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Mental Models Based on Students Thinking Style About Objects in Static Fluid

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Abstract: This study aims to describe a mental models based on students' thinking styles about objects in static fluids. The type of research used is quasi-qualitative with a research design using Simple Research Design (SRD). This research was carried out at MAN Insan Cendikia, Palu City for grade XII students in the 2023 academic year, with 30 students as subjects. The instruments of this research are questionnaires, two-level test and interview guide. The data analysis technique used is the "Miles and Huberman Model" namely data reduction, data modeling and drawing conclusions. The results of data analysis showed that out of 30 students, there were 8 students with a Concrete sequential (Cs) thinking style, 12 students with an Abstract sequential (As) thinking style, 6 students with a Concrete random (Cr) thinking style, and 4 students with a Abstract random (Ar) thinking style. The group tested with abstract problem tended to have a higher average score than the group tested with concrete problem. When given abstract ploblem the Abstract sequential (As) and Sequential concrete (Cs) groups had a higher average score than the Abstract random (Ar) and Concrete random (Cr) groups.

Keywords: Mental models; Static fluid; Thinking style

Introduction

The cognitive science study of mental models has been and continues to be a quite interesting area of research in cognitive psychology and science education (Corpuz & Rebello, 2011). This area is interesting for testing students' mental models for physical systems. There are enough objects, events or phenomena on a macroscopic scale so that students have direct visual experience which becomes the basis for their mental models and conceptions of the material being studied.

According to Hegarty et al. (2013) stated that mental models play a role in the learning process because learning in general can be viewed as a mental model. Mental models provide valuable information about a phenomenon from the conceptual framework, or underlying knowledge structure. When someone interacts with a system, it means they gain knowledge about the operation of the system and the structural relationships between its components (Kaharu & Mansyur, 2021). Individuals use these models to reason, explain, predict phenomena and produce models that are expressed as external representations in various formats such as verbal descriptions, diagrams, simulations, and concrete models to communicate ideas to other people or in solving problems (Buckley & Boulter, 2000).

Mental models can be assessed through physics problems in the microscopic realm. For example, in static fluids. Static fluid is a part of physics that is closely related to natural phenomena. Most previous research revealed the difficulties experienced by students in static fluid material. Students have difficulty understanding the concept of static fluids. Students' lack of conceptual understanding will affect students' problem solving abilities (Purnamasari et al., 2018). Through the difficulties and errors experienced by these students, it can be further analyzed regarding students' mental

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models regarding how students collect previous knowledge to answer problems with objects in static fluids with correct and scientific explanations.

This research is supported by research conducted by Mansyur et al. (2022) regarding objects in static fluids which states that there is a tendency for mental models applied by students in the context of floating and sinking to influence the phenomena of objects in liquids. These patterns were chosen without examining substantial aspects of fluid phenomena regarding the concept of density. The concept of a floating object is only related to the similarity between the density of the object and the density of water. The presentation of floating objects in liquid which is always in the middle (from the depth of the liquid in the container) influences the conception of floating objects.

The formation of this mental model is thought to be influenced by textbooks and teacher habits in class or a combination of both. Another possibility is that students use an intuitive approach and overgeneralize based on the properties and representations of floating and sinking objects (Mansyur et al., 2022). To successfully restructure concepts towards scientific mental models, students need to be involved in the process of knowledge integration, that is, they need to connect newly constructed scientific ideas with their current concepts, refining or rejecting them.

The mental model formed from this cognitive process can also be seen based on thinking style. Each student has a different way of absorbing information and organizing/processing information, these differences are called thinking styles. Thinking style is a typical way of learning, both related to receiving and processing information, attitudes towards information, and habits related to the learning environment (Rahayu & Firdausi, 2016).

Understanding thinking styles is important because it makes a unique contribution to understanding a person's differences (Zhang, 2004). It is difficult for someone to change their dominant thinking style, but they have the ability to adapt to environments that do not suit their thinking style (Chamorro-Premuzic & Furnham, 2009). With their thinking style, students can process information in their minds related to personality and how to interact with the environment and adapt to obtain new information. In this case, it allows students to acquire thinking strategies related to investigation, information processing, reasoning, problem solving, evaluation and reflection. Therefore, teachers should not create a learning environment that is dominant in one style of thinking.

