UNIVERSITY OF EDUCATION, WINNEBA

INTEGRATING MULTIMEDIA INTO COGNITIVE LOAD THEORY: ITS IMPLICATIONS ON STUDENTS IN THE TEACHING OF FLUID MECHANICS

KROFA MAXWELL

MASTER OF PHILOSOPHY

2024

UNIVERSITY OF EDUCATION, WINNEBA

INTEGRATING MULTIMEDIA INTO COGNITIVE LOAD THEORY: ITS IMPLICATIONS ON STUDENTS IN THE TEACHING OF FLUID MECHANICS

KROFA MAXWELL

(220021452)

A Thesis in the Department of Science Education,
Faculty of Science Education, submitted
to the School of Graduate Studies, in partial fulfilment
of the requirements for the award of the degree of
Master of Philosophy
(Science Education)
in the University of Education, Winneba

JUNE, 2024

DECLARATION

STUDENT'S DECLARATION

I, Krofa Maxwell, hereby declare that this dissertation, "Integrating Multimedia into Cognitive Load Theory: Its Implications on Students in the Teaching of Fluid Mechanics", with the exception of quotations and references contained in published works which have all been identified and acknowledged, is entirely my own original work and that it has not been submitted either in part or whole for another degree programme elsewhere.

SIGNATURE: ……………………..……………

DATE: …………………………….……………

SUPERVISOR'S DECLARATION

I, hereby declare that the preparation and presentation of this dissertation were supervised in accordance with the guidelines on supervision of dissertations laid down by the University of Education, Winneba.

SUPERVISOR'S NAME: PROF. K. D. TAALE

SIGNATURE: ……………………..……………

DATE: …………………………….……………

DEDICATION

I humbly dedicate this work to God, who has made this study possible. His guidance and inspiration has been my unwavering source of strength throughout this academic journey.

I also extend my heartfelt thanks to my family members, who supported and encouraged me unwaveringly. Their love, patience, and sacrifices have been instrumental in my accomplishments.

ACKNOWLEDGEMENTS

First of all, I would like to thank Almighty God for giving me the wisdom, stamina, and time to complete my master's studies. Next, I would like to express my thanks and recognition to the following people:

My supervisor, Professor K.D. Taale (University of Education, Winneba), for placing great importance on academic achievement and encouragement throughout my studies. Thanks to Dr. Appiah-Twumasi Eric (AAMUSTED) for helping me read and edit my drafts.

My family; Susana Boaah Krofa, Franklin Krofa Akuoku, Maxwell Ahoto Krofa–Agyapong and Noah Krofa-Agyapong, for providing me with personal encouragement and support, their love, moral support, and understanding when I could not be with them.

The academic staff of the Department of Science and the students of Asamankese SHS for their cooperation with me in carrying out the intervention and completing it successfully.

TABLE OF CONTENTS

Content **Page**

LIST OF TABLES

Table **Page**

LIST OF FIGURES

ABSTRACT

This research explores the impact of integrating multimedia tools into cognitive load theory (CLT) learning strategies to improve the teaching and understanding of fluid mechanics among Senior High School students. The primary objectives were to assess students' pre-existing knowledge of fluid mechanics, evaluate the effectiveness of multimedia-enhanced CLT strategies in fostering conceptual change, and understand students' attitudes toward this instructional approach. The research focuses on the challenges students face in grasping fluid mechanics concepts and aims to design educational interventions that reduce cognitive overload while enhancing student engagement. Employing a mixed-methods research design, the study gathered data from students at Asamankese Senior High School in the West Akim Municipality, Eastern Region of Ghana, using the Fluid Mechanics Conceptual Test (FMCT), Physics Student Attitude Questionnaire (PSAQ), and Physics Student Semi-Structured Interview (PSSI). The findings reveal that students' prior conceptions of fluid mechanics fell into three categories: correct, alternative, and null conceptions. Initial assessments showed a significant number of students at Asamankese SHS held alternative or null conceptions, coupled with negative attitudes towards fluid mechanics. This highlighted the need for targeted educational interventions. Post-intervention results indicated notable improvements in students' understanding and attitudes. The study emphasizes the role of multimedia tools - such as text, visuals, simulations, and diagrams - integrated with cognitive load theory principles like segmentation and modality to enhance understanding of fluid mechanics at Asamankese Senior High School. The research concludes with recommendations for educators and policymakers to refine fluid mechanics instruction through these strategies, contributing to the advancement of physics education and setting the stage for future studies in this field.

