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Students' Conceptual Understanding And Difficulties On Static Fluids: A Literature Review

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ABSTRACT

The research is a literature study that aims to explain students' concept understanding and difficulties in Static Fluid material. The research method uses descriptive qualitative by analyzing sinta/international conference/scopus accredited journals. The analysis was conducted on the concepts of hydrostatic pressure, Archimedes' law and Pascal's law. The articles used were 9 articles published between 2019-2023. The results of the analysis show that most of the studies show that the understanding of the concepts in static fluid material is rather low. There are many difficulties experienced by students on the concepts of hydrostatic pressure, Archimedes' law and Pascal's law. Various efforts to improve and overcome the difficulties include the application of guided inquiry learning models, CCBL models, formative assessment in collaborative inquiry learning, and STEM-integrated experimental learning with formative assessment. The profile of understanding and difficulties can be used by teachers as a basis for designing solutions to create more effective learning and designing research to overcome difficulties.

1. INTRODUCTION

Mastery of static fluids is important for students. The concept of static fluid is closely related to everyday life (Pisnanji et al., 2022). The concept of static fluid is also often used in various technological applications. For example, a submarine can float and sink at sea because of a tube that can be filled with water or air. Another example is heating an air balloon with a burner to reduce the density of the air in the balloon. Therefore, learning about static fluids is done at different levels starting from middle school (Jamaludin & Batlolona, 2021; Wibowo et al., 2023).

The importance of the concept of static fluid emphasizes the need to measure students' understanding of the concept after the learning process. Several studies have been conducted to measure and identify the profile of students' concept understanding in static fluid material. A study conducted by Wicaksono et al, (2019) explained that students' concept understanding in static fluid material on the topic of Archimedes' principle was, on average, 63.47% in the good category. Another study conducted by Pisnanji et al, (2022) showed that the achievement of concept understanding of students on average was 51.5294. These results indicate that the understanding of physics concepts in static fluid material is not maximized and has difficulties.

Various problems of understanding and difficulties of students still occur. A common problem experienced by students is the assumption that physics is a difficult concept to understand (Wicaksono et al., 2019). Another problem that occurs is the inability of students to draw and represent graphs (Wicaksono et al., 2019). Specific to the concept of static fluid, students' conceptual understanding of the phenomenon of floating objects is still low (Hewitt, 2020; Kim & Paik, 2021; Nikolić, 2022). Previous research by Dyahesita et al, (2019) also explained that students experienced misconceptions in identifying the effect of liquid depth on hydrostatic pressure, Pascal's law in closed fluids, and the effect of object volume on Archimedes' force.

The various student difficulties and changes in concept understanding in the static fluid material encourage researchers to conduct literature studies related to the problem. This literature study aims to address the following research questions: (1) What is the level of students' conceptual understanding of static fluid material? (2) What kinds of difficulties or misconceptions do students mostly find while learning about hydrostatic pressure, Archimedes' law, and Pascal's law? (3) What learning strategies have been used for solving these conceptual difficulties?

This research was conducted by collecting related articles that discuss the profile of concept understanding and learning difficulties. The selected articles were published in SINTA accredited journals and international conferences within the last six years or between 2018 and 2023. The results of this research are expected to be able to provide concise information containing a collection of identical research on the profile of students' concept understanding of static fluid material. The research can later be used as a determinant in developing solutions to the problems of students' understanding in Static Fluid.

2. METHODS

The literature review study aims to explain how the profile of students' concept understanding on static fluid material along with the difficulties they face. The PRISMA method was used in the study to collect research data. The research data is in the form of articles that discuss the profile of students' concept understanding and difficulties in static fluid material. The data was retrieved from Google Scholar. This was chosen because Google Scholar is a complete platform containing a variety of research articles on different topics. In accordance with the PRISMA method, a selection process is carried out on the articles obtained to ensure that the articles selected are in line with the research objectives and are able to answer the research questions comprehensively. The steps of the PRISMA method are shown in Figure 1(Ghorbiy et al., 2024; Latifah et al., 2024). Inclusion criteria were applied in the selection of articles. Some of the criteria used in the study are:

1. Articles that explain the conceptual understanding profile of static fluid materials,
2. Published within a 6-year period, namely 2018 to 2023,
3. Published in SINTA accredited journals and national/international conferences,
4. Explaining the difficulties encountered in understanding static fluid material according to the three sub-chapters of the material, namely hydrostatic pressure, Archimedes' law and Pascal's law.