An initial literature review showed that research on mental models based on thinking styles was still understudied. So the urgency of this research is very important because it can contribute to the world of education, especially the Madrasah Aliyah Negeri Insan Cendekia (MAN IC) Palu school, regarding how the mental model of each group of students' thinking styles is described. As well as providing a map of the power of thinking characters that students have in solving physics problems, especially regarding objects in static fluids. This will help in developing physics learning models and strategies to achieve success in physics learning goals. So this study aims to describe students' thinking styles based on mental models about objects in static liquids. A complete description containing all mental models and connectivity for each grouping of thinking styles will be presented, explained with diagrams and qualitative meaning.

Method

This research is a type of quasi-qualitative research with a qualitative descriptive approach (Sugiyono, 2022). This research was carried out by Madrasah Aliyah Negeri Insan Cendekia (MAN IC) Palu City in the odd semester of the 2023 academic year, with research subjects totaling 30 students grade XII.

The data collection techniques used were questionnaires, tests and interviews. The instruments in this research were a thinking style questionnaires, a two-tier test sheet to determine students' mental models about objects in static fluid adapted from research and an interview guide.

To collect data in this research, an instrument was used in the form of a student thinking style problemnaire adapted from research by Haeruddin et al. (2023) with a test reliability of 0.90 in the very high category. This thinking style problemnaire follows the development model of Gregorc's mind style which consists of 3 indicators, namely, Things you like, Best learning conditions, and Difficult conditions faced.

The problemnaire is used to describe the type of thinking style that students have by using a scale, namely very inappropriate (score 1), not suitable (score 2), quite suitable (score 3), suitable (score 4), very suitable (score 5). The time used to complete this problemnaire is around 45 minutes. Respondents fill out the problemnaire by selecting the statement items given based on the situation that best describes them. Categorization of thinking styles is done by placing individuals in a group. The grouping process does not have the meaning of more, less and higher. Grouping is based on categorization which refers to differences in the way individuals process information that occurs (Gregorc, 1982).

The thinking style problemnaire was given to research subjects totaling 45 students. Then, from the results of the problemnaire, several respondents were selected to represent Concrete sequential (Cs), Abstract sequential (As), Concrete random (Cr), Abstract random (Ar) thinking styles using purposive sampling techniques. Selected respondents were then given a two tiers test sheet to determine students' mental models of objects in static fluids.

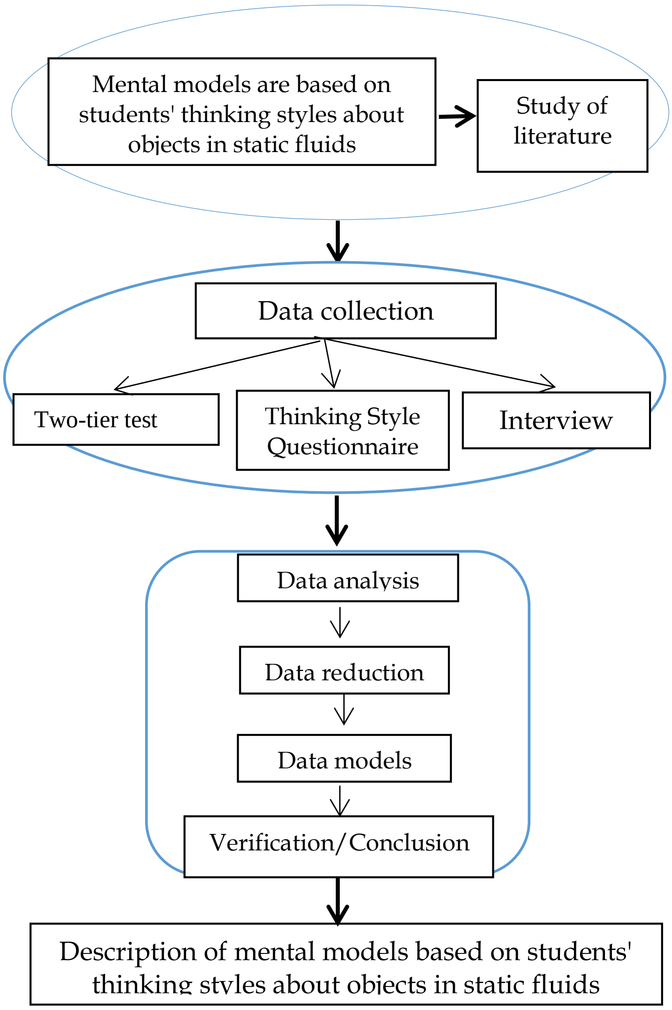

Figure 1. Research Implementation Flow

To find out students' mental models about objects in static fluids, a two tiers test instrument was used which was adapted from research by Kaharu et al. (2024), with test reliability of 0.895 in the very high category. This two tiers test takes the form of multiple choices at the first level and is accompanied by a choice of reasons at the second level. The number of problems used was 46 problem items, consisting of 12 concrete problem items and 34 abstract problem items. Data analysis Results of two-tier test, namely Correct answer choices are given a score of one (1), and wrong answer choices are given a score of zero (0) for each problem on the level. Next is the calculation of the average value using the Formula 1.