CHAPTER ONE

INTRODUCTION

1.0. Overview

This chapter is on the background of the study, statement of the problem, purpose of the study, objectives of the study, research questions, and significance of the study, delimitations of the study as well as the limitations of the study. The chapter also discusses organisation of the study and operational definitions of key terms

1.1. Background to the Study

Fluid mechanics is a crucial yet challenging area of physics that many students struggle to comprehend due to its inherent mathematical and conceptual complexities. As noted by Wong et al. (2009), the subject often leads to cognitive overload, resulting in student disengagement, frustration, and suboptimal performance. To address these challenges, it is essential to explore how cognitive load theory (CLT) can be effectively applied to fluid mechanics instruction, thereby developing educational interventions that enhance student engagement and understanding.

At the senior high school level, fluid mechanics is an integral part of the physics curriculum, particularly within Science, Technology, Engineering, and Mathematics (STEM) education. Key concepts such as Archimedes' principle, Pascal's principle, the continuity equation, and Bernoulli's principle are typically covered, with fluid mechanics being a foundational topic in understanding fluid dynamics and statics. These concepts, as highlighted by Sappington and Taylor (2023), are essential for understanding the behaviour of gases and liquids, which form the basis of fluids as states of matter.

Archimedes' principle, one of the foundational topics in fluid mechanics, explains that any object submerged in a fluid experiences a buoyant force equal to the weight of the displaced fluid. This principle, which dates back to approximately 250 B.C., is fundamental in explaining why objects appear to weigh less when submerged in liquids (Walker et al., 2014, as cited in Ashenafi, 2022). Similarly, Pascal's principle states that pressure applied to a confined fluid is transmitted undiminished to all parts of the fluid and the container walls. This principle is widely used in hydraulic systems and other applications (Luoma, 2022; Nice CXone, 2022). Another key area in fluid mechanics is fluid dynamics, which deals with fluids in motion, such as steady and compressible flows. The continuity equation and Bernoulli's principle, which relate fluid velocity and pressure, are essential for understanding fluid behaviour in various real-world applications, from aviation to hydraulic engineering (Thakur, 2019; Baroth, 2021).

Despite the significance of these concepts, research has shown that students often harbour misconceptions about fluid mechanics, even after instruction. For instance, many students struggle with understanding buoyant forces, fluid flow, and the relationships between kinetic energy and Bernoulli's principle (Goszewski et al., 2013; Distrik et al., 2021). Additionally, concepts such as pressure, temperature, and the conservation of mass in fluid dynamics are often difficult for students to grasp, contributing to widespread misunderstandings in the subject (Ornet et al., 2008; Hartini & Sinensis, 2019). These challenges are often exacerbated by the cognitive load imposed by traditional teaching strategies and the complexity of the physics curriculum (Jong, 2010; Mupa & Chinooneka, 2015).

To address these challenges, cognitive load theory provides a valuable framework for designing instructional strategies that minimize cognitive overload and enhance learning. According to Sweller (1998, as cited in Soloman & Culatta, 2023), effective learning requires instructional methods that avoid overloading the working memory. Paas et al. (2016, as cited in Tianlong, 2017) further emphasize that reducing cognitive load is crucial for optimizing educational interventions. In the context of fluid mechanics, multimedia tools such as numerical simulations, visual aids, and interactive learning applications have been shown to facilitate understanding by presenting information in diverse formats that align with students' individual learning preferences (Ashenafi, 2022; Fraser et al., 2006; Zhou et al., 2009).

Integrating of multimedia into physics education has been demonstrated to improve student comprehension and problem-solving abilities (Gestson et al., 2018; Bakri & Mulyati, 2018). By utilizing multiple representations—such as text, formulas, diagrams, and simulations—multimedia learning strategies help reduce cognitive load, allowing students to process complex information more effectively (Opfermann et al., 2017; Joshua, 2017). This approach is particularly beneficial in teaching fluid mechanics, where the abstract nature of the concepts often requires varied instructional methods to facilitate deeper understanding.

Given the importance of fluid mechanics in fields such as engineering, healthcare, and environmental science, it is essential to improve how this subject is taught at the senior high school level. Effective instruction in fluid mechanics not only prepares students for advanced studies and professional careers but also contributes to a more scientifically literate society. This research is, therefore, critical in informing educators, curriculum developers, and policymakers on best practices for integrating multimedia and CLT into physics education. By exploring the implications of these strategies on student performance and attitudes, this study aims to contribute to the broader field of educational research and offer practical recommendations for enhancing the teaching of fluid mechanics.