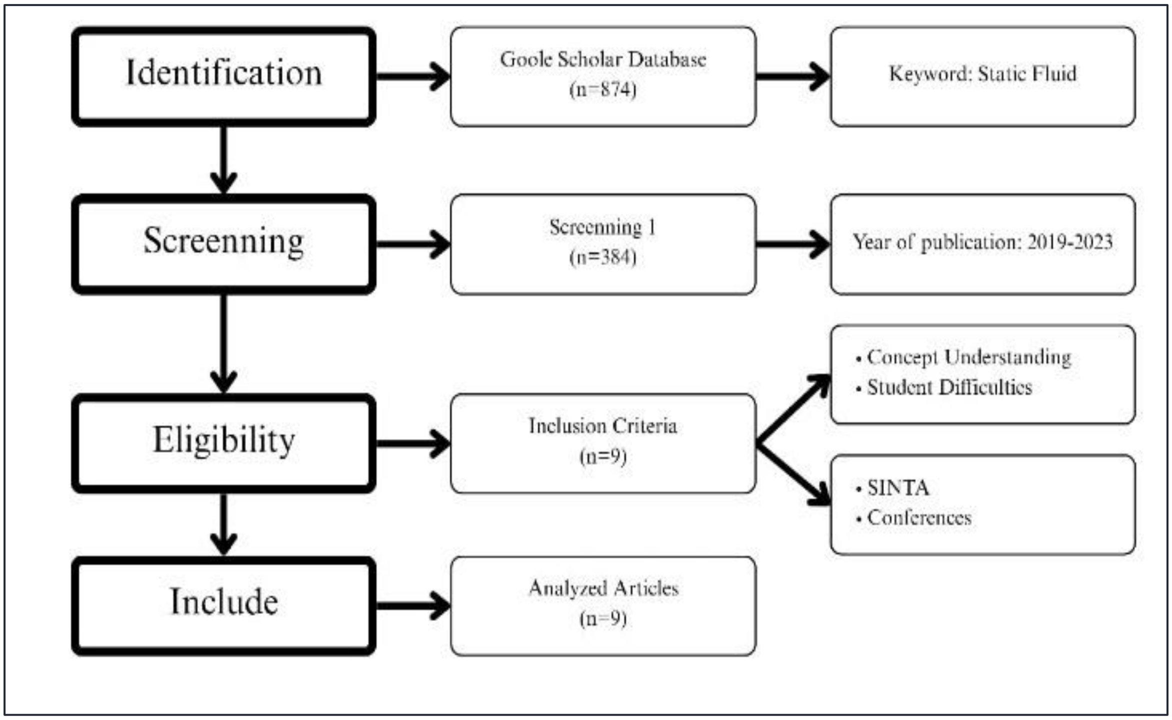

Figure 1. Stages of Article Selection with the PRISMA Method

In addition to some of the above inclusion criteria, this article also seeks to explain the methods that have been used in research to solve problems of concept understanding in static fluid material. The methods used may be through learning models or specific media used in learning. The final results of the research data selection process obtained 9 articles that are in accordance with the research objectives.

The analysis was carried out using descriptive analysis by explaining the profile of students' concept understanding on static fluid material along with the difficulties experienced. The analysis was carried out by presenting each research result obtained. Furthermore, the difficulties of students in understanding the concept of static fluid were grouped. The topics discussed in the analysis of difficulties focused on the concepts of hydrostatic pressure, Archimedes' law, and Pascal's law. The results of the analysis are presented in the form of a descriptive picture of the various difficulties experienced by students.

The results of the analysis also present a variety of efforts that have been made to overcome the difficulties and low understanding of the concepts of students in Static Fluid material. Ways that can be done to overcome the problem are also presented. The result is expected that teachers can design the right solution based on their difficulties and concept understanding profiles, so that Static Fluid learning in schools can be carried out more effectively and efficiently.

3. RESULT AND DISCUSSION

3.1 Understanding the Static Fluid Concept

Analysis of concept understanding by summarizing the results of different articles in a table to determine the profile of students' conceptual understanding in each study conducted. A detailed overview of the results regarding the concept understanding profile is presented in Table 1.

