translate
Criticism and advice
- fix the Module view
- The content of the material was corrected and added examples as suggested.
- position size replacement position size

Figure 2. The Revised E-Module

According to the results of the E-Module revision by expert reviewers (see Figure 2), the E-Module is considered good. However, there are suggestions for making the appearance of the E-Module more engaging and communicating the use of language in the introduction to help users find solutions to mathematical literacy questions. This is intended to aid students in understanding the problems and enable them to solve them using procedures that incorporate mathematical literacy skills.

Furthermore, based on the assessments from the three expert product reviewers, the developed E-Module has achieved product validity and is deemed suitable for use with minor revisions and improvements, as per the recommendations of the validators. The E-Module received a validity score of 90% for content suitability, 89.58% for presentation, 90% for language, 100% for appearance, and 91.67% for user-friendliness. The average percentage of validity ratings is 92.25%, indicating that the E-Module based on mathematical literacy skills is highly valid. These results are consistent with previous research, which found that E-Modules created using Flip PDF Professional are suitable for learning with a percentage of 86.11% (Meliana et al., 2022).

In the **Implementation** phase, the validated E-Module is considered suitable for use by mathematics teachers and students. The objective here is to assess its practicality, which is evaluated through practicality questionnaires. This product trial aims to determine whether the developed product is effective and can be used in schools. To assess practicality, questionnaires are distributed to students and teachers, allowing for an evaluation of the developed teaching material's practicality in line with the research implementation (Razak et al., 2023).

Based on the sample selection tailored to the theory (Rayanto & Sugianti, 2020), which suggests conducting field trials with small groups of students,

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typically comprising 10-15 students, to assess the practicality and benefits of the developed instructional media, The practicality assessment by the students yielded practicality values for the E-Module as follows: ease of use aspect scored 90.83%, time efficiency aspect scored 87.5%, and benefit aspect scored 86.46%. The average percentage of practicality ratings is 88.26%, indicating that the E-Module based on mathematical literacy skills is highly practical. Consequently, observations during the learning activities show that students are delighted, especially as they use an E-Module for the first time. The presence of an E-Module with mathematical literacy-based questions, including example questions facilitating the problem-solving process, makes it easier for students to solve the given problems.

Similarly, based on the practicality assessment by mathematics teachers, the E-Module received practicality scores of 80% for user-friendliness, 87.5% for time efficiency, and 87.5% for usefulness. The average percentage of practicality ratings is 85%, indicating that the E-Module based on mathematical literacy skills is highly practical. Observations by teachers during the learning activities indicate that the E-Module is beneficial in various ways. It helps teachers deliver content and makes their role as facilitators more efficient. Teachers also noticed that students are enthusiastic about learning when using the E-Module. The research findings obtained are relevant to (Kurnia et al., 2019), who state that instructional materials are considered practical if the practicality assessment results fall into the "good/practical" category according to predefined criteria. If the results do not meet the practicality standards, improvements will be made based on the feedback provided by the respondents.

In the evaluation phase, the researcher conducts formative evaluations at each of the previous stages. (1) During the analysis and design stages, the researcher evaluates the work personally; (2) In the development stage, validation is carried out by experts to assess the validity of the E-Module based on mathematical literacy skills and gather feedback for improvement; (3) In the implementation stage, evaluation is based on the responses of the participants to assess the practicality of the E-Module. This approach aligns with the findings of previous research (Puspasari & Suryaningsih, 2019) that solely conducted formative evaluations. Formative evaluations are linked to the stages of research and development to enhance the resulting developmental product. Additionally, in this phase, the researcher assesses how students' attitudes change when using the E-Module. It helps determine whether the provided E-Module is effective in increasing students' knowledge and understanding.

4. Conclusions and Suggestion

Based on the research and data analysis conducted, it can be concluded that the E-Module with mathematical literacy-based questions on the topic of statistics is highly valid, with a validity rate of 92.31%. It is also practical, with a practicality rate of 85% according to teachers and 88.26% for students, which falls into the category of highly practical. This demonstrates that the use of the E-Module with mathematical literacy-based questions can be effectively utilized by both teachers and students in the learning process for statistics after being tested.

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Based on the research findings and conclusions, the following recommendations can be made:

1. The E-Module that was tested should be further implemented in all classes and schools.
2. The E-Module with mathematical literacy-based questions on the topic of statistics should be continued for further effectiveness assessments.
3. The E-Module with mathematical literacy-based questions on the topic of statistics, which is both valid and practical, can be used as a teaching resource for teachers when delivering statistics lessons to students in Grade X Phase E of high school.

The challenges faced during the research and development process included time constraints, particularly during the practicality testing, which limited the extent to which the E-Module's content could be effectively delivered to the students.

Author Contributions

All authors have sufficiently contributed to the study, and agreed with the results and conclusions.

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You're welcome! If you have any more questions or need further assistance in the future, feel free to reach out. Good luck with your research, and I hope your E-Module based on mathematical literacy skills proves to be a valuable resource for both teachers and students. Have a great day!

Declaration of Competing Interest

No conflict of interest is declared by authors.

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The Effect of Nanoparticles on Drug Distribution in The Mathematical Model of Blood Flow

Yolanda Norasia [1*], Ajeng Oxa Nisa [1], Sitti Rosnafi'an Sumardi [2]

[1]Department of Mathematics, Walisongo State Islamic University, Indonesia
[2]Department of Mathematics, Cendrawasih University, Indonesia

**Email Correspondence:* yolandanorasia@walisongo.ac.id*

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ABSTRACT

This research examines the influence of nanoparticles in the distribution of drugs in healthy blood flow on linear, angular velocity and blood temperature. Construction and simplification of a blood flow model based on boundary layer equations, dimensionless variables, stream functions, and similarity variables. The initial step is to establish a dimensional blood flow model. Using dimensionless variables, the equation is simplified into a dimensionless equation. A similarity equation is generated by converting the non-dimensional equation. The nanoparticles used are Cu, TiO_2, Al_2O_3. At the linear velocity and temperature of blood flow, Al_2O_3 is in the highest position. At the angular velocity of blood flow, the position of blood flow with Cu nanoparticles is in the uppermost position. This research is used to estimate the velocity and temperature of blood flow with the influence of nanoparticles as drug distribution.

