Prediction Ability of College Students in Solving Graph Problems

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Abstract: The capacity to generate prediction is indispensable in daily existence, particularly amidst the swift transformations that are occurring on a global scale. Therefore, this study aimed to analyze the levels of prediction ability among mathematics students when presented with data in graphs. A qualitative approach was adopted, involving 37 mathematics students, using task-based tests and interviews as data collection techniques. The results showed that the ability of most students to make a prediction based on the Covid-19 graph was at a multi-structural level of 35.14%. This level was characterized by students making predictions based on the trends of the pandemic graph patterns, but they tended to overlook the overall patterns. The prediction generated at the *unistrutural, multistructural, relational, and extended abstract levels was considered reasonable because of the graph or data provided. These findings indicated the existence of predictive reasoning conducted by students in making predictions of problems related to the Covid-19 graph. The insights gained into the prediction ability prompted teachers to enhance graphic literacy instruction, to equip students with the skills needed to thrive in the 21st century.*

Keywords: *Prediction, Ability, Graph, SOLO Taxonomy*

INTRODUCTION

The ongoing development of technology and information in the industrial revolution 4.0 has made data more widely available and easily accessible to many individuals (Duijzer et al., 2019; Ramadhani et al., 2022; Sima et al., 2020). This increased access has resulted in a growing demand for the processing and interpretation of data. Despite the copious amount of readily available data, its utility remains unrealized in the absence of adequate processing and analysis. Therefore, the ability to process and interpret data is becoming increasingly critical in the era of the industrial revolution 4.0 (ÇİL & Kar, 2015; Ergül, 2018a; Oslund et al., 2021).

Data are usually presented in the form of table or graph (Ergül, 2018a; Friel et al., 2001). Graphs, in particular, serve as practical forms of representation that enable the gathering and derivation of new knowledge from complex data, as well as the summarization of data sets, among other uses (Uzun et al., 2012). They possess the ability to present information quantitatively in a manner that is often more comprehensible than data presented narratively or descriptively (Kilic et al., 2012). Furthermore, graph is capable of presenting quantitative information useful for decision-making purposes (Okan et al., 2019). By aiding in the comprehension and analysis of data through visualization and representation of variations, patterns, and trends, graphs play a crucial role (Glazer, 2011; Kukliansky, 2016). Therefore, graph is an important part of daily life since it is used in different contexts (González et al., 2011).

Currently, graph has become ubiquitous in daily life, as it can be found in various mediums, including newspapers, magazines, articles, online news, and televised news (ÇİL & Kar, 2015). Moreover, it is frequently utilized to present information about election results, and public reports on topics such as education and health. Graph is also used in various subject disciplines, such as geography, economics, health, science, and mathematics (ÇİL & Kar, 2015; Ergül, 2018a; Lai & Hwang, 2016). The significance of graph in statistical education is also noteworthy (Franklin et al., 2007; NCTM, 2000), playing a fundamental role in mathematics curriculum (Ozmen et al., 2020). In mathematics, drawing, interpreting, and analyzing graphs are basic skills expected to be achieved by students (NCTM, 2000). Graph is considered as a fundamental component of mathematics, and educational programs place a strong emphasis on the need for students at all levels to develop their graphing skills (Uzun et al., 2012). These skills require abilities such as visual perception, logical reasoning, plotting po ints from data or function rules, predicting the movement of the connecting line, and determining the relationship between variables (Uzun et al., 2012). However, when invalid information is provided, a serious loss may be encountered by the individuals or organizations who make straight decisions based on the graph without conducting a proper analysis. Graph literacy skills are then needed to avoid decision making mistakes (Galesic & Garcia-Retamero, 2011).