Tabel 1. Tabulation of Article Analysis Results

Citations	Descriptions
(Irma et al., 2022)	Most students are at Level 4 (SU) on the sub-material of fluid density. Level 3 (PU) on the sub-materials of fluid density, depth of an object, and types of buoyant objects. Level 2 (PU/SM) on the sub-materials of depth of an object, fluid pressure in a closed space, buoyancy force, and position of objects in a liquid.
(Wardaningsih & Supriyatman, 2021)	Static Fluid material has an average concept understanding of 32.70 with details of 28.12 on the concept of Archimedes' law, 41.66 on the concept of hydrostatic pressure, and 22.91 on the concept of Pascal's law.
(Estianinur et al., 2021)	The students' concept understanding based on the pretest results obtained an average score of 22.114. After learning shows that students still experience misconceptions on the concept of Pascal's Law and Archimedes' Law.
(Kusairi et al., 2021)	Based on the pretest results, the average understanding of the concept is 32.65. Students have difficulties after learning the concept of buoyancy force and the application of Pascal's law.
(Jamaludin & Batlolona, 2021)	The results of the study's analysis showed that static fluid misconceptions occurred in cases 2, 3, and 5.
(Wibowo et al., 2023)	The results show that the object will sink when $\rho_{object} = \rho_{fluid}$ but does not touch the bottom of the container. In addition, the object moves upward until it floats when ρ_{object} is slightly smaller than ρ_{fluid}.
(Wicaksono et al., 2019)	Students' understanding of the concept averaged 63.47% with a good category. Students have difficulty understanding the concept of buoyancy (Archimedes) and the state of floating objects.
(Saputra et al., 2019)	The results of the analysis show that the students' conceptions are low and have misconceptions with details of Pascal's law by 70.8%, Archimedes' law by 67.6%, and hydrostatic pressure by 55.7%.
(Prahastiwi et al., 2021)	Based on the pretest results, students' understanding of the concept of hydrostatic pressure was 23%, Pascal's law was 25%, and Archimedes' law was 19%.

The results of the analysis of 9 related research articles show that students' conceptual understanding of static fluid material tends to be low and even then, they experience various difficulties in understanding the material. The difficulties experienced may be in the form of misconceptions, inability to contextualize concepts into phenomena, or students' incomplete understanding. In accordance with the nine articles analyzed, a summary of students' difficulties in understanding Static Fluid material is presented in Section 2 Results.

3.2 Students' difficulties in understanding static fluids

3.2.1 Hydrostatic pressure

Hydrostatic pressure is the pressure of a liquid (fluid) caused by the weight of the fluid. Students face several difficulties in understanding the concept of hydrostatic pressure, including the misconception that the volume of a liquid affects hydrostatic pressure (Estianinur et al., 2021; Irma et al., 2022). Students assume that the volume of a liquid is directly proportional to the hydrostatic pressure within it. Another misconception is that the concept of hydrostatic pressure is the same as the concept of Archimedes' law (Wardaningsih & Supriyatman, 2021). Students are unable to distinguish the pressure caused by the fluid from the upward force exerted by the fluid. Another misconception is that hydrostatic pressure is inversely proportional to its cross section (Saputra et al., 2019). Another misconception described is students' assumption that the greatest hydrostatic pressure is at the highest surface (Saputra et al., 2019).

3.2.2 Archimedes' law

The concept of Archimedes' law is related to the buoyancy force of objects or the lifting force of objects in a liquid. One of the understanding problems that students still have with the concept of buoyancy is the assumption that the surface area of the object is directly proportional to Archimedes' force (Irma et al., 2022). This means that students have not been able to explain that the magnitude of Archimedes' force is affected by the volume of the submerged object, not the total volume. Students also assume that mass affects Archimedes' force (Estianinur et al., 2021). If the mass of the object is the same, then the Archimedes' force received by the object is the same, even though it has a different volume (Kusairi et al., 2021). Research by Kusairi et al, (2021) also explained that students have difficulty determining the buoyancy force of non-liquid fluids, such as when using air balloons. Another difficulty experienced by students is the inability to identify Archimedes' force and the gravitational force of sinking and floating objects (Wicaksono et al., 2019). Saputra et al, (2019) explained that students experience many misconceptions about the concepts of Archimedes' law, such as heavy objects sink, large objects sink, and the thicker the liquid, the more the object floats.

3.2.3 Pascal's Law

Pascal's Law states, "When pressure is applied to a liquid, the pressure is transmitted in all directions and is equal. Students' misconceptions about Pascal's Law include the assumption that in a hydraulic jack, the force applied to the small piston is equal to the force applied to the large piston (Irma et al., 2022). This assumption indicates that students have not connected the concept of hydraulic jacks to the Pascal's Law equation. Students also experience misunderstandings when placing concepts in the context of Pascal's Law problems (Estianinur et al., 2021; Irma et al., 2022). The understanding that students have cannot be contextualized in the given problem. Students understand that the pressure of a small cross section is equal to the pressure of a large cross section, but are unable to solve the problem in the context of a hydraulic jack (Kusairi et al., 2021).