1. Introduction

Mathematical modeling is part of applied mathematics. The formulation of mathematical models is used to find a solution to a problem, and can be applied in the applied sciences of physics, biology, and so on. An example of applying a mathematical model is fluid flow. The viscosity classification of fluids is divided into two, namely viscous fluids and inviscid fluids (Norasia et al., 2022). In terms of viscous fluids, blood falls into this category. Blood is in the human circulatory system and plays an important role in the internal transportation of the human body. Blood flow moves throughout the body to distribute oxygen and nutrients to all cells and body tissues. The blood flow media are blood vessels, namely arteries, veins, and capillaries. The blood flow velocity in the middle and edges

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of the artery is the same in laminar flow(Saqr et al., 2020). Mathematical models regarding bone tissue blood flow are solved using computational fluid dynamics (D. Ali & Sen, 2018). Blood flow with constant pressure boundary conditions at the coronary ostium is solved using computational fluid dynamics (Yoshikawa et al., 2020). Modeling blood flow in viscoelastic vessels can be used to model human circulation in arteries and veins (Bertaglia et al., 2020). Mathematical modeling of blood flow through three different types of stenosis shows nonnewtonian behavior can influence blood flow behavior (Owasit & Sriyab, 2021). Mathematical models of blood flow with hematological disorders show that changes in hematocrit values can significantly influence the physical quantity and volumetric flow rate(Karthik et al., 2022). Mathematical models of blood flow in stenosis show that velocity increases as the angle of inclination increases (Dhange et al., 2022). The Navier-Stokes equations in blood flow can be solved using the finite difference method (Hu et al., 2023).

Nanotechnology is the science that studies the manipulation of materials on the atomic and molecular scale. Nanoparticles are one of the main applications of nanotechnology. Nanoparticles have sizes between one and 100 nanometers. The physical and chemical properties in the form of electronic, magnetic and thermal stability of nanoparticles make them superior to large-sized materials (Fahmi, 2020). Nanoparticle size is used to control particle size, surface properties and release of active substances in drug delivery systems. Nanoparticles added to the base fluid are called nanofluids. Al_2O_3 nanoparticles can increase friction by 67 percen (Wei et al., 2021). The influence of the Eckert number and nanoparticles causes the fluid temperature to increase (Gul et al., 2021). Nanofluid research carried out by comparing metal particles and metal oxides shows that metal oxides move faster than metal particles (Norasia et al., 2023).

In the medical field, nanoparticles are widely used for diagnostic and therapeutic purposes. Gold (Au) nanoparticles can be used for drug delivery, cancer detection, and photothermal therapy (Singh et al., 2018). The effect of Cu, TiO_2, Al_2O_3 particles can increase blood flow velocity in blocked blood vessels (Zaman et al., 2019). Mathematical models of blood flow show that the length of blood vessels can influence blood pressure (Khalid et al., 2021). Blood flow with nanoparticle suspension through blood clot arteries shows that as the size of the clot increases, the blood temperature also increases (Shah & Kumar, 2020). The application of nanoparticles is important for further development. The ability of nanoparticles as drug distribution is interesting to research. Treatment efficacy is increased by targeting diseased cells and avoiding healthy cells with nanoparticles (Yusuf et al., 2023). This research aims to look at the linear velocity, angular velocity, temperature and pressure of blood flow with the addition of particles Cu, TiO_2, Al_2O_3. The blood flow medium is a porous artery without any blockages. The model building process starts from dimensional similarities, non-dimensional similarities, and similarities. The similarity equation is solved using the Thomas and Backward Euler Algorithms.

2. Method

This research involves physics and mathematics approaches in building a blood flow model, so there are research stages as follows.

2.1. Mathematical Model Construction

In this research, a mathematical model was built including continuity,

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momentum, and energy equations. The model equation obtained is then simplified into a non-dimensional equation with non-dimensional variables. The non-dimensional equation obtained was substituted for the nanoparticle and base fluid variables. In this research, nanoparticles and blood as base fluid were used with the following parameter values.

Table 1. Nanoparticles and Basic Fluid Parameters/Blood (Ahmed & Nadeem, 2016) (Ali et al., 2022)

Parameters	Al_2O_3	TiO_2	Cu	Blood
Density (ρ)	3970	4250	8933	1063
Spesific Heat (c_p)	765	686.2	385	3594
Conductivity (k)	40	8.9538	400	0.492

Taking the boundary layer approach, using the flow function, and using the similarity variables, the equation becomes one variable (similarity). The following is the equation for the boundary layer approach, flow function, and similarity variable.