Graph literacy is a very important skill in the 21st century (ÇİL & Kar, 2015; Duijzer et al., 2019; Glazer, 2011). It is part of the high-order thinking skills, required to be mastered in the current era (Duijzer et al., 2019a).Furthermore, the concept refers to a person's ability to evaluate and extract data presented in graphical form (C.M et al., 2020; Galesic & Garcia-Retamero, 2011). These include making an interpretation of graphical representations, drawing relationships between variables on the horizontal and vertical axes, such as for time and distance, making graphical representations, critically evaluating data represented in graphs, using graphs to communicate findings to others, and making comparisons (Boote, 2014). Graph literacy is also very important in mathematics lessons, such as when teaching students about linear functions (Watson & Kelly, 2008).

Assessing graph literacy involves a range of skills, encompassing not only comprehension of data but also the ability to draw inferences and identify connections between presented data, as well as extrapolate beyond the provided information (Friel et al., 2001, 2001; Zeuch et al., 2017). The aptitude for reading involves extracting relevant information from graphical representations, while the ability to read between denotes the capacity to discern correlations and interrelationships among the data displayed. Moreover, the ability to read beyond the data presented entails the capability to make informed prediction and draw well-supported conclusions (Boote, 2014; Curcio & Artzt, 1997; Friel et al., 2001; González et al., 2011; Monteiro & Ainley, 2003, Thuy & Le Phuoc, 2023).

The ability to make prediction is a crucial skill in anticipating future outcomes, particularly in the realms of education and daily life (Katarína & Marián, 2017a; G. Oslington et al., 2020). Prediction is essential for decision-making (Okan et al., 2019; Oslund et al., 2021) to potentially prevent the occurrence of future errors (Katarína & Marián, 2017b). In the context of learning mathematics, prediction-making provides an opportunity to establish connections between mathematical concepts. By predicting outcomes, students can connect prior concepts with new ones, enhancing their learning experience (Kim & Kasmer, 2007a; G. Oslington et al., 2020). Through prediction, they develop critical thinking skills by observing data and drawing conclusions from the given information (Thaiposri & Wannapiroon, 2015; Uzun et al., 2012). Students also improve their understanding of concepts and can improve students problem-solving skills by making predictions. Teachers can improve their students' understanding of mathematical concepts and enhance their problem-solving skills by promoting prediction-making on graph. Furthermore, they can enhance their teaching skills by involving students in activities related to graphing to develop learning strategies more effective and responsive to the needs of students.

The ability to predict data presented in graphical form is a valuable skill that holds significant importance for society. The process of generating patterns from graphical data remains challenging, requiring a high level of graphic literacy (Harsh et al., 2019). At both the school and college levels, students' skills in this area tend to fall into the low category. Consequently, conducting a dedicated study to assess students' prediction ability is necessary.

Various frameworks have been used to measure prediction ability, including in physics at the junior high school level (Katarína & Marián, 2017a), and at the elementary age level (G. Oslington et al., 2020; G. R. Oslington et al., 2021). To measure data prediction ability, several different frameworks are used. (Katarína & Marián, 2017a) distinguished prediction from general statements, filled in incomplete predictions, predicted answers to questions, and formulated predictions. This category can be utilized to assess prediction that has a solid foundation but remains overly generic. Another framework used (G. Oslington et al., 2020) is *AMPS* (*Awareness of Mathematical Pattern and Structure*), categorized into *prestructural, emergent*, *partial,* and *advanced structural*. This framework focuses on students' understanding of the statistical concepts provided. Furthermore, it applies to the framework used by (Watson & Moritz, 2001), which uses a 4-level solo taxonomy to describe students' ability to make prediction based on pictographs, namely *iconic*, *unistructural, multistructural,* and *relational*. The framework used by Oslington and Watson exhibits a similar attribute, intended for Elementary School children, thereby making it less applicable for use at the university level. Therefore, it is imperative to adjust the level of prediction ability under the type of task and the degree of cognitive advancement.