$$\bar{X} = \textit{Total score} / \textit{Number of problem items} \qquad (1)$$

To support, explore and strengthen the test results, interviews were conducted with respondents. The interview method used was a semi-structured interview.

This research design uses Simple Research Design (SRD) with 5 (five) research steps/stages, including building research formulations, literature review, data collection, data analysis, and reporting (Burhan, 2021). The data analysis technique "Miles and Huberman Model which includes: data reduction, modeling/presenting data and drawing conclusions/verification. The final stage of this research is reporting. The entire implementation stages in this research can be shown in Figure 1.

Result and Discussion

Result Research

The results of students' thinking styles are obtained in `Table` 1. Table 1 shows that the most dominant student thinking style group is the Abstract sequential (As) thinking style group at 40.00% and the less dominant is the Abstract random (Ar) thinking style group at only 13.30%. The percentage of thinking style groups can also be interpreted through Figure 2.

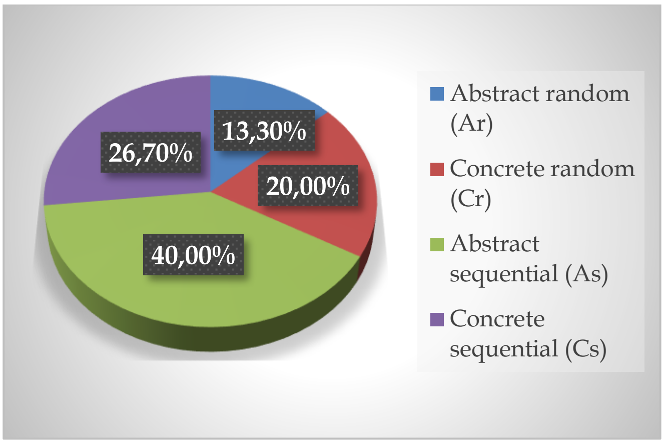

Figure 2. Percentage of Student Thinking Style

Based on Table 2 above, it can be seen that the students who had the highest score had a Concrete sequential (Cs) thinking style with an average score of 27.27 with the highest score on the abstract problem form being 17, 88 and the lowest score being 9.88 on the concrete problem form. Meanwhile, the lowest score was for students with a Concrete random (Cr) thinking style, namely only getting a total mean score of 21.20 with a score of 12.00 in the abstract problem form and a score of

9.20 in the concrete problem form. The result of these scores can also be depicted in Figure 3.