Boundary layer equation (Saeed et al., 2021)

$$Re \to \infty, Re = \frac{r\alpha u}{v_f} \quad (1)$$

with
Re is Reynolds number

Stream function (Ullah et al., 2020)

$$u(x,y) = \frac{\partial \psi}{\partial y}, v(x,y) = -\frac{\partial \psi}{\partial x} \quad (2)$$

with
ψ is stream function variables
u, v is velocity of blood flow

Similarity Variables (Alsenafi & Ferdows, 2022)

$$\psi = F(x,Y,t)u\,(x)r(x) \quad (3)$$

with
u_e is velocity of free flow
r is radius of the porous medium

3. Results and Discussion

This research discusses the development of a blood flow model with the addition of nanoparticles for drug distribution. By Building continuity, momentum, and energy equations by applying the laws of physics of Lavoisier, Newton, and thermodynamics. The addition of nanoparticles in the bloodstream is measured through density ρ_{fn} and viscosity μ_{fn}. Then the microrotation ability of the blood flow is measured using the microrotation parameter N. The mathematical model of blood flow forms four, the first is the continuity equation, namely the rate of mass change is constant. Second, the linear momentum equation which is influenced by pressure p, magnetic parameters B, and gravity on the x-axis g_x

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and y-axis g_y. Third is the angular momentum equation, namely the existence of microrotation in the blood which is influenced by γ , $\mathcal{J}$. Fourth, the energy equation is influenced by heat diffusivity α to temperature T of blood flow. The dimensional equations of continuity, momentum, and energy are respectively obtained as follows.

1. $\frac{\partial ru}{\partial x}+\frac{\partial rv}{\partial y}=0$
2. $\rho_{fn}\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial p}{\partial x}+\left(\mu_{fn}+k\right)\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+\sigma B^2 u-\rho_{fn}(T-T_\infty)\,g_x+k\frac{\partial N}{\partial y}$
3. $\rho_{fn}\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial p}{\partial y}+\left(\mu_{fn}+k\right)\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+\sigma B^2 v-\rho_{fn}(T-T_\infty)\,g_y+k\frac{\partial N}{\partial x}$
4. $\rho_{fn}\,\mathcal{J}\left(\frac{\partial N}{\partial t}+u\frac{\partial N}{\partial x}+v\frac{\partial N}{\partial y}\right)=\gamma\left(\frac{\partial^2 N}{\partial x^2}+\frac{\partial^2 N}{\partial y^2}\right)-k\left(2N-\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y}\right)$
5. $\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)$

(4)

The boundary conditions of the model are.

$t=0, u=v=0, N=0, T=T_\infty$ when x, y

$t>0, u=v=0, T=T_w, N=-N\frac{\partial u}{\partial t}$ when $y=0$

$u=u_e(x), u=v, N=0, T=T_\infty$ when $y\to\infty$

The next step is to approach the boundary layer (1), flow function (2) and similarity variable (3), equation (4) becomes the similarity equation for linear, angular momentum and temperature respectively as follows.

1. $\frac{(1+K)}{\left((1-\chi)+\chi\left(\frac{\rho_s}{\rho_f}\right)\right)(1-\chi)^{2.5}}\frac{\partial^3 F}{\partial Y^3}+K\frac{\partial H}{\partial y}+\frac{3}{2}\cos x\left[-\left(\frac{\partial F}{\partial Y}\right)^2+2F\frac{\partial^2 F}{\partial Y^2}+1\right]=\frac{\partial^2 F}{\partial t\partial Y}+\frac{3}{2}\sin x\left[-\frac{\partial F}{\partial x}\frac{\partial^2 F}{\partial Y^2}+\frac{\partial F}{\partial Y}\frac{\partial^2 F}{\partial x\partial Y}\right]+\left(1-\frac{\partial F}{\partial Y}\right)M-\frac{2}{3}\lambda S$
2. $\left(1+\frac{K}{2}\right)\frac{\partial^2 H}{\partial Y^2}+\frac{3}{2}\cos x\left(-H\frac{\partial F}{\partial Y}+2F\frac{\partial H}{\partial Y}\right)=\frac{\partial H}{\partial t}+K\left(\frac{\partial^2 F}{\partial Y^2}+2H\right)+\frac{3}{2}\sin x\left(\frac{\partial H}{\partial x}\frac{\partial F}{\partial Y}+\frac{\partial H}{\partial Y}\frac{\partial F}{\partial x}\right)$
3. $\left(\frac{k_s+2k_f-2\chi(k_f-k_s)}{k_s+2k_f+\chi(k_f-k_s)}\frac{1}{\left((1-\chi)+\chi\left(\frac{\rho_s}{\rho_f}\right)\right)}\right)\frac{\partial^2 S}{\partial Y^2}+3\cos x\,Pr\,F\,\frac{\partial S}{\partial Y}=Pr\,\frac{\partial S}{\partial t}+\frac{3}{2}\sin x\,Pr\,\left(\frac{\partial S}{\partial x}\frac{\partial F}{\partial Y}-\frac{\partial S}{\partial Y}\frac{\partial F}{\partial s}\right)$

(5)

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The boundary conditions of the model are.

$F = \frac{\partial F}{\partial Y} = 0, H = -n\frac{\partial^2 F}{\partial Y^2}, S = 1$ when $Y = 0$

$\frac{\partial F}{\partial Y} = 1, H = 0, S = 0$ when $Y \to \infty$

In the similarity equation above, the Backward Euler numerical approach and the Thomas Algorithm are carried out. Then simulated linear, angular velocity and blood temperature. The aim of this research is to look at the linear, angular velocity and blood temperature when distributing drugs using nanoparticles Al_2O_3, TiO_2, Cu.

