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ANALYSIS OF STUDENTS' THINKING STYLES IN READING FREE-BODY DIAGRAMS AND ANALYTICAL THINKING ON NEWTON'S LAWS

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Abstract :
Analytical thinking skills are essential for understanding and solving physics problems, particularly those involving Newton's Laws. One effective way to develop these skills is through the use of free-body diagrams. This study aims to analyze the influence of students' thinking styles, Concrete Sequential, Abstract Sequential, Concrete Random, and Abstract Random on their analytical thinking abilities in interpreting free-body diagrams. Conducted using a qualitative descriptive approach at State Junior High School 1 Mlarak, Ponorogo Regency, data collection methods included observation, interviews, and document analysis. The findings reveal that students' thinking styles significantly affect their ability to comprehend and represent forces in free-body diagrams. Students with a Concrete Sequential style demonstrated a more systematic approach in identifying and organizing forces, while those with an Abstract Random style faced greater challenges in structuring information. These results suggest that visual-based learning, such as the use of free-body diagrams, can enhance physics understanding and analytical thinking skills when aligned with students' thinking styles. This study serves as an initial effort to support the development of students' analytical thinking skills, especially in the context of visual representation in physics. Additionally, the findings can be used by teachers as a reference for designing instructional strategies that cater to diverse thinking styles, thereby enriching the practice of physics education and promoting higher-order thinking skills.

Keywords: Analytical Understanding, Free-body Diagram, Thinking Style.

INTRODUCTION

Physics is a branch of Natural Science that seeks to systematically build and organize knowledge through testable explanations to predict natural phenomena. As a scientific process, physics includes mindsets, attitudes, and scientific steps used to produce scientific products (Ifriliya et al., 2022). One of the goals of learning physics is to develop reasoning skills through inductive and deductive analysis using physical concepts and principles to explain various natural phenomena and solve problems qualitatively or quantitatively. In the Merdeka Curriculum, a similar principle is applied by providing greater flexibility for teachers to design learning that supports the development of critical and analytical thinking skills in students (Mahyastuti et al., 2021).

Analytical thinking skills are implemented skills in understanding and solving physics problems, especially in Newton's Law material, because Newton's law is one of the materials that play an implemented role in the dynamics of motion. (Winarno et al., 2019). Analytical thinking skills are the competence of breaking down information into small elements, understanding the relationships between the elements, and evaluating their implications logically (Lantian et al., 2021). This ability is significant for solving problems, making the right decisions, and understanding complex concepts. Analytical encompasses the ability to differentiate facts from opinions, identify the relevance of information, and organize data to produce structured arguments. The stages of analytical thinking include recognizing significant elements, analyzing relationships between components, and evaluating the whole to draw correct conclusions. (Qolfathiriyus et al., 2019).

The three play indicators of analytical thinking include the skills: of differentiating, organizing, and connecting. The ability to differentiate includes identifying elements and understanding differences or similarities between concepts (Fitriani et al., 2021; Kusnaini, 2023). In the context of Newton's Law, this ability plays an important role in identifying the forces acting on objects and compiling mathematical equations to solve problems (Winarti, 2015). Each student has different analytical thinking abilities, this is because analytical thinking abilities are closely related to students' thinking styles (Fatmawati et al., 2022; Sanusi et al., 2020).

Gregorc (1982) classifies thinking styles into four categories, namely Concrete Sequential, Abstract Sequential, Concrete Random, and Abstract Random. Students with a sequential thinking style tend to use the left brain, while students with a random thinking style tend to be more dominant in using the right brain (Rahmawati et al., 2024; Syamsuddin, n.d.). Students with an abstract sequential thinking style organize information logically and systematically, but they are more comfortable with abstract and theoretical concepts. They tend to process information in a structured order, but focus more on conceptual relationships and larger ideas, rather than on things that can be seen or felt directly (Masegosa et al., 2024; Tipani, 2019).