The framework used is SOLO taxonomy based on cognitive development used to measure students' level of understanding. Biggs and Collis (1982) created the framework for assessing the composition of observable learning outcomes (İhsan Yurtyapan & Kaleli Yilmaz, 2021). In addition, SOLO taxonomy can be used as an effective tool in determining the level of concept learning (Akbaş-Ertem, 2016; Groth & Bergner, 2006). It is a framework based on cognitive development theory by Piaget and the framework identifies a particular student's developmental stage, with the response to an assignment by a particular student (Aoyama, 2007). This taxonomy can explain the complexity of students' understanding and assess their cognitive learning outcomes (Adeniji et al., 2022). There are two main features in the taxonomy, namely the mode of thinking and the level of response (Caniglia & Meadows, 2018). Meanwhile, the level of response is the individual's ability to respond to increasingly sophisticated tasks.

Every framework possesses its own set of strengths and limitations. There is an existence of a framework explicitly designed to evaluate college-level students' graph prediction exists. However, the framework is inadequate in comprehending the intricacy of students' prediction advancement influencing graph literacy proficiencies.

This study is limited to graphs with linear curves and exclusively employs generalization-prediction task categories. Furthermore, it addresses the following research questions:

1. What levels of thinking on SOLO taxonomy do students align with when making prediction?
2. How can the prediction aptitude of mathematics students concerning a particular graph be described?

By understanding the level of prediction ability among mathematics students based on a given graph, teachers can assess their comprehension of the subject matter and determine the effectiveness of graphical representations. The rate at which students respond to graphical representations can be used to gauge their comprehension of graphs and the ability to solve problems. The accuracy of students' predictions is an indication of the concept and ability to apply it in practical situations.

METHODS

Approach and Subject

To fulfill the objective of describing students' ability to make prediction, this study employed a descriptive qualitative method. Qualitative study allowed students to furnish comprehensive reports on situations and phenomena by using various data collection tools (Creswell, 2012). The qualitative descriptive approach was preferred to present an elaborate account of students' ability to make prediction based on the data gathered.

This study comprised 37 students from the Mathematics Education Study Program at a state university in South Kalimantan. The participants were comprised of 8 male and 29 female students, with a secondary school background ranging from high school to Islamic high school. Furthermore, the average age of students was 19-20 years old. This study focused on early-semester college students who had attended calculus courses, as they possessed the necessary background knowledge required to comprehend the ideas involved in the generalization-prediction task. Students were carefully selected as subjects, given their suitability for the study objectives.

Data Collection

Data were collected using tests and interviews with students. Students worked individually to solve a generalization-prediction task. The study instrument was in the form of a problem-solving task, which was a *generalization-prediction task* based on the pattern created, as shown in Figure 1.