In conclusion, this study seeks to address the challenges of teaching fluid mechanics by integrating multimedia tools within the framework of cognitive load theory. The research aims to improve student engagement, understanding, and performance in this critical area of physics, ultimately contributing to the development of more effective instructional strategies that can be applied across various educational contexts.

1.2. Statement of the Problem

Fluid mechanics occupies a privileged position in the sciences; it is taught in various science departments including physics, chemical and civil engineering, and environmental sciences, each highlighting a different aspect or interpretation of the foundation and applications of fluids (Vaidya, 2020). The application of fluid mechanics is predominant and important at the domestic and industrial levels. It is applied in aviation, hydraulic press, hydraulic jack, car braking systems, siphons, syringes, and drinking with a straw (Crowe et al., 2009). However, learning the complex principles of fluid mechanics can be difficult for students, which is frequently made worse by the subject's cognitive demands (Wulandari & Santoso, 2019). The reason has been that students may experience cognitive overload as a result of complicated fluid mechanics ideas, which are entwined with mathematical difficulties and dynamic fluid behaviours (Wickens et al., 2021).

The interaction of intrinsic, extraneous, and germane cognitive loads may affect students' motivation and interest in fluid mechanics, consequently affecting the attitude and the academic performance of students in fluid mechanics. This abysmal academic performance of physics students and students’ poor attitude toward fluid mechanics has been revealed by West African Examinations Council (WAEC) from 2011 to 2021. Specifically, according to the WAEC chief examiner's reports for physics, most candidates do not realise that pressure exerted on the floor is in two parts, the atmospheric pressure and pressure due to the water. That is, Pressure required equals to Pressure of the atmospheric plus calculated pressure (WAEC, 2011). The chief examiner's report revealed that, it appeared pressure in the fluid was not treated by most candidates. A greater number of candidates avoided answering the question on terminal velocity, according to the chief examiner's report (WAEC, 2019). The major cause of this challenge is that students constantly report that the concept is too abstract to comprehend its reality (Crowe et al., 2009; Vaidya, 2020), which stems from inappropriate teaching methods, as well as poor instructional design (Mayer & Moreno, 2003; Aloraini, 2011; Joshua, 2017).

The issue of senior high school (SHS) students' conceptual difficulties in fluid mechanics concepts cannot be grossed over because these physics students may staff the country's engineering, healthcare, and other fluid mechanics sectors in the near future. As a result, it implies that deliberate and rigorous efforts should be taken to address this ongoing problem in physics, as highlighted in the background. However, study findings indicate that integrating multimedia into cognitive load theory teaching strategies, such as videos, pictures, and audio-visual instructional teaching models will enhance the attitudes and conceptual change of physics students (Ashenafi, 2022; Bransford et al., 2000; Hmelo-Silver et al., 2007).

Therefore, this study seeks to investigate integrating multimedia into cognitive load theory and its implications on students' attitudes and performance in fluid mechanics concepts in Physics, at Asamankese Senior High School in the West Akim Municipality in the Eastern Region, Ghana.

1.3. Purpose of the Study

The purpose of the study was to examine the impact of integrating multimedia into Cognitive Load Theory (CLT) learning instructional strategies on the improvement of the student's attitude and performance in learning fluid mechanics in physics at Asamankese Senior High School (ASASCO) in West Akim Municipality, Eastern Region of Ghana.

1.4. Objectives of the Study

The following specific objectives that guided the study were to;

1. establish the student's prior conceptual knowledge in fluid mechanics
2. determine the extent to which integration of Multimedia into Cognitive Load Theory enhance SHS students' conceptual change in Fluid Mechanics
3. determine the students' attitudes towards the integration of Multimedia into Cognitive Load Theory instructional strategies in the study of the Fluid Mechanics concepts in physics

1.5. Research Questions

This study was designed to answer the following research questions:

1. What prior conceptual knowledge do students 'hold in fluid mechanics?
2. What extent does the integration of multimedia into cognitive load theory enhance SHS students' conceptual change in fluid mechanics?
3. What is the effect of integration of Multimedia into Cognitive Load Theory on students' attitude towards the study of fluid mechanics?

1.6. Significance of the Study

1. The findings in this study are hoped to help policy makers and curriculum designers to establish effective instructional approaches to teaching fluid mechanics concepts in physics that will help improve students' performance.
2. The findings in this study, the cognitive load theory (CLT) with multimedia learning techniques is hoped to help teachers and Asamankese SHS instructors to adapt and modify their lessons in the context when presenting lessons.
3. By defining each concept using cognitive load theory (CLT) with multimedia learning methodologies, other researchers and academicians in higher education can utilise or modify these lessons to fit their setting.
4. Knowledge about students' prior understanding of fluid mechanics concepts in this study is hoped to help other researchers focus their research and produce solid conclusions that will help students understand the fluid mechanics concepts they are learning in senior high schools.