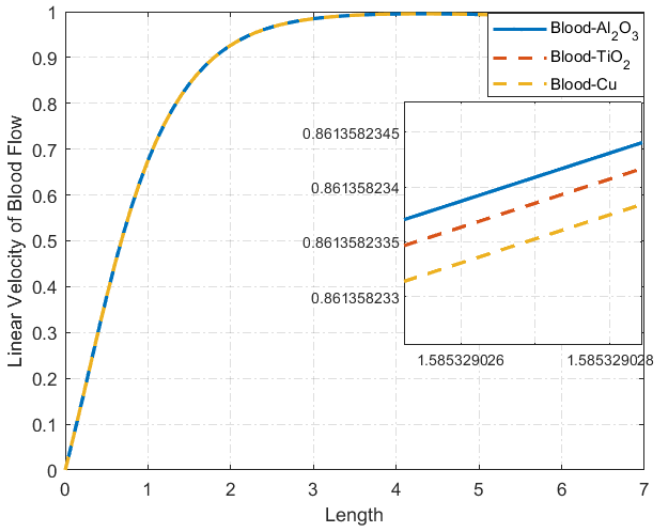

Figure 1. Linier Velocity of Blood Flow

Figure 1 shows the linear velocity of blood flow with the addition of nanoparticles Al_2O_3, TiO_2, Cu. The blue line shows blood flow with the addition of nanoparticles Al_2O_3. The red line shows blood flow with the addition of nanoparticles TiO_2. The orange line shows blood flow with the addition of nanoparticles Cu. Each nanoparticle moves at the same linear velocity, namely from zero to one. That is, the linear velocity of movement increases in the bloodstream. By enlarging the image scale at a distance between 1.585329026 to 1.585329028, it can be seen that the blue line is at the top position, in other words the linear velocity of blood flow with the addition of Al_2O_3 nanoparticles moves faster than the other two particles (TiO_2, Cu). The density of Al_2O_3 particles is 3970, which is the smallest density. Due to this, blood flow with Al_2O_3 nanoparticles is at its highest velocity.

Figure 2 shows the angular velocity of blood flow with the addition of nanoparticles Al_2O_3, TiO_2, Cu. The angular velocity of blood flow with each nanoparticle moving is the same, namely experiencing microrotational movement from zero to a peak at a distance of two and decreasing. Blood is a category of microrotational fluid, so that blood flow has an angular velocity. By enlarging the image scale to a distance of 1.9566964551, it can be seen that the orange line is at the top position, in other words the angular velocity of blood flow with the addition of Cu nanoparticles moves faster than the other two particles (TiO_2, Al_2O_3). The density of particle Cu is 8933, which is the largest density. The opposite of linear velocity, at angular velocity Cu particles move

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faster. The greater the density, the more nanoparticles. As a result, microrotation becomes greater, and the angular velocity of blood flow with Cu nanoparticles also moves greater than other particles.

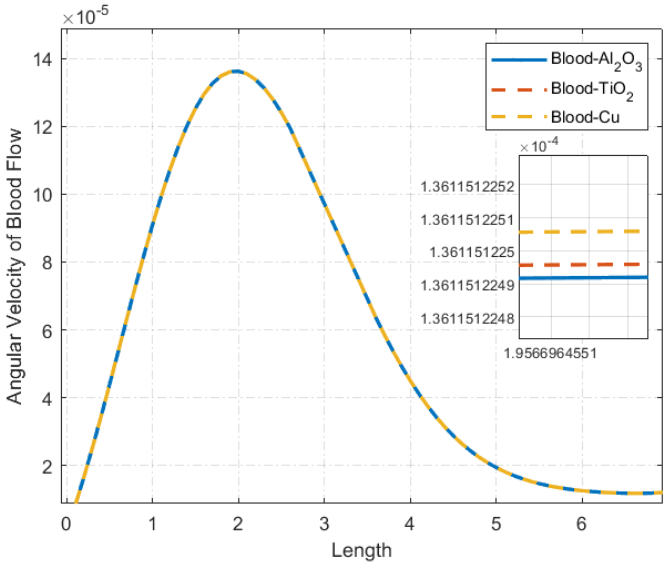

Figure 2. Angular Velocity of Blood Flow

Figure 3 shows the blood flow temperature with the addition of nanoparticles Al_{2O_3}, TiO_2, Cu. The temperature of the blood flow with each nanoparticle moves the same, namely experiencing microrotation movement from one to zero.

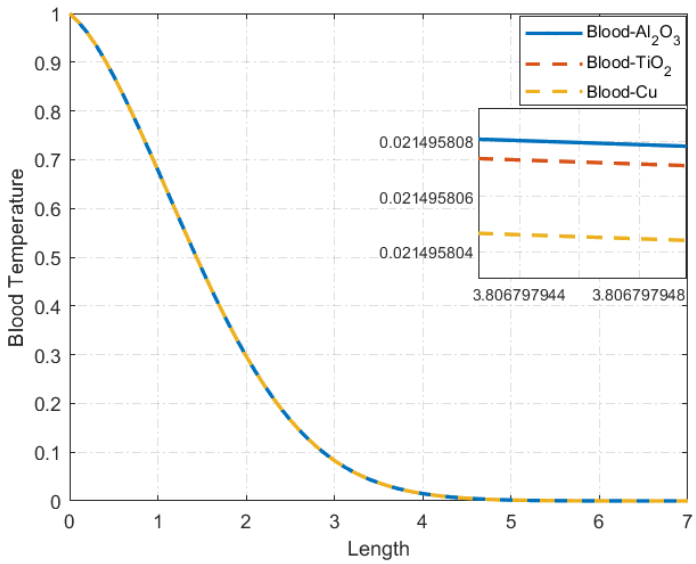

Figure 3. Blood Temperature

In other words, blood temperature decreases. By magnifying the image scale at a distance of 3.806797944, you can see the blue line at the top position, in other words the blood flow temperature with the addition of nanoparticles Al_2O_3 moves faster than the other two particles (TiO_2, Cu). Specific heat of particles Al_2O_3 is 765, which is the largest specific heat. An increase in temperature arises due to the energy that appears in a unit mass of a substance. As a result, the temperature of the blood flow with nanoparticles Al_2O_3 at highest position.