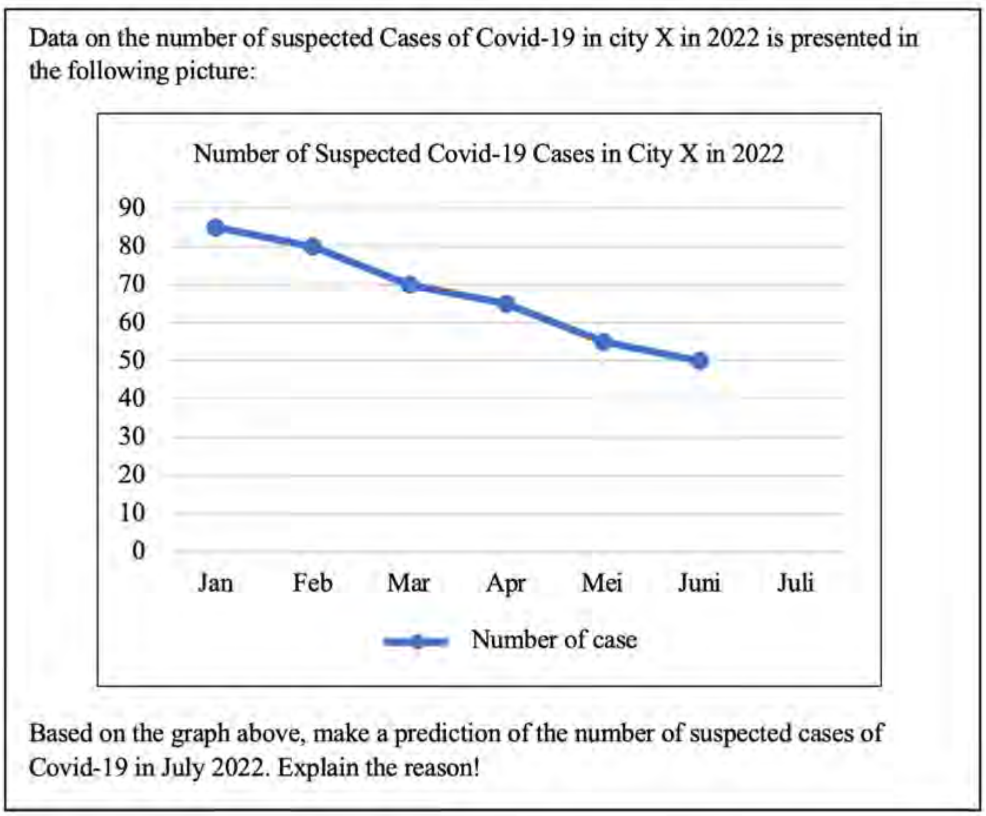


Figure 1. The question for predicting the Covid-19 graph.

The data collection process involves several steps by preparing study tests such as generalization-prediction tasks, with necessary tools including paper and pencils. Furthermore, this study introduces the generalization-prediction task to students and provides instructions on task evaluation. Students are then given time to work on the task individually and expected to understand the exploration of linear functions. After the assignment is completed, students are asked to answer the test questions presented in Figure 1. Subsequently, they are interviewed to evaluate their comprehension of the exploration of linear functions. Individual interviews are also performed with semi-structured questions. The results are recorded and collected before evaluating the quality of the data and identifying any problems in the collection procedure.

Data Analysis

The process of data analysis was conducted in multiple stages. Firstly, students' answer sheets were checked and then analyzed using SOLO taxonomy framework by Biggs and Collis (1982). Regarding students' prediction ability level, Watson, and Moritz (2001) used a four-level SOLO taxonomy to describe the ability to make prediction, namely iconic, unistructural, multistructural, and relational. These were used in the instrument to measure prediction using pictographs for elementary school children. This study also used the framework of Watson and Moritz (2001) based on a similar SOLO taxonomy to analyze the prediction ability of university students, with a description in line with the generalization-prediction task, as shown in Table 1.

Level	Description
Prestructural	Prediction without referring to the provided graph
Unistructural	Prediction with baseless guesses or based on a simple aspect in the graph
Multistructural	Prediction using multiple values in the graph
Relational	Prediction by integrating all information, such as using all values and trending patterns on graph
Extended Abstract	Prediction integrating all information such as values, patterns in graphs, previous knowledge, or experience, as well as generalizing structures to adopt new and more abstract features

Table 1. The Framework of Prediction Ability Classification on Graphs

The prediction results from students were coded using the framework in Table 1. These determined codes were put together based on their similarity and collected under descriptors representing the level of prediction ability. Therefore, the level of predictability is determined based on this coding. A descriptive analysis was performed to calculate the frequencies for each level of the specified outcome. The analysis gave the needed tools to calculate the frequencies for each level of predicting ability and map out how these levels were distributed among students. Consequently, deductions regarding students' overall prognostic aptitudes and any domains that may necessitate guidance or assistance have been derived from the data.