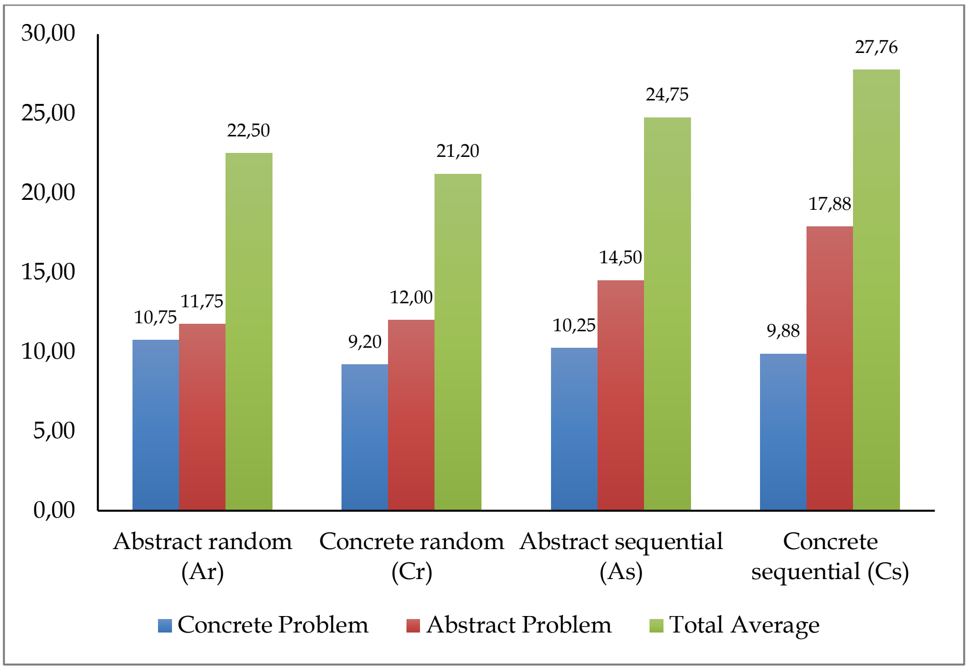

Figure 3. Obtaining the average score of the thinking style group

Table 1. Grouping of Students' Thinking Styles

Student Initials	Thinking Style	Amount Students	Percentage %
Kn	Abstract random (Ar)	4	13.30
Ra	Abstract random (Ar)		
Nm	Abstract random (Ar)		
Zs	Abstract random (Ar)		
Msh	Concrete random (Cr)	6	20.00
An	Concrete random (Cr)		
Ap	Concrete random (Cr)		
Mrn	Concrete random (Cr)		
Ai	Concrete random (Cr)		
Mf	Concrete random (Cr)		
Mbr	Abstract sequential (As)	12	40.00
Muf	Abstract sequential (As)		
Fa	Abstract sequential (As)		
Ms	Abstract sequential (As)		
Ra	Abstract sequential (As)		
Mh	Abstract sequential (As)		
Ip	Abstract sequential (As)		
Hk	Abstract sequential (As)		
Dn	Abstract sequential (As)		
Hu	Abstract sequential (As)		
Mt	Abstract sequential (As)		
Pa	Abstract sequential (As)		
Ma	Concrete sequential (Cs)	8	26.70
Aa	Concrete sequential (Cs)		
Mua	Concrete sequential (Cs)		
Das	Concrete sequential (Cs)		
Aaz	Concrete sequential (Cs)		
Ra	Concrete sequential (Cs)		
Sna	Concrete sequential (Cs)		
Af	Concrete sequential (Cs)		
Total		30	100

Table 2. Students' Mental Models Based on Students' Thinking Styles About Objects in Static Fluids

Thinking Styles	Average Score		Total Average
	Concrete Problem	Abstract Problem	
Abstract random (Ar)	10.75	11.75	22.50
Concrete random (Cr)	9.20	12.00	21.20
Abstract sequential (As)	10.25	14.50	24.75
Concrete sequential (Cs)	9.88	17.88	27.75

Based on these results, the group tested with abstract problem tended to have a higher mean score than the group tested with concrete problem. The Abstract sequential (As) and Concrete sequential (Cs) groups had a higher mean score than the Abstract random (Ar) and Concrete random (Cr) groups which were tested with abstract problems.

Discussion

This research aims to describe mental models based on students' thinking style about objects in a static fluid. Based on the results of data analysis, it was found that there were 30 subjects There are 8 students with Concrete sequential (Cs) thinking style, 12 students with Abstract sequential (As) thinking style, 6 students with Concrete random (Cr) thinking style, and 4 students with Abstract random (Ar) thinking style. Furthermore The subject was given a test about objects in a static fluid using two tier test to find out the mental model of the student.

Results of data analysis of students' mental models about objects in static fluids The highest score was obtained from students who had a Concrete sequential (Cs) thinking style with an average score of 27.27 with the highest score in the abstract problem form being 17,88 and the lowest score was 9.88 on the concrete problem form. While the lowest score was at students with a Concrete random (Cr) thinking style only get an average total score 21.20 with a score of 12.00 in the abstract problem form and a score of 9.20 in the concrete matter. Meanwhile, students have an Abstract random (Ar) thinking style obtained an average score of 22.50 and students who had an Abstract sequential (As) thinking style obtained an average score of 24,75. Based on these results, it can be seen that the Abstract sequential (As) and Concrete sequential (Cs) groups had a higher mean score than the Abstract random (Ar) and Concrete random (Cr) groups which were tested with abstract problems.

Based on the results of data analysis, it can be stated that each concrete problem item tested in each thinking style group gave varying results. For example, in concrete form problem No. 1 to 3 object determination (Objects float, float and sink) Figure 4 below.