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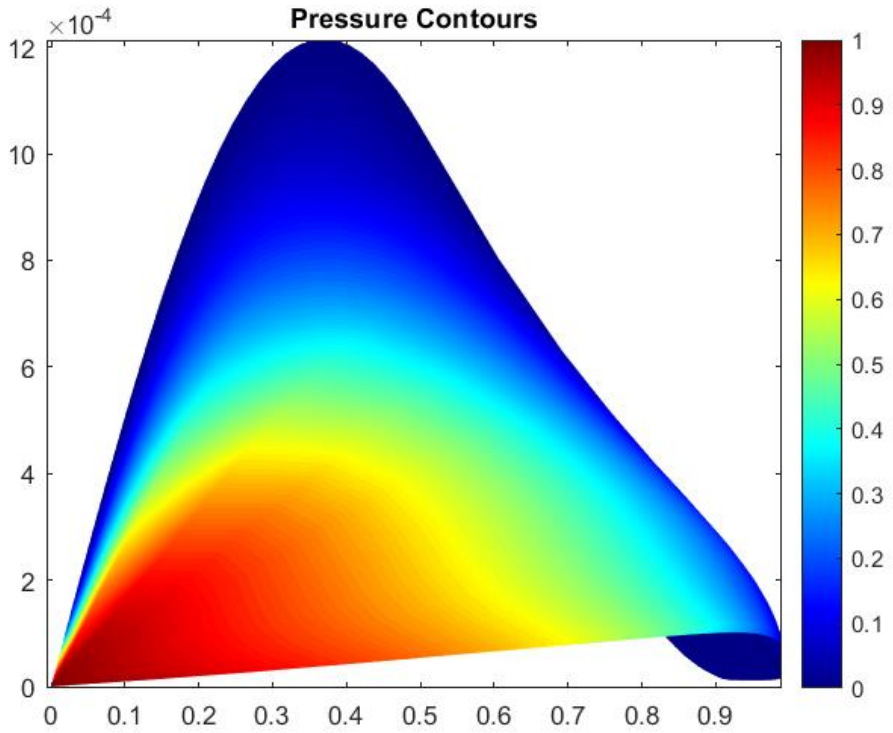

Figure 4. Pressure Blood Flow

Figure 4 shows blood flow pressure based on linear and angular velocity. Blood pressure moves from zero to a peak at a distance of 0.4 and decreases towards zero. Blood flow pressure increases at a peak of 0.4 and decreases at 0.9. Nanoparticles can interact with the blood flow to change the flow dynamics and pressure in the flow system. The more nanoparticles in the blood flow can cause an increase in pressure at certain points in the flow.

4. Conclusions

This research builds a mathematical model of blood flow by adding nanoparticles as drug distribution to the linear, angular velocity and temperature of blood flow. The model construction obtained is then simplified into non-dimensional equations and similarity equations. Numerical solution to the similarity equation uses the Backward Euler method. The simulation results show that if we want to accelerate linear velocity and increase blood flow temperature, we can use drug distribution with nanoparticles Al_2O_3. If we want to accelerate up the angular velocity, we can use nanoparticles Cu. In this case, blood flow can be modeled using the nanoparticle effect in a two-dimensional way. Blood flow can become turbulent in some areas of blood vessels. Two-dimensional models are able to properly model the turbulence phenomena that can occur in blood flow. The research can be developed in a three-dimensional environment.

Author Contributions

First author and second author contributed to construct the model and simplifying it into a similarity equation. First author and third author contribute to the solution of numerical method. All authors contributed to the analysis of

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the simulation results. Reviewers and journal editors provided feedback to the first author for the revision of the article.

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Declaration of Competing Interest
The author declares that this research has no conflicts of interest reported in this article.

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Mathematical Representation Ability-Based Mathematical Contextual Problems of Sequences and Progression Material

Lis Diana Sri Wahyuning[1*], Nida Sri Utami[1]

[1]Department of Mathematics Education, Universitas Muhammadiyah Surakarta, Indonesia

*Email Correspondence: a410200187@student.ums.ac.id

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ABSTRACT

This research objective is to analyze and explain the student's capacity for mathematical representation based on mathematical contextual problems of arithmetic and geometric sequences and progression material. Students enrolled in SMA 1 Sukoharjo X.E10 were the subject of this research. The data collection process used interviews, tests, and documentation. This research used a descriptive research approach with a qualitative research type. Based on the findings of this research, students who have visual representation skills in mathematics are more likely to complete challenges that involve visuals, such as diagrams. Typically, mathematically symbolic representation-capable pupils utilize mathematical formulas and symbols to solve problems. Furthermore, students who have the ability to verbally represent mathematics have a tendency to encrypt problem-solving steps into words.

1. Introduction

Indonesian mathematical ability is still not optimal. According to (OECD, 2023:426), the average math score in PISA 2022 was 366, which fell by 13 points compared to the average math score in PISA 2018. In addition, a study from TIMMS in 2015 showed that Indonesia's average math score was 397, ranking 44 out of 49 countries, with the average score of the whole country being 500 (Mullis et al., 2016). This shows that Indonesia's average math score is still below the international average. Mathematics is one of the most helpful studies for developing intelligence because it prepares students for the changing state of life

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through mathematical thought patterns (Azkiah & Sundayana, 2022) . Thus, each individual must master mathematics well.

Understanding mathematics participants' education can be influenced by several factors to obtain optimal learning results. Various factors cover external and internal factors. External factors influence the understanding of mathematics, including learning methods, models, and strategies (Diana et al., 2020) . According to Nisa & Muhtar (2022), an appropriate learning model is needed to give students an understanding of the material.

Beyond the previously mentioned external elements, the student's internal factors also influence mathematical learning outcomes. According to the National Council of Teachers of Mathematics (2000), there are five mandatory learning process standards mastered by students, namely: 1) ability to solve the problem; 2) mathematical references and proof; 3) communication skills; 4) linking idea skill; and 5) representation skill. Mathematical representation ability is one of the skills a student must have to solve a math problem. When studying math, students are encouraged to focus on various forms of mathematical representation to address the mathematics problem properly (Afriyani et al., 2018) .