RESULT

A description of the findings obtained at the level of prediction ability is presented in the following table

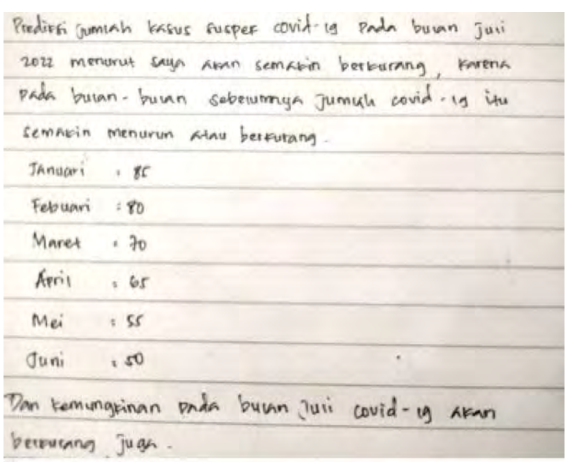
	Quantity	Percentage (%)
Unistructural	8	21.62
Multistructural	13	35.14
Relational	7	18.92
Extended Abstract	9	24.32
Total	37	100

Table 2. Students' Prediction Ability Level Based on SOLO Taxonomy

As seen in Table 2, most mathematics students belong to level 2, multistructural, accounting for 35.14%. The lowest number is found at the relational level, which is 18.92%. Since no students are encompassed within this category during the study conducted to expose the prediction levels, the ensuing depiction provides an account of the capability to make prediction for the unistructural, relational, multistructural, and extended abstract levels.

Level 2 – Unistructural

At this level, students made predictions based on a simple aspect of the graph.



Prediksi jumlah kasus suspek covid-19 pada bulan Juli 2022 menurut saya akan semakin berkurang, karena pada bulan-bulan sebelumnya jumlah covid-19 itu semakin menurun atau berkurang.

Januari : 85
Febuari : 80
Maret : 70
April : 65
Mei : 55
Juni : 50

Dan kemungkinan pada bulan Juli covid-19 akan berkurang juga.

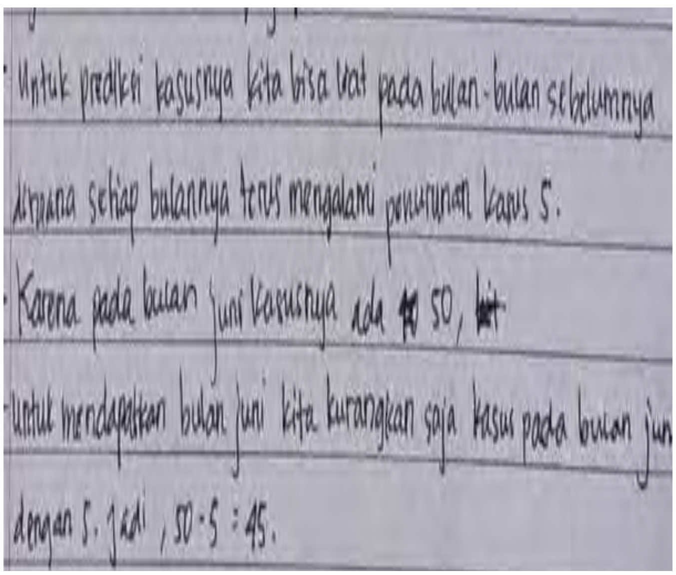
Predicting the number of Covid-19 cases in July, in my opinion, it is decreasing because in the previous months the number of Covid-19 cases is decreasing.
January: 85
February: 80
March: 70
April: 65
May : 55
June: 50
And the probability of covid-19 a in July is decreasing

Figure 2. A sample answer from a student at the unistructural level

According to Figure 2, the student predicted the number of Covid-19 cases in July by analyzing the decrease in cases for every preceding month, commencing with 85 cases in January, followed by 80 in February, 70 in March, 65 in April, 55 in May, and 50 in June. By observing the decline that transpired in all prior months, the student inferred that there would be a reduction in the number of Covid-19 cases in July.

Level 3 – Multi-structural

At this level, students make prediction using several values in the data presented in the form of graph.