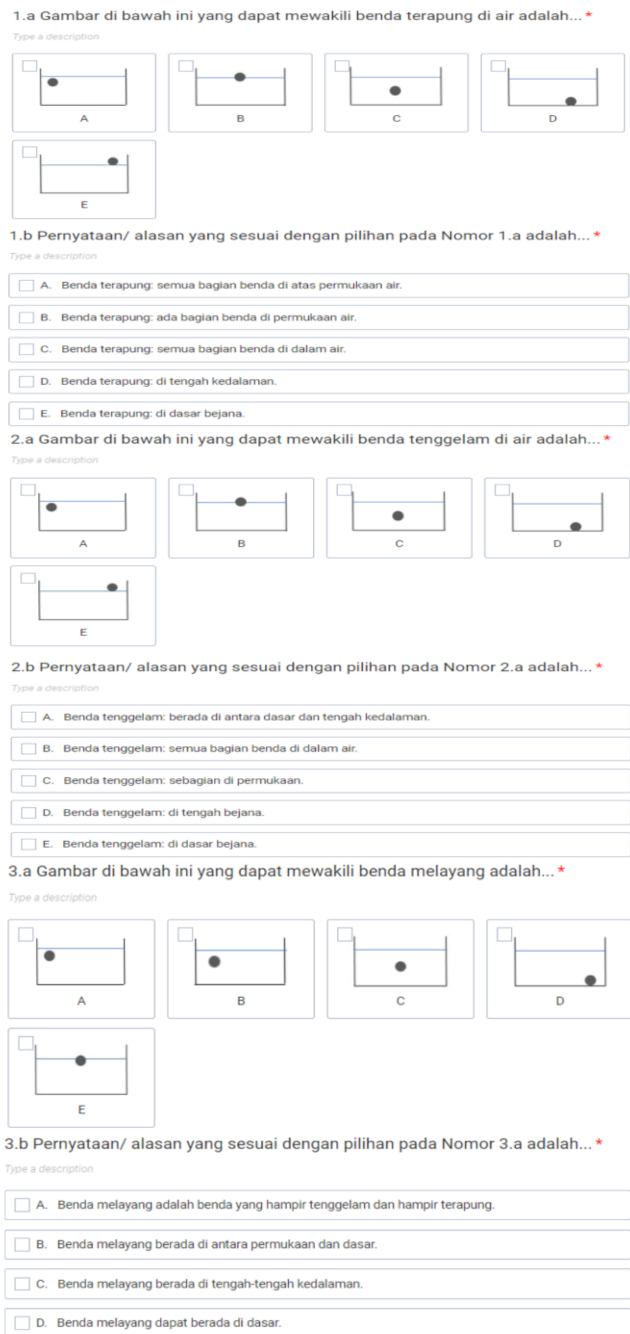

Figure 4. Concrete form problems

In general, all groups of thinking styles can determine the position of floating, sinking and floating objects correctly through pictures. However, there are various reasons. They give wrong reasons says that floating objects are all parts of objects above the surface water. Concrete sequential group (Cs) another wrong reason viz floating objects all parts of the object in the water. The correct concept is that floating objects have part of the object on the surface of the water. Meanwhile, determining position sinking objects Abstract random (Ar), Concrete random (Cr), and Concrete sequential (Cs) groups can determine the position of a sinking object precisely through picture, but chose the wrong reason for the answer. They stated that Submerged objects are all parts of objects in water. Another thing is wrong reasons which is stated by the Abstract sequential (As) group that the object sinks, namely is between the bottom and the middle of the depth, all parts of the object in the water, some on the surface and in the middle of the vessel. The correct concept is that the object sinks, namely at the bottom of the vessel.

In determining floating objects, that is, all groups of thinking styles can determine the position of floating objects precisely through pictures. However, they give wrong reasons states that a floating object is an object that is almost sinking and almost floating. The only difference is that the Abstract random (Ar) group and the Concrete random (Cr) group stated the wrong reasons The other is that floating objects are in the middle of the depth. The correct concept of floating objects is that they are between the surface and the bottom. For instance, the majority of students in Joung (2008) answered that there was a stronger tendency to consider objects that were directly under the water as floating, whereas they sank if they were closer to the bottom of the water. Apart from that, one of the most common alternative ideas held by students is that students most often state that an object can float because it is small and/or light, and sink because they are large and/or heavy (Fassoulopoulos et al., 2003; Smith et al., 1992). Based on the analysis of abstract form problems, one example is problem no. 15 Figure 5.