Students with a concrete sequential thinking style tend to follow structured and logical steps in solving problems and focus more on data and information that can be seen or felt directly. They process information sequentially, follow a systematic sequence of steps, and prefer clear and practical information (Agoestanto & Shufah, 2023). Students with an abstract sequential thinking style organize information logically and systematically, but they are more comfortable with abstract and theoretical concepts. They tend to process information in a structured sequence but focus more on conceptual relationships and larger ideas, rather than things that can be seen or felt directly (Anisya et al., 2024; Hasanuddin, 2021). Students with a concrete random thinking style are more flexible in thinking and organizing information, but they are more interested in things that can be seen or felt directly (Masegosa et al., 2024; Rosdianti et al., 2025). They are less concerned with the order of steps to be followed and are more focused on the elements around them or more practical information. Students with an abstract random thinking style tend to think flexibly and are not tied to a systematic order of steps, but they are more interested in larger theoretical concepts and abstract ideas (Mariano et al., 2024; Sari et al., 2018). They can connect concepts in unexpected ways and more often think about broader conceptual relationships than concrete details (Abdullah et al., 2024; Hartono & Putra, 2014).

In previous studies, it was found that many students find it difficult to solve physics problems, such as research conducted by Ummah (2015) which showed that many students still make mistakes in solving physics problems because they are considered difficult and involve many effective representations (Ummah, 2015). On the other hand, it was revealed that learning carried out using visualizations such as sketches or diagrams was more successful in solving problems than without using diagrams (Mulyani, 2017). In addition, one study also revealed that problem-solving in mechanics involving the use of media such as free body diagrams, and visual aids that identify objects and forces, can provide accurate information and answers (Niyomufasha et al., 2024). Despite these findings, previous research has not specifically examined how students' thinking styles affect their ability to interpret visual representations like free-body diagrams. Most studies have focused on the general benefits of visual aids, without considering individual cognitive differences. This study addresses that gap by analyzing the influence of thinking styles (Concrete Sequential, Abstract Sequential, Concrete Random, and Abstract Random) on students' analytical thinking skills in interpreting free-body diagrams. This novelty is expected to provide insights for designing more personalized and effective physics learning strategies.

There are many types of diagrams in physics, one of which is the free-body diagram. This diagram depicts objects separately, which shows the overall force on the object or system (Mardini et al., 2018). Free-body diagrams depict the direction and magnitude of the forces on the system. Making a free-body diagram can be a primary strategy in solving Newton's Law problems because it helps students identify the forces acting on an object (Mardini et al., 2018; Suwasono et al., 2023). If students can identify the force accurately, students can more easily solve the problem. The use of free-body diagrams is very helpful for students in solving physics problems (Djajadi et al., n.d.; Winarno et al., 2019). In addition, free-body diagrams also provide instructions for the next steps in solving the problem (Bancong & Subaer, 2013; Winarno et al., 2019).

Free body diagrams are used to describe the magnitude and direction of the forces acting on an object under certain conditions (Pratiwi et al., 2021). Therefore, free body diagrams can be an alternative to improve student competence, especially in materials related to the force and motion of objects ,diagrams represent features or processes of the world and provide important information about spatial and geometric relationships so diagrams are very necessary for learning Natural Sciences (Anisya et al., 2024; Groothoff et al., 2022). The learning system that is implemented by considering students' learning styles can provide experience and make students more enthusiastic in participating in learning because each student has different ways and processes of thinking, depending on the skills and thinking styles they have (Lantian et al., 2021).

Based on this background, this study aims to analyze how the influence of students' thinking styles (Concrete Sequential, Abstract Sequential, Concrete Random, and Abstract Random) in reading free body diagrams of Newton's Laws material for grade VIII and their analytical thinking skills. The urgency of this research lies in the critical role that thinking styles play in shaping how students process scientific representations such as diagrams, which are essential in comprehending abstract physics concepts like forces and motion. Misinterpretations of free-body diagrams often lead to conceptual misunderstandings, hindering students' overall achievement in science. Furthermore, the development of analytical thinking is a key competence in the 21st-century education framework, yet remains underdeveloped among many junior high school students. By identifying how different thinking styles affect the interpretation of diagrams and the application of analytical skills, this research provides valuable insights that can inform differentiated instructional strategies. These strategies are crucial for accommodating diverse cognitive preferences, improving conceptual understanding, and ultimately enhancing science learning outcomes at the junior high school level.