Untuk prediksi kasusnya kita bisa liat pada bulan-bulan sebelumnya
dimana setiap bulannya terus mengalami penurunan kasus 5.
Karena pada bulan juni kasusnya ada 50,
untuk mendapatkan bulan juni kita kurangkan saja kasus pada bulan juni
dengan 5. Jadi, 50-5 = 45.

For the prediction of cases, we can see in the previous months, where every month it continues to experience a decrease of 5 cases. Because in each June there are 50 cases, to get june we reduce the cases in June by 5.
So 50-5=45

Figure 3. A sample of a students' answer at the multistructural level

Based on Figure 3, in making prediction the student used the number of cases in the previous months, which had been decreasing by 5 cases. For example, the number of Covid-19 cases was predicted in July by analyzing the decrease in cases from May to June, which was 55 - 50 = 5 cases. Based on this calculation, the number of monthly decline patterns was 5 cases. Therefore, when predicting for July, the number of Covid-19 cases was subtracted in the previous month with a decreasing pattern, obtaining a prediction of 50 - 5 = 45. Analyzing the answers of the student, prediction was made for July using the data from May to June, which had a decrease in the cases. Regarding the number of cases from January to February and March to April, a decrease was not reported in the pattern. Different patterns of decrease in 10 cases were reported from February to March and April to May.

Level 4 – Relational

At this level, students formulate prediction using all data values, and graph patterns exhibiting trends, or distinctive conditions within the dataset. This level involves the use of the number of cases in each month, considering the downward trend, while observing the graph trend patterns.