Mathematical representation is one of the components that deal particularly with the student's cognitive development in the learning process. Mathematical representation is a process of interpreting a problem by developing a student's mindset, which is a mathematical knowledge-building and abstraction process (Umbara et al., 2020) . Niss & Højgaard (2019) describe the ability of mathematical representation as the ability to interpret an object of mathematics or phenomena into symbols, verbal, graphic, diagrams, or visuals to correct a mathematical problem. Yudhanegara & Lestari (2015) point out three aspects of the present's mathematical ability: mathematical visual, symbolic, and verbal representation. The mathematical representation ability of a student is low. This matter was expressed by Fitrianna et al. (2018), who said that students have low mathematical representation ability because of difficulty presenting data according to the description provided.

Mathematical representation ability can be developed through context-based learning (Clarke & Roche, 2017) . Problem solving based contextual problems require exellent mathematical representation ability. Student's ability to solve contextual based math problems can thus encourage students them to discover a mathematical concept and idea independently and contribute to the student learning process (Priyadi & Yumiati, 2021) .

Students can develop their knowledge and skills by studying mathematics-based contexts. Contextual problems are those related to activities in daily life (Achir et al., 2017) . The contextual problems containing daily life activities require students to interpret problems into mathematical forms to be solved to obtain a solution. Contextual problem-solving needs to manipulate reading ability and interpret a problem for reference to mathematical concepts (Pradana & Murtiyasa, 2020). It is also supported by Anditiasari (2020) research that math requires problem-solving ability as well as mathematical storytelling, and good literacy ability is required.

Based on an interview with one of the mathematic's teacher at SMA N 1 Sukoharjo, previously never experienced the problem of mathematical representation capability on students but that math learning has already been linked to real-life contexts. Thus, researchers will research to identify the

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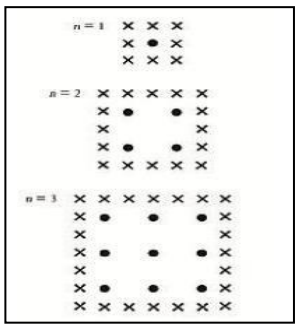
student's mathematical representation ability with a contextual problem based on mathematics.

2. Method

This research uses a qualitative research model with a descriptive method. Sutama et al. (2022) mention that qualitative studies are conducted to obtain in-depth and meaningful data. Research data retrieval was performed at SMA N 1 Sukoharjo with the subject of 34 students in class XE 10. Thirty-four subjects were given a mathematical representation test based on contextual problem solving to identify the type of mathematical representation capability about that visual, symbolic, and verbal representation capability. Furthermore, six subjects were selected according to their mathematics representation ability: two subjects capable of representing visual mathematics, two subjects capable of representing mathematical symbolism, and two subjects capable of representing verbal mathematics. To strengthen primary data by providing analytical descriptions to students in solving problems, interviews were conducted. The data obtained was analyzed using reduction and representation data, and drawing conclusions (Miles & Huberman, 1992).

Tests for obtaining primary data on student representation capabilities on contextual problems with material sequence and progression arithmetic and geometry. Math teachers and professors verify instrument resources before being tested to students. The instrument test used in research is displayed in the following Table 1:

Table 1. A Contextual Problem of Sequence and Progression Arithmetic and Geometry

No.	A Contextual Problem of Sequence and Progression Arithmetic and Geometry
1.	At the SMA N 1 Sukoharjo anniversary, the Student Council cheered him up. One of the Student Council races was a softball. The student council is stacking six cans. The top or first row has as many as 2 cans. The second row has 4 cans. The third row has 6 cans and so on with the same row pattern. Danang is in the race. In order for Danang to win the race, a strategy is needed. a. Write the completion plan if Danang wants to calculate the total number of cans that were dropped! b. If Danang can drop down all of the cans, then the total number of cans that were dropped was 56. Right or wrong? Give a reason!
2.	**My Beautiful Garden**  × is a stained-glass; ● is a plant flower Each student at SMA N I Sukoharjo will contribute to the school's backyard by planting flowers. They give the flower a stained-glass bottle around it to give it

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No.	A Contextual Problem of Sequence and Progression Arithmetic and Geometry
	an aesthetic appearance. The arrangement of the bottle and its flowering plant is like the picture of the pattern above. Flower planting and the tunneling continued like the above pattern until it found a specific n that caused the same number of flowering plants and glass bottles. a. Can you find the math process and tell me how many of them are n? b. Draw a diagram of the bar number of glass bottles and the number of flowering plants toward n!
3.	Ana is a religious novelist. In January, the novel sold 3 copies, in February it sold 6, in March it sold 12. As of August, the number of sales increased exponentially from previous sales. If the price of the novel was Rp78,000 and she sold it for Rp88,000, a. What is Ana's profit in sales for 8 months? b. Draw a line diagram of the profit Ana gets each month!

The test results are scored according to the rubric for assessing mathematical representation skills according to Cai et al. (1996) to determine the predicate of students' mathematical representation ability in solving mathematical contextual problems. In addition, the problem-solving process carried out by students based on aspects of their mathematical representation ability will be described based on mathematical representation indicators. Researchers combine and triangulate all existing data from test results of mathematical representation ability about contextual problems and interviews in the analysis process. In this research, test and interview instruments are based on the mathematical representation adaptive of the Rista et al. (2019) indicators as presented in the following Table 2:

Table 2. Aspects and Indicators Representation Mathematical

No.	Aspect Representation	Indicator
1.	Visual representation	Presents data, or information in a visual representation form (of charts, diagrams, and tables) to solve problems.
2.	Symbolic representation or expression	To solve issues using mathematical concepts and expressions to construct symbolic models or equations.
3.	Verbal representation	To solve the problem using words and write the steps to resolve it.