The results of the analysis of students' answers to the abstract problem form (example no. 15) are Abstract random (Ar), Abstract sequential (As) and Concrete sequential (Cs)groups can mostly determine the position of objects precisely (objects remains submerged) and gives the correct reason, namely the creation of a hole causes water to enter and makes the density of the object increase. Whereas Concrete random (Cr) groups are mostly unable to determine the position of objects precisely for the wrong reasons, namely making holes causes the density of the object decreases and the object moves up (floats), and creation The hole causes the object's density to increase and the object remains sinking. The correct concept in this problem is that the object remains sinking because there is no effect of making a hole, making a hole causes water to enter and the density of the object increases, and making a hole causes the density of the object to increase and the object remains sinking.

15.a Benda H adalah benda tenggelam di air. Jika pada benda dibuat lubang maka benda.... *

Type a description

- A. melayang
- B. terapung
- C. hampir terapung
- D. tetap tenggelam
- E. memiliki sifat semakin tenggelam

15.b Pernyataan/ alasan yang sesuai dengan pilihan pada Nomor 15.a adalah... *

Type a description

- A. Tidak ada pengaruh pembuatan lubang.
- B. Pembuatan lubang menyebabkan massa jenis benda < massa jenis air.
- C. Pembuatan lubang menyebabkan air masuk dan massa jenis benda bertambah.
- D. Pembuatan lubang menyebabkan massa jenis benda bertambah dan benda tetap tenggelam
- E. Pembuatan lubang menyebabkan massa jenis benda berkurang dan benda bergerak naik (melayang).

Figure 5. Abstract form problems

In research by Kallery (2015) regarding floating and sinking phenomena as one of the properties of the materials that make up objects. for example solid and hollow objects. percentage of students' understanding of the type of material that is the determining factor in the behavior of objects in water. In other words, students formulate their estimation concerning the floating of solid objects in a liquid by taking into account: (a) the heaviness/size of the objects, (b) the existence of hollows, (c) the existence of holes, (d) the interface/edge, orientation, shape and/or texture of the floating object, (e) the dimensions of the tanks in which floating takes place, (f) the amount and/or depth of the liquid, and (g) the liquid stickiness (Yin et al., 2013).

The Abstract sequential (As) and Concrete sequential (Cs) groups were the most dominant in providing incorrect reasoning statements on concrete problems. This is because the Abstract sequential (As) group finds it difficult to analyze objects thoroughly based on reality, because they tend to think less about concrete things. The Concrete sequential (Cs) group is systematic, linear, and based on concrete things, but they have a tendency to follow the information provided without analyzing it. Meanwhile, the wrong reason was chosen by the Abstract random (Ar) group because this thinking style group had difficulty concentrating on one thing, could not provide precise details in analyzing physics problems and did not like concrete things. For the Concrete random Group (Cr) it is difficult to show how they got the right answer. This is because they use intuition in solving physics problems.

The thinking style group that was tested with abstract problems tended to have a higher mean score than the group that was tested with concrete problems and also gave mixed results. In this problem form, the Abstract sequential (As) and Concrete sequential (Cs) groups had a higher average score than the Abstract random (Ar) and Concrete random (Cr) groups. However, the Abstract sequential (As) and Abstract random (Ar) groups were more likely to choose the right reason than the other groups when tested with abstract problems.

The Abstract sequential (As) group has various choices of ways to determine answers to problem solving, analyzing each situation and having assumptions or other ways to obtain the same results. This is because the Abstract sequential (As) group analyzes the situation before making a decision and applies logic in solving physics problems/problems. The Abstract random (Ar) Group in solving physics problems/problems uses other methods that are deemed necessary even though they are not planned, has other assumptions that are sometimes not implemented, and can determine/describe the position of objects with certain non-systematic assumptions and have supporting arguments in drawing conclusions without analyzing further. This is because the Abstract random (Ar) group focuses on physics problems and tends to be abstract.

The Concrete sequential group (Cs) views problems based on facts and works on them systematically, having no other arguments to support drawing conclusions from solving the problem. This is because the Concrete sequential (Cs) group believes they can solve physics problems in predictable situations and based on facts. Meanwhile, the Concrete random (Cr) group has a certain way of solving physics problems/problems, and solves physics problems/problems according to plan. This is because the Concrete random (Cr) group uses a trial and error approach. The resulting data was strengthened from time triangulation and interviews with research respondents for each thinking style group.