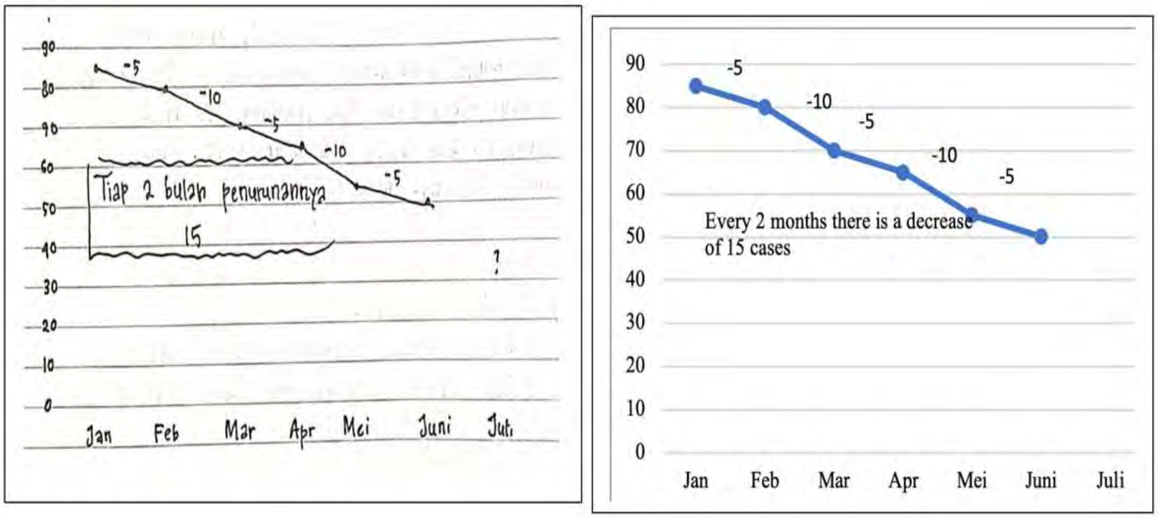


Figure 4. An example of a student's answer at the Relational level

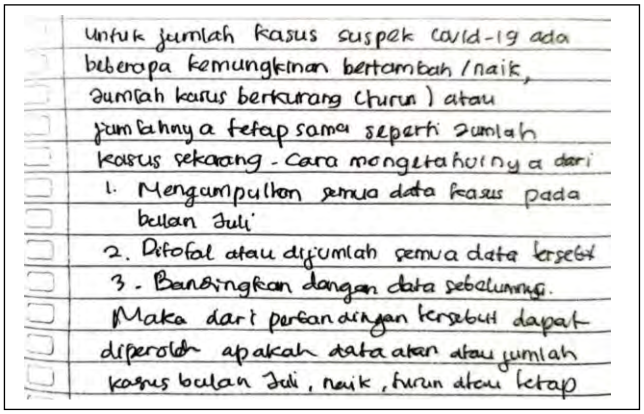
Based on Figure 4, the student made a prediction using the information in the graph, such as the number of cases in each month. The graph trend was analyzed by paying attention to the decrease every 2 months, such as from January to February, 85 - 80 = 5, which was 5 cases decrease. The decrease in the number of cases from February to March was also calculated, which were 80 and 90. The decrease from April to May, which was 5 was obtained, and the number was the same from January to February. The result showed a 10-cases decrease, which was the same from February to March. In conclusion, there was a potential trend of a decrease of 10 cases from June to July, and the predicted number was 40.

In this case, students predicted by analyzing the pattern every two months to obtain a decrease of 15 cases. Therefore, the result of the prediction in July was obtained by subtracting the 55 cases in May by 15 to obtain 40. The subject identified a pattern of decrease in the first and second months of 5 and 10 cases, hence, the pattern of decline every 2 months was 15 cases.

From these results, students predicted by using all information in each month from January to June by finding the monthly and bi-monthly patterns, and paying attention to the decreasing pattern.

Level 5 – Extended Abstract

At this level, students are expected to make prediction, integrate all information, values and patterns on graphs, and generalize structures to adopt new and more abstract features. At this stage, they can integrate the data on the graph with the existing previous knowledge.


Untuk jumlah kasus suspek covid-19 ada
beberapa kemungkinan bertambah / naik,
jumlah kasus berkurang (turun) atau
jumlahnya a tetap sama seperti jumlah
kasus sekarang. Cara mengetahuinya dari
1. Mengumpulkan semua data kasus pada
bulan Juli
2. Ditotal atau dijumlah semua data tersebut
3. Bandingkan dengan data sebelumnya.
Maka dari perbandingan tersebut dapat
diperoleh apakah data akan atau jumlah
kasus bulan Juli, naik, turun atau tetap

For the (predictive) number of Covid-19 cases (in July), there could be some possibilities. It is possible that the number of cases will increase, decrease, or remain the same with the number of cases now.
Ways to find out:
1. Collecting all case data in July
2. Summing all the data
3. Comparing it with previous data

Figure 5. An example of a students' answer at the Extended Abstract level

According to Figure 5, the student did not refer to the Covid-19 case graph to formulate prediction. This was corroborated during an interview, where preexisting knowledge of graphed data was used to conclude. Specifically, there were various potential outcomes for the Covid-19 case graph, such as an increase, decrease, or maintenance of the current count. Another student, upon observing a reduction in the cases in previous months, made a prediction based on observations. The students drew upon their personal experience and knowledge to generate prediction. In addition, the government's ongoing efforts to conduct vaccinations and implement health protocols across a variety of activities should reduce the number of cases.

DISCUSSION

This present study describes the level of prediction ability using the theoretical framework presented in Table 1. The proposed framework highlights the crucial role of a resource to gain insights into students' capacity and make accurate predictions based on graph analysis. The process requires a sound awareness of data patterns and trends. The results indicate that a majority of students show a multistructural level of prediction ability. This level is characterized by limited aspects or information, such as identifying the downward trend in the graph and using only one data pattern. Moreover, students at this level tend to overlook some patterns in the graph. Students possess some relevant knowledge and can accurately identify the phenomenon but fail to integrate these facts into a comprehensive whole. Therefore, this present study underscores the need for developing pedagogical strategies to enhance students' prediction ability and promote a deeper understanding of data patterns and trends (Caniglia & Meadows, 2018).