3. Results and Discussion

Based on the results of the representation ability test of mathematics based on contextual problems, the development of mathematics test shows that the student is ranked into the three aspects of representation, as in the following Table 3:

Table 3. Category Student According to Aspect Representation Mathematical

Aspect Representation Mathematical	Frequency	Percentage (%)
Mathematical visual representation	6	17.65%
Mathematical symbolic representation	10	29.41%
Mathematical verbal representation	18	52.94%
Total	34	100%

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Table 3 above shows, the distribution of representation abilities of mathematics based on some aspects. Most students' ability represents verbal mathematics, amounting to 52.94%. Whereas students who can picture mathematical symbols were 29.41%. Students who can represent visual mathematics have the smallest amount, only 17.65% of the total. Each student has a different problem-solving, so the representation ability also varies. The statement is backed by research by Huda et al. (2019), who found that every student has unique competencies to finish a problem.

3.1 Mathematical Visual Representation

The student who has mathematical visual representation capability tends to solve contextual problems by using diagrams such as the problem-solving in the students shown in the following Figure 1 and Figure 2.

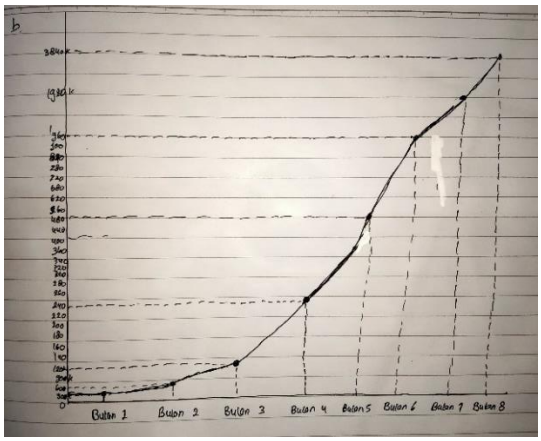

Figure 1. Problem-solving 1 by EAB student

Figure 1 and Figure 2 indicate that EAB students can interpret contextual problems into diagram pictures. The diagram drawn by the EAB student shows that consistent intervals of coordinates result in a corresponding line diagram and bar diagram. In addition to being able to place the correct X and Y coordinates. EAB students who prefer problem-solving rather than procedural, supported by analysis of interview results.

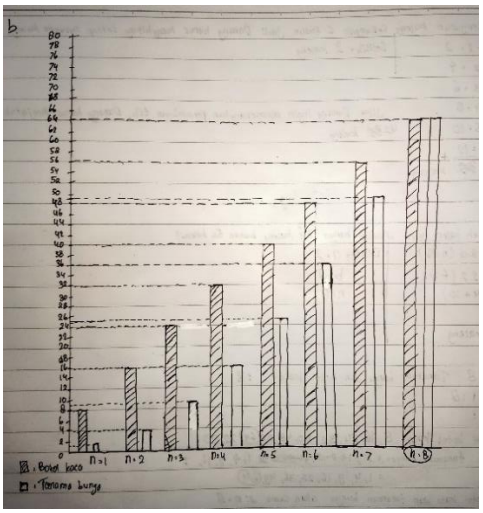

Figure 2. Problem-solving 2 by EAB student

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Here is a transcript of the interview with EAB students.

P : "Which issue do you think is the easiest one?"
EAB : " The question asked to draw the ma'am, questions 2b and 3b?"
P : "Why do you find it easy to solve the problem?"
EAB : " Because I feel it easier than counting by the formula."
P : "Do you understand this diagram that you drew?"
EAB : " I understand it, ma'am."
P : "Please, try to figure out the diagram you have made."
EAP : "The profit for the sale of novels in January was thirty thousand rupiahs, the profit for the sale of novels in February sixty thousand rupiahs, until August that kept rising in profits."

Students with the ability of a mathematically visual representation could solve visualization problems correctly. Images are produced in detail to produce an accurate diagram. Reinforced by the findings of Marifah et al. (2020), students with mathematical visual representation capabilities are more likely to be meticulous and more detailed in manufacturing charts and diagrams included in title writing and identification on the charts. Students with mathematical visual representation capabilities are more likely to solve visual problems.

4.1 Mathematical Symbolic Representation

Students with mathematical symbolic representation capability are more likely to solve the problem by using formulas, symbols, and mathematical expressions, such as problem-solving by students shown in the following picture 3:

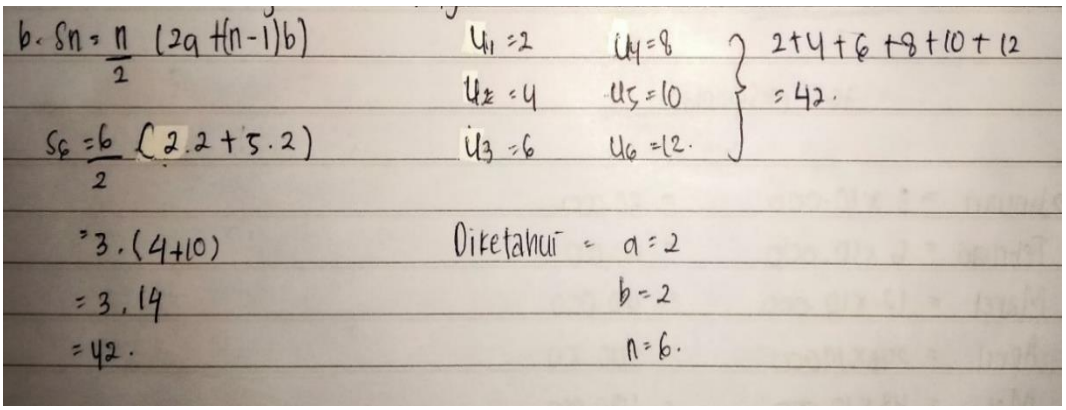

Figure 3. Problem-solving by HRM students

Figure 3, indicate that students with mathematical symbolic representation abilities are likelier to use mathematical symbols. By writing it using mathematical symbols, HRM students could demonstrate what is already known. Problem-solving also involves a systematic approach. These results were supported by interviews of HRM students with transcripts as follows:

P : "Would you prefer a matter that is calculated with a formula or a matter that is related to drawing like a drawing a diagram or chart?"
HRM : "Preferable direct calculation enters to formula, ma'am."
Q : " Why ?"