RESEARCH METHOD

This research is qualitative. Bogdan and Taylor, explain that qualitative research is a research procedure that produces descriptive data in the form of written or spoken words from individuals being observed (Sugiono, 2016). Qualitative methods are considered appropriate in this study because the study aims to understand in depth how students' thinking styles affect their ability to read free-body diagrams in Newton's law material. The qualitative approach allows for a broader exploration of thinking patterns, problem-solving strategies, and challenges faced by students in understanding visual representations (Hardani et al., 2020; Istiqomah et al., 2022).

The research subjects involved four eighth-grade students and one science teacher at SMP Negeri 1 Mlarak Ponorogo. The research flow can be seen in the image below:

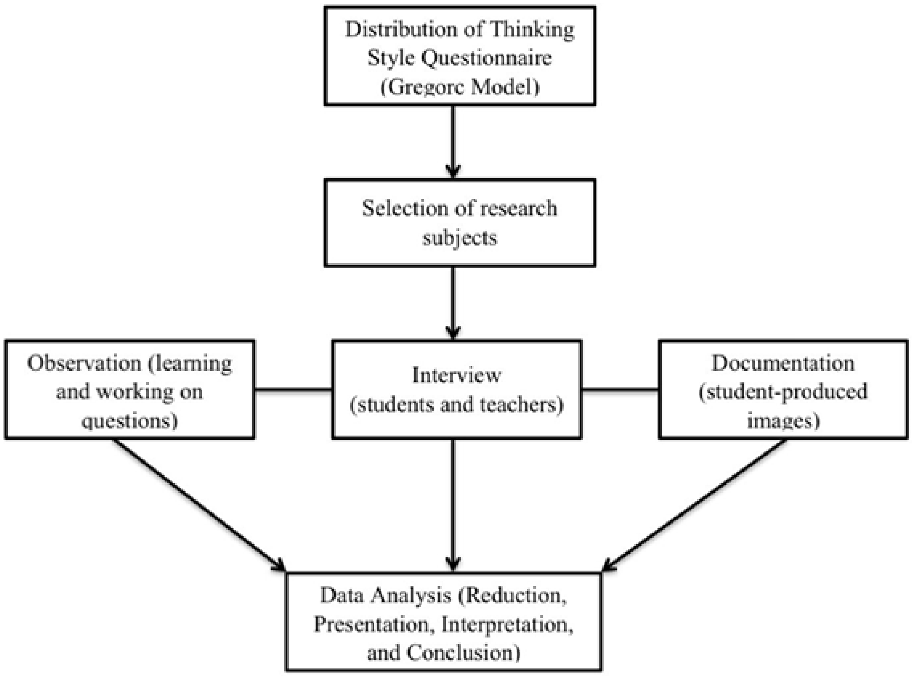

Figure 1. Research flow

This sampling technique was carried out through a thinking-style questionnaire distributed to all eighth-grade students. Then take children who This questionnaire is designed to identify students' thinking preferences based on the Gregorc model. Technique data collection was carried out with method observation, interviews, and documentation. In the study, this, observation was implemented To investigate in a way direct How influences the style think students on their ability to read object diagrams free material Newton's law of measurement ability think analytical students to read object diagrams freely (Anisya et al., 2024). Technique observations used in the study is observation participatory, where the researcher observes in a way direct during the learning process, working on questions taking notes on the steps they take use, and noticing the difficulties they face face it in representing object diagrams free with the use three indicator main think analytical that is ability distinguish, organize, and connect concepts in a system (Qolfathiriyus et al., 2019).

Interview done To dig information more about the difficulty students in understanding Newton's law submit a question to students like "*When learn Newton's law, part what according to You difficult to underst*and?". Besides that, interviews were also conducted to measure the understanding of students about object diagrams free, (Annisa, Dwiastuti, and Fatmawati 2016). Questions focused on How students identify the style that works on objects And the strategy they use. The interview was done in a semi-structured manner which made it possible for exploration more flexible to answer students.

Researcher gives *object diagram images free* For analysis, as shown in Table 1:

Table 1. Free-body Diagram Questions that students must complete

	Question
1.	State the forces acting and the direction of these forces on *a free-body diagram* of a plane.
2.	Explain *the free body diagram* on an inclined plane along with the forces and direction of the forces.