Students' mistakes in answering two tier test problems from the results of this research provide a model of students' difficulties in solving physics problems on static fluid material. This research supported by research conducted by Mansyur et al. (2022) states that there is a tendency that mental models are adopted by students in the context of floating and sinking influence the phenomena of objects in fluid. The model pattern is related to the depiction of objects in a fluid with just choose the condition between floating and sinking. These patterns are selected without reviews substantial aspects of fluid phenomena regarding the concept of mass type. The concept of floating objects is only associated with similarities between the density of an object and the density of water. presentation of objects floating in a liquid which is always in the middle (from the depth of the liquid in the vessel) influence their conception of floating objects. relevant to the research results of Teo et al. (2017) also revealed that the concept of an object floating or sinking is because of its weight, and that an object sinks because the water is "soft".

This is also shown in research by Valiyov & Yegorenkov (2000) students think fluid will always press upward on objects. Another error students assume large pressure is caused by the large amount of water above a point which causes the hydrostatic pressure to be large (Goszewski et al., 2013). In addition, on the topic of Archimedes' law which explains the concept floating, drifting and sinking students still experience difficulties.

According to Zoupidis et al. (2021) researchers who have studied students' conceptions of density (Hardy et al., 2006; Smith et al., 1992; Wiser & Smith, 2009) have found that they had difficulty in understanding this abstract concept. Firstly, students find it hard to understand the ratio of two quantities (Rowell & Dawson, 1977), such as that of mass per volume, particularly when those quantities are changing simultaneously (Smith et al., 1992). Secondly, the concept of density is a property that is not directly perceived through the senses but can only be understood through mental reasoning and/or calculations (Wiser & Smith, 2009; Xu & Clarke, 2012). Thirdly, students' difficulty in understanding density is rooted precisely in an already developed conceptual framework about matter and material kind (Vosniadou et al., 2008), which is composed of perception-based physical quantities where the raw scientific notions of weight, volume and density coexist undifferentiated (Wiser & Smith, 2009) Consequently, these students consider density to be proportional to the size of an object or the object's quantity of matter. As a result, when interpreting static fluid phenomena, students tend to focus on properties of objects or liquids. by using causal linear reasoning, it only refers to the nature of an object or liquid, not to relational causal reasons.which involves comparing the density of objects and fluids in its interpretation (Perkins & Grotzer, 2005).

Through the difficulties and mistakes experienced by these students, they can depicts students' mental models of how students are gather previous knowledge to answer object problems in a static fluid with correct and scientific explanations through the thinking style of each student. This is relevant to research by (Barrett et al., 2013; Haili et al., 2017; Mumford et al., 2012; Purnamasari et al., 2018) shows that there is a relationship between problem solving abilities and students' mental models. There is a relationship between thinking style and the success of solving physics problems and understanding of concepts (Devy et al., 2022; Haeruddin et al., 2023). Students have ways to manage and organize different information. Therefore, teachers should use the best learning methods that take into account students' thinking styles (Evendi, 2022; Syahfitri, 2023) (Bancong & Subaer, 2015).

Conclusion

Based on the results of data analysis, it can be concluded that of the 30 students there were 8 students with a Concrete sequential (Cs) thinking style, 12 students with an Abstract sequential (As) thinking style, 6 students with a Concrete random (Cr) thinking style, and 4 students with a Abstract random (Ar) thinking style. The group tested with abstract problem tended to have a higher average score than the group tested with concrete problem. When given abstract problem the Abstract sequential (As) and Sequential concrete (Cs) groups had a higher average score than the Abstract random (Ar) and Concrete random (Cr) groups.

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Author Contributions
Conceptualization, GU and JU; methodology, GU and JU; software, MW; instrument development, JU and HA; formal analysis, GU and JU; investigation, GU and WNL; resource, GU, WNL, FR, and TF; Data curation, GU and JU; writing—preparation of original draft, GU; reviewing and editing, GU and WNL; visualization, MW; supervision LPPM UNTAD; project administration, GU, WNL, and IWRM; obtaining funding, DIPA FKIP UNTAD.

Author Contribution

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Conflicts of Interest
The authors declare no conflicts of interest. The funders did not participate in the study's design, data collection, analysis, interpretation, manuscript writing, or decision to publish the results.

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