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HRM : "For when it comes to formula, only the number counts."
P : "Do you find it more difficult to solve question numbers 2b and 3b that were told to draw the diagram than the rest?"
HRM : "Yes, ma'am. I found it difficult to draw the diagram."

Students with symbolic representation ability solved the problem by writing mathematical symbols. In addition, the student solved the problem by using systematic steps, formulas, and calculations. This is supported by Komala & Afrida (2020) research that students with symbolic representation ability can solve the problem by presenting it in the form of a mathematical model of algebra or mathematical expression. Students prefer solutions using the available formulas rather than using mathematical concepts.

5.1 Mathematical Verbal Representation

Students with mathematical verbal representation abilities are more likely to solve the problem with phrased sentences, such as the result of the SKF student problem described in Figure 4 as follows.

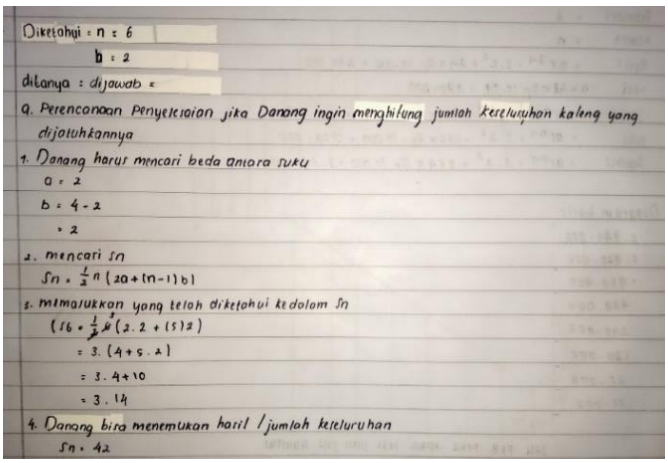
Diketahui : n = 6
b = 2
ditanya : dijawab =
a. Perencanaan Penyelesaian jika Danang ingin menghitung jumlah keseluruhan kaleng yang dijatuhkannya
1. Danang harus mencari beda antara suku
a = 2
b = 4 - 2
= 2
2. mencari Sn
$Sn = \frac{1}{2} n [2a + (n-1)b]$
3. memasukkan yang telah diketahui kedalam Sn
$(S6 = \frac{1}{2} 6 (2.2 + (5)2)$
$= 3.(4+5.2)$
$= 3.4+10$
$= 3.14$
4. Danang bisa menemukan hasil / jumlah keseluruhan
Sn = 42

Figure 4. Problem-solving by SKF students

Based on Figure 4 above, students with mathematical verbal representation abilities tend to solve mathematical problems using new words followed by mathematical symbols. This is like when the teacher gives an oral explanation to the student about the steps of problem-solving. According to Huda et al. (2019) research, students with the ability to mathematical representation can generally resolve problems using mathematical problem-solving measures using words and writing an interpretation of a representation. The analysis of the problem is supported by an interview with SKF students with transcripts as follows:

P : "Would you prefer a problem where you finish using a description sentence, mathematical formula, or drawing?"
SKF : "Prefer the one with the word ma'am."
P : " Why so? "
SKF : "Because if counting, I am confused about calculating it, and if I looked at the picture, I did not know what it looked like, ma'am. If with the sentences, I feel easy to remember it."

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Students with mathematical verbal representation abilities tend to solve mathematical problems using sentences or words. Students write phrases such as new oral explanations followed by mathematical symbols if available because explanations in sentences are more accessible for students to remember than symbolism and other visuals. According to Wati et al. (2019), who found that students who tend to be able to absorb learning conducted by teachers through verbal teaching can write mathematical sentences correctly. In addition, research by Wati et al. (2019) also mentioned that verbal representation ability does not have work steps but only directly writes the answer to the problem.

4. Conclusions

Based on the results of this research, the mathematical representation abilities of students based on contextual problems are different. Students with mathematical visual representation abilities are more likely to be able to solve visual problems, such as drawing diagrams with accurate results. Students with mathematical symbol representation abilities are more likely to solve mathematical problems using mathematical symbols and a systematic approach to completion. Students with mathematical verbal representation capabilities are more likely to solve the problem using words or words like verbal explanations.

In the conclusions and recommendations of the conducted research, it is suggested that future investigations broaden the scope of the assessment instrument to include arithmetic and geometric sequences and progression material. This would enhance the precision and specificity of the predicate about mathematical representation ability. Future researchers can also conduct research with mathematical problems with other materials in order to assess the degree of proficiency in mathematical representation and discuss strategies for improving the mathematical representation skills of students deemed to be deficient.

Author Contributions

The first authors contributed to formulating research, designing research methods and instrumentation. In addition, the first writer also acted as an observer, analyzing data produced by research, documenting, and textual writing. The second author acted as an advisor both in the text and in the process of extracting data from research.

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Declaration of Competing Interest

According to the author, there was no conflict of interest in this research.

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