3.3 Discussion

Conceptual understanding is an important and fundamental part of learning. As explained in Abdullah et al, (2021), concept understanding is important for students to develop and improve their skills. Conceptual understanding has three main categories, namely the process of translation, interpretation and extrapolation (Şefik & Dost, 2020). The results of the analysis of 9 articles show that students' conceptual understanding in static fluid material is still low, and they experience various difficulties. The difficulties that arise are very diverse and are influenced by different things. According to Docktor & Mestre (2014), difficulties in conceptual understanding are called misconceptions or naive conceptions.

Misconceptions are usually deeply rooted and resistant to change, making them difficult to eliminate (E. Etkina et al., 2005). This is also explained by Docktor & Mestre (2014), who adds that misconceptions can interfere with true scientific understanding. Learners are sometimes unaware that they have misconceptions (Irawati et al., 2022). Misconceptions occur because the concepts understood are not consistent with scientific concepts and scientific thinking (Capriconia & Mufit, 2022). Misconceptions occur due to several factors, including students' general abilities and personal abilities (Trisniarti et al., 2020). Erman (2017) also explained that teaching materials, reference books, students, and even teachers can be a contributing factor to misconceptions. Students are less involved in the scientific thinking process and only focus on the process of memorizing the material (Resbiantoro & Setiani, 2022).

Various efforts are needed to solve the problem of students' conceptual understanding in static fluid material. Solutions that can be implemented include the application of learning models such as in Maknun (2020), which applies the guided inquiry model to improve students' conceptual understanding in Static Fluid material. Mufit et al, (2019) also conducted research using the CCBL model to remediate misconceptions. Aside from using a learning model, another solution that can be implemented is the use of formative assessment media. This research has been conducted by Kusairi et al, (2021) who applied formative assessment in collaborative inquiry learning and Estianinur et al, (2021) who implemented STEM-integrated experimental learning with formative assessment. In addition, the development of physical teaching aids such as hydraulic pump models has proven effective in improving students' understanding of static fluid concepts (Parahna et al., 2022). Likewise, the use of interactive multimedia has shown significant improvement in students' conceptual mastery compared to traditional methods (Mazlina & Annisa, 2017).

Based on the findings of conceptual understanding achievement and students' difficulties in understanding static fluid material, it is encouraging to innovate improvement efforts. Analysis of 9 articles shows that opportunities can be made to improve concept understanding and overcome difficulties. Efforts can be made by improving the quality of learning by conducting related experiments in the classroom, deriving the hydrostatic equation and buoyancy force, and determining the density ratio (Irma et al., 2022). The information generated from this article can be used by teachers as an effort to design improvement efforts according to the difficulties experienced and consider the level of effectiveness of each effort.

This research has limitations, including the use of articles that focus on research in Indonesia. This limits articles that reveal the conceptual understanding profile and difficulties of students abroad in understanding static fluid material. Apart from these limitations, the purpose of limiting research in Indonesia is to focus on domestic problems so that the solutions produced are appropriate to the context and can be realized. This research has also provided an overview of the state of students' understanding as part of efforts to improve the education system.

4. CONCLUSION

The results of the analysis of 9 articles show that students' conceptual understanding of static fluid material tends to be low. The low level of students' conceptual understanding is due to the many difficulties students have with static fluid material. The students' difficulties are spread over all concepts discussed, including hydrostatic pressure, Archimedes' law, and Pascal's law. Various improvement efforts have been made to overcome and solve the problem of students' difficulties, including the application of Guided Inquiry learning model, CCBL model, formative assessment in collaborative inquiry learning, and STEM integrated experimental learning with formative assessment. The results of the analysis can be used by teachers as a basis for designing solutions to create more effective learning or designing research to solve students' difficulties.

The results of the analysis of the profile of students' conceptual understanding and difficulties in static fluid material provide an overview of the fact that there are still many pedagogical problems. Further research that can be done is a). to conduct a similar analysis with a larger scope so that more accurate and credible results can be obtained, b). to design learning that emphasizes direct experience so that students' conceptual understanding is more embedded, c). to use teaching media that are interesting and relevant to the times to increase interest and motivation. Use instructional media that are interesting and contemporary to increase interest and motivation to learn, and d). Provide feedback in learning as an effort to improve students' understanding of concepts that are not appropriate.

This review contributes to the physics education research by mapping students' conceptual comprehension profiles and frequent misconceptions about static fluid concepts. The findings contribute to the physics education literature through integrating empirical results from multiple studies and identifying instructional approaches that have been successfully implemented to solve conceptual difficulties. The information collected in this review will assist curriculum designers, educators, and researchers develop better targeted intervention measures. Furthermore, this study makes avenues for deeper future research, such as increasing the scope to include international contexts for more comprehensive comparisons, investigating the use of digital and interactive media in reducing misconceptions, and examining teachers' readiness and perceptions in addressing students' conceptual challenges.

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