1.7. Delimitations of the Study

This study could have covered all the science students of Asamankese Senior High School (ASASCO), thus form one, form two, and form three science students. However, much emphasis was placed on form three science A class, because of the limited time available.

Secondly, due to financial constraints, only Asamankese Senior High School form three Physics students were involved in this study. This prevented the general representation of the research findings to other learning contexts.

Finally, due to limited teaching and learning resources, the study focused on only specific topics in fluid mechanics concepts in physics, such as Bernoulli's principle, Archimedes' principle, and Pascal's law. Hence, this does not permit the generalisability of the research findings to all other topics in physics, and this narrows the scope of the study.

1.8. Limitations of the Study

The study was influenced by the following four major limitations:

1. The instruments adapted for data collection, tests, questionnaires, and interviews may not produce a vivid picture of what is happening in the school. This is because the participants may not give clear information on the questionnaire or during the interview session, which may not be enough to draw such general conclusions about the students. As a result, the final conclusion may not be a true reflected image of the problem on the ground.
2. The quantitative and qualitative methodologies are based on different assumptions, it is possible that different techniques could produce different results.
3. Through open-ended questionnaires (OEQs), it was difficult to obtain in-depth qualitative and conceptual information from students.
4. The student's cognitive load and performance are not static and may change over time with learning. The dynamic nature requires continuous evaluation and reassessment of cognitive load to identify the most effective teaching strategies for helping students achieve their academic goals.

1.9. Organisation of the Study

This thesis is structured into several key sections to provide a comprehensive understanding of the research.

Introduction: This section provides an overview of the research problem, articulates the research questions and objectives, and describes the significance and purpose of the study.

Literature Review: In this section, existing research on cognitive load theory and multimedia learning theory is synthesized, focusing particularly on their intersection. The review also examines previous studies on the integration of multimedia in education, specifically in the context of fluid mechanics teaching, and sets out the theoretical framework for the study.

Research Methodology: This section describes the research design, including the chosen approach (quantitative, qualitative, or mixed methods) and provides a rationale for its selection. It details the sampling strategy, participant selection criteria, data collection methods (e.g., surveys, interviews), and the rationale for their appropriateness. In addition, the planned data analysis techniques such as descriptive statistics, content analysis, and thematic coding are described.

Results: The results section presents the findings of the study, organized according to the research questions. It uses tables, thematic coding, and graphs to visually represent the survey responses or data collected. The section also analyses and interprets the results, relating them to the theoretical framework, and discusses the implications for teaching fluid mechanics through multimedia integration in cognitive load theory in education.

Conclusion: This section summarises the key findings, reiterates their implications for theory and practice, and offers recommendations for educators, curriculum developers, and policymakers based on the results of the study. Limitations of the study and potential areas for future research are also discussed.

References: This section includes all sources cited in the paper.

Appendices: The appendices contain supplementary materials such as the survey questionnaire, interview protocols, and informed consent forms, concluding the organisation of the study.

1.10. Operational Definition of Key Terms

1. Cognitive load theory: This is defined as the number of cognitive resources used to process and integrates information relevant to learning fluid mechanics in physics.
2. Fluid mechanics: The branch of physics that deals with the study of fluids in motion and the mechanical forces that cause fluids to move.
3. Integration: The act of combining or incorporating different elements, such as multimedia, into a unified whole within the context of cognitive load theory
4. Performance: The use of objective measures, such as test scores, grades, and assessments, to evaluate how well students understand and apply fluid mechanics concepts in physics.
5. Prior conceptual knowledge: Prior conceptual knowledge of students in fluid mechanics refers to the understanding and familiarity that students already possess about the fundamental concepts and principles related to fluid mechanics before they engage in a specific educational or instructional context
6. Implication: The possible consequences, effects or applications that arise from the integration of multimedia in the cognitive load theory for teaching Fluid Mechanics.

7. Students: Individuals who participate in learning activities, particularly in the context of education or academic studies, and who are the primary focus of the implications discussed in the topic.
8. Cognitive: Related to the mental processes involved in learning, understanding, and acquiring knowledge, which are fundamental to cognitive load theory.
9. Load: The amount of mental effort or processing capacity required by a learning task, influenced by factors such as the complexity of the material and the learner's prior knowledge.
10. Theory: A coherent set of principles or concepts that explain phenomena or guide practice within a particular field of study, in this case, cognitive load theory applied to the teaching of Fluid Mechanics.