Analysis of the two free-body diagram questions was carried out to assess the extent to which free-body diagrams influence students' analytical thinking skills, by looking at how they differentiate and identify the forces acting on an object and differentiate them based on type and direction, arranging the forces in logical and systematic visual representation, and linking diagrams to the concept of Newton's laws (Rizkita & Mufit, 2022). Students' work in the form of free-body diagrams was also analyzed to identify common errors, representation patterns, and the level of students' analytical understanding.

The collected data were analyzed descriptively to describe students' ability to read *free body diagrams* and the factors that influence them through four stages, namely, data reduction, data presentation, interpretation and analysis, and conclusion. At the data reduction stage, the researcher grouped data from observations and interviews based on analytical thinking indicators (distinguishing, organizing, and connecting), in data presentation, the researcher compiled data in the form of narrative descriptions (Asis, Alkia Agustami Ria, 2021).

RESULTS AND DISCUSSION

Based on the research results, it was found that students' analytical thinking skills in understanding free body diagrams in Newton's law material had significant variations, which were closely related to force. Think about each student. Fanny Ahmad Fauzi, et al (2020) also revealed that style thinking can influence skills taught to students because style thinking depends on the method they understand And absorb the learning provided (Fauzi et al., 2020). As De Porter & Hernacki (2015) in Aulia Firdaus, et al (2019) revealed style thinking is a fusion between How to accept And process information that is obtained in the brain. Because that's it each person will own style and think differently depending on his habit in processing information However, some limitations show that although they can sort information in a way systematic (Firdaus et al., 2019).

Activity interviews were done to find out the difficulties experienced by students in analyzing object diagrams. The various things interviewed include students' basic conceptual understanding, analytical reasoning, and force identification. The transcript of the interview before the students analyzed the free body diagram is as follows.

X: Has the teacher ever taught and introduced free-body diagrams in class?
Y 1: The teacher never taught about free-body diagrams.
Y 2: Never taught about free-body diagrams, but the teacher has shown me how to describe the forces acting on an object.

Based on the results interview It is known that during the learning process, the teacher has never taught free-body diagrams, so students do not understand the concept of free-body diagrams themselves. During the learning process, the teacher only teaches about the forces that work without teaching the terms object diagram free. Teachers should be able to integrate the use of object diagrams free Because the presentation of object diagrams free is Wrong One presentation of multiple representations teachers can give learning about steps in drawing object diagrams free in a way detailed (Sekarpratiwi et al., 2018). After asking about this case, the researcher provided a free body diagram for further analysis, from the results analysis known that:

Table 2. Ability to Think Analytical Student in Reading Free-body Diagram Reviewed From Style Think Gregoc

No	Indicator	Thinking Style Gregoc			
		Sequential Concrete	Sequential Abstract	Random Concrete	Random Abstract
1.	Differentiate (Mentioning the forces at work determines the direction vector)	✓	✓	✓	
2.	Organize (Compile parts until something is complete And regular.	✓	✓		
3.	Connect (Connecting the style that works with Newton's Law)	✓			

1. Concrete Sequential Thinker

Students who have a concrete sequential thinking style in reading free body diagrams on a flat plane are quite good, students can mention the forces that work sequentially and know the relationship between each force that works.

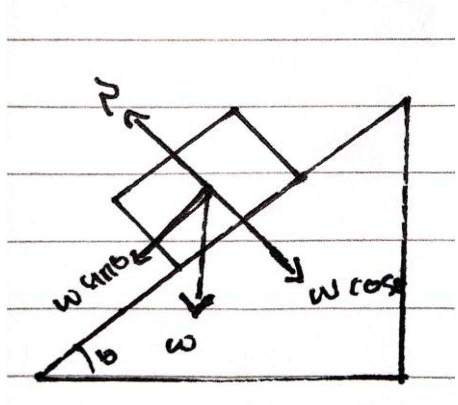

Figure 1. Answer to question no. 2 Concrete sequential thinking style

Researchers also conducted interviews to confirm students' answers regarding difficulties in drawing free-body diagrams.