The results at level 2 *unistructural* indicate that the students predicted the downward trend of the graph. At this level, information is not related to the number in the decreasing pattern. Furthermore, students show an awareness of the downward pattern in the graph, with limited knowledge of the Covid-19 graph. A type of information, which is the downward trend of the graph, is used while failing to notice the relationship between ideas. Students do not understand problems involving mathematical concepts and environmental situations during the pandemic (Mumu et al., 2021).

At level 4, *relational*, the subjects use all information, trends, and patterns in the graph, by observing various interrelated components. Attention was given to the variables of the cases and the months in the graph to draw the connection between the two variables and obtain the number for each month. In addition, the subjects also consider the similarity of the patterns since the number of cases decreases monthly. At this level, the subjects integrate information and explain some ideas related to the topic.

The results for level 5, *extended abstract,* indicate that students refer to the data provided and also use their existing previous knowledge or information in making prediction. In addition, they also adapted the situation to their experiences as a consideration in making prediction. Individuals consider their existing knowledge and experiences acquired in their daily lives when formulating prediction (Bazinger & Kühberger, 2012; Fotou, 2014; G. Oslington et al., 2020). This finding shows that students are more aware of trends and patterns and can integrate information in the graph with previous knowledge or experience.

Based on the findings for the *unistructural, multistructural, relational,* and *extended abstract* levels, prediction can be made based on the information or data in the graph. At these levels, students perform formal thinking and the predictions generated are considered reasonable due to the use of graphs or data. This is under study conducted by (G. R. Oslington et al., 2021), where reasonable prediction is obtained from the given data or context. Furthermore, a reasonable prediction relies heavily on identifying patterns in the provided data (G. R. Oslington et al., 2021). Making reasonable predictions involving the identification of patterns reflects a process of reasoning that does not rely on feelings or experiences. Therefore, students use predictive reasoning based on the graph presented In line with (Russo et al., 2022) where prediction should lead leads to the generalization of patterns (Kim & Kasmer, 2007a).

According to Table 2, the majority of Mathematics Education students who make prediction on graphs are at the multistructural level. At this level, prediction is made based on a limited number of aspects or information, such as the downward trend in the graph and the use of only one data pattern. At this level, students can identify the phenomenon correctly, but this knowledge is not integrated as a whole (Caniglia & Meadows, 2018).By acquiring knowledge of students' prediction ability, comprehension of concepts, problem-solving skills, critical thinking ability, and graphical literacy can be augmented. Additionally, teachers can improve their pedagogical skills by engaging students in predicting graph related to mathematical concepts. This approach can assist teachers in devising and executing more efficient and pertinent strategies, catering to the diverse needs of students. Knowing the level of prediction ability of mathematics students from graphs can enable teachers to evaluate their comprehension of the subject matter and interpret graphs. The rate of response can also serve as a metric of understanding graph to tackle problems involving graphical representations. The accuracy of students' prediction is indicative of the capacity to apply the concept in practical situations.

CONCLUSION

In conclusion, the study shows that mathematics students primarily demonstrate their prediction ability at the multistructural level, accounting for 35.14%. A smaller percentage of students exhibit prediction skills at the relational level, accounting for 18.92%, where predictions are made using limited information from the graph. To enhance the teaching of mathematical concepts related to graphing, teachers can involve students in the process, allowing for the development of their skills. By leveraging knowledge of students' predictive abilities, learning activities can be better planned and executed using relevant and efficient strategies. Students who possess the capacity to make predictions at the unistructural, multistructural, relational, and extended abstract levels are capable of making reasonable predictions based on the information presented in the graph. This finding indicates the presence of predictive reasoning, which may warrant further investigation in future studies.

Acknowledgments

The authors are grateful to the Ministry of Education, Culture, Research, and Technology of Indonesia, Directorate General of Resources (Decree Number: 0162/E5.4/DT.05.00/2023, for sponsoring this study and publication in the Doctoral Dissertation Research 2023 program.

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