CHAPTER TWO

REVIEW OF THE RELATED LITERATURE

2.1. Overview

The study focused on using interventional instruction to address students' conceptual difficulties with fluid mechanics. It starts with history of fluid mechanics in physics explanation and continues with sections on physics education research subjects; definition of fluid mechanics concepts; specific descriptions of the difficulties that physics students encounter in developing a conceptual understanding of physics ideas; fluid mechanics teaching approaches. It also addresses the theoretical and conceptual frameworks in which the study is grounded. Other key areas this chapter focuses are the multimedia representations and empirical framework that relate to the study.

2.2. The History and Development of Fluid Mechanics

The knowledge of fluid flow is as old as human history. People have developed an interest in knowing more about fluid flow and have become more concerned about identifying the factors behind the flow of substances. Accordingly, people began to seek answers to the questions of fluid flow and the nature of air and water. Fluid flow has been categorised as hydraulics and hydrodynamics. In this regard, hydraulics is concerned with experimental studies, while hydrodynamics focuses on the theory of fluid flow. Therefore, the study of fluid mechanics resulted from the combination of hydraulics and hydrodynamics (Nguyen et al., 2019). As hydraulics evolved, it became a purely experimental science with practical applications. In the Great Rift Valley regions, including the Nile Valley and the Tigris and Euphrates River Valleys, people developed irrigation agriculture supported by a continuous stream of water used to produce their food. Egypt and Mesopotamia, in particular, played a significant role in developing irrigation technology about 8,000 years ago (Nguyen et al., 2019). Since then, irrigation systems have been used to irrigate agricultural land to produce crops and vegetables to meet household demands. Hydraulics is thus believed to have originated in water channels and floating ships (Nguyen et al., 2019).

As time passed, the history of fluid mechanics advanced to support daily life (Nguyen et al., 2019). Meanwhile, the theory of viscous flow remained underexplored. Contributions from Navier (1785–1836) and Stokes (1819–1903) added Newtonian viscous terms to formulate the equations of motion. The equations developed by Navier-Stokes were challenging to analyse for arbitrary flows (Nguyen et al., 2019). A significant paper on fluid mechanics was written by the German engineer Ludwig Prandtl (1875–1953). Prandtl is credited with identifying the division of water and air flow, particularly by applying the Bernoulli and Euler equations to study small viscosity fluids. Since then, boundary layer theory has become a crucial tool in the analysis of fluid flows (Nguyen et al., 2019). Other notable contributors to fluid mechanics include Theodore von Kármán (1881–1963) and Sir Geoffrey I. Taylor (1886–1975), both of whom laid the foundation for modern fluid mechanics (Nguyen et al., 2019).

2.3. Physics Education Research and its Impact on Students' Conceptual Understanding

Physics Education Research (PER) has grown significantly over the past few decades, driven by the need to enhance students' understanding of complex physical concepts. PER focuses on understanding how students learn physics, identifying common misconceptions, and developing teaching strategies that promote deeper conceptual comprehension (Loverude et al., 2003). The implications of PER on students' conceptual understanding are profound, particularly in areas like fluid mechanics, where traditional teaching methods often fail to address underlying cognitive challenges.

One of the core objectives of PER is to identify and address students' misconceptions in physics. Studies have shown that students often enter physics courses with pre-existing beliefs that are inconsistent with scientifically accepted concepts (McDermott & Redish, 1999). These misconceptions can hinder the learning process, as students may struggle to reconcile their prior knowledge with new information. In fluid mechanics, for instance, students often misunderstand principles such as pressure distribution and buoyancy. PER has provided insight into these difficulties, leading to the development of instructional strategies that explicitly target and correct these misconceptions (Loverude et al., 2003).

Furthermore, PER has emphasized the importance of active learning and inquiry-based approaches in improving conceptual understanding. Traditional lecture-based teaching methods have been found to be less effective in fostering deep understanding of physics concepts (Hake, 1998). In contrast, interactive engagement methods, such as peer instruction and problem-based learning, have shown significant improvements in students' conceptual understanding (Crouch & Mazur, 2001). These methods encourage students to actively participate in the learning process, engage with the material, and collaboratively solve problems, which has been particularly effective in teaching complex topics like fluid mechanics.

Moreover, PER has highlighted the role of metacognition in learning physics. Metacognitive strategies, which involve students reflecting on their own thinking and learning processes, have been shown to enhance conceptual understanding (Redish, 2003). By encouraging students to monitor their own understanding and recognize gaps in their knowledge, educators can help students