X: *What are the difficulties experienced when drawing free-body diagrams?*
Y: *It's not too difficult, but sometimes I still feel confused about changing text into images.*

Based on the results interview Figure 1, shows that students with a concrete sequential thinking style can describe diagrams in a structured manner, they do not describe objects as points or particles, which are more abstract representations in mechanics. Students do not experience much difficulty, only that they have to be very careful in changing writing into images. Because, individuals with sequential concrete thinking tend to process information systematically and structure (Pramono et al., 2025). This reflects a fairly good analytical thinking ability in terms of compiling steps in a way logical. However, the ability of students with style to think concrete sequential in analyzing the connection between cause and effect in depth still needs to be improved. They tend to focus on basic steps without delving deeper into the important underlying physics concepts. In think analytical.

2. Random Sequential Thinker

Students with a random sequential thinking style in the first question were able to determine the base of the vector, but they still had difficulty in determining the forces acting on the free-body diagram.

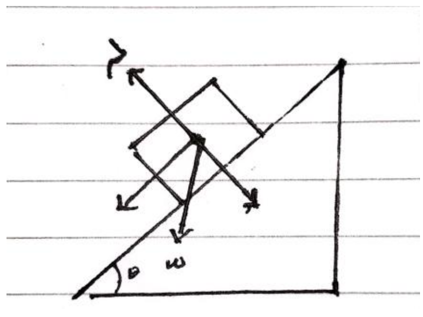

Figure 4. Answer to question no. 2 random sequential thinking style

To confirm students' answers, the researcher asked about students' difficulties in free-body diagrams.

X: *What are the difficulties experienced when drawing free-body diagrams?*
Y: *Usually has difficulty determining the force acting, can describe the direction of the vector but still has difficulty determining the force acting.*

Based on the results of the interview and the images produced by the students, in determining the direction of the vector it is correct, but the students did not write down the forces acting on the free body diagram according to what was requested in the question. This shows a lack of analytical thinking skills in connecting cause and effect correctly. Although they sequence the steps correctly, they do not understand the reasoning behind the forces at work, indicating that they are not yet fully capable of conducting a thorough analysis of physical phenomena. They tend to only see the results without delving deeper into the processes that cause them.

3. Concrete Random Thinker

Students with a concrete random thinking style in solving question no. 1 tend to represent the force and direction of the vector randomly and not sequentially.

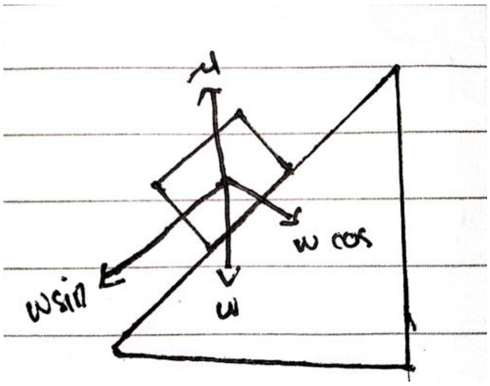

Figure 3. Answer to question no. 2 concrete random thinking style

To confirm students' answers, the researcher asked about students' difficulties in free-body diagrams.

X: *What are the difficulties experienced when drawing free-body diagrams?*
Y: *It is difficult to analyze and include the styles contained in the image because they are rarely studied.*

Based on the results of interviews and drawings produced by students, thinkers with a concrete random thinking style tend to represent free-body diagrams. Irregularly, students only mention the forces that work as they know them. They are less able to organize information systematically and often do not realize the importance connect information available in a larger context. As seen in the pictures they produced, students were still less careful in drawing the lines of force they faced which should not be in the same direction. With style Wsin throughout that, the absence of This research also has an impact on the images they produce. produce (Pranata, 2024; Sanusi et al., 2020). In the context of analytical thinking, this shows a lack of ability to identify and connect interrelated variables. They often think based on memory limitations and are less able to carry out in-depth analysis to connect the forces acting on the object And its impacts.

4. Abstract Random Thinker

Students who have an abstract random thinking style in completing the first question are still less precise in stating the force and direction of the vector working on the free body diagram.

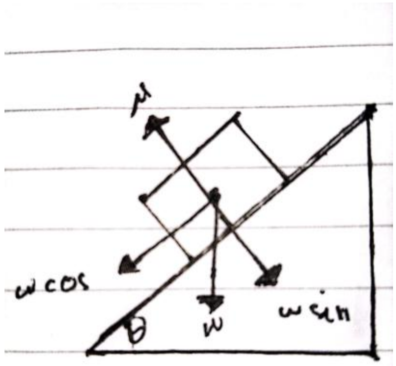

Figure 4. Answer to question no. 2 Abstract random thinking style

To confirm students' answers, the researcher asked about students' difficulties in free-body diagrams.

X: *What are the difficulties experienced when drawing free-body diagrams?*
Y: *Difficulty in understanding free body diagrams and distinguishing between the forces at work*

Based on the results of interviews and drawings produced by students, thinkers with an abstract random thinking style represent free-body diagrams irregularly, and these students do not convey the facts contained in the free-body diagram using their language. They rely more on existing information without really understanding or expressing their thoughts logically and in structure. In addition, the drawings produced by students contain forces that are not placed correctly, the force that works in the direction of the Wcos vector is Wsin, and vice versa. This shows that their analytical thinking skills are very limited because they have difficulty analyzing and organizing information in a clear and organized way (‘Iffa, Supriana, & Sutopo 2019). They cannot distinguish important concepts and connect them effectively in the free-body diagram representation.

Previous studies that discuss analytical thinking skills and Newton's Laws generally focus on students' conceptual understanding or conceptualization errors in force material, but there are still several gaps that have not been widely explored. First, most previous studies have not considered students' individual thinking styles, even though thinking styles play an important role in how students process information, including in understanding visual representations such as free-body diagrams (FBDs). Second, there are still few studies that specifically examine students' analytical abilities in interpreting and constructing FBDs as an important part of applying Newton's Laws (Azahra & Wasis, 2024) . Third, the approach used is generally quantitative without delving deeply into students' reasons or thinking processes through qualitative data, such as interviews. Fourth, previous studies rarely examine how limitations in delivering material such as not being given explicit teaching about FBDs can affect students' analytical thinking output, especially when associated with different thinking styles. This study is here to fill this gap with students' thinking styles with variations in their analytical thinking abilities in understanding FBDs, using a qualitative approach and focusing on the role of suboptimal learning.

This study provides significant contributions to the world of education, especially in science learning at the junior high school level. The findings of the study indicate that students with different thinking styles have unique ways of processing visual information, so teachers need to pay attention to students' thinking styles when developing learning strategies. This study also emphasizes the importance of explicit teaching of FBD so that students not only understand the concept of style in general, but are also able to apply it visually and analytically. Theoretically, this study enriches the literature by linking aspects of cognitive psychology, namely thinking styles, with analytical thinking skills in the context of science learning. In addition, the results of this study can be the basis for the development of more targeted learning interventions, such as the application of scaffolding that is adjusted to thinking styles to improve students' analytical skills.

This study has several limitations that need to be considered. First, the limited number of subjects makes the generalization of the research results less strong. Second, the study was conducted in a limited context, namely in a certain tutoring institution in the Ponorogo area, so the findings do not necessarily represent conditions in other schools or other areas. Third, the data obtained are snapshots and do not describe the development of students' abilities longitudinally. Fourth, because students do not receive explicit learning about free-style diagrams, it is difficult to completely separate the influence between thinking styles and lack of mastery of the material. Finally, qualitative analysis through interviews relies heavily on the researcher's interpretation, so the potential for subjectivity remains if cross-validation is not carried out. Nevertheless, this study still provides a significant contribution as an initial step to understanding the variation in students' analytical thinking abilities from the perspective of different thinking styles.

CONCLUSION

The study found that students' analytical thinking skills in understanding free-body diagrams differ based on their thinking styles. Concrete Sequential thinkers excel in identifying and describing forces systematically, while Abstract Random thinkers face challenges in organizing information. The primary obstacle to understanding free-body diagrams is the lack of explicit teaching, as educators often focus on the concept of forces without detailed applications. To address this, teachers should integrate free-body diagrams into lessons on Newton's Laws, adapt teaching methods to suit students' thinking styles, and provide gradual practice to enhance analytical skills. This research underscores the connection between thinking styles and analytical abilities in motion dynamics. Based on the limitations of this study, it is recommended that further research involve a larger and more diverse number of subjects to increase the generalizability of the findings. In addition, further research can also use an experimental approach to test the effectiveness of free-style learning diagrams that are adjusted to students' thinking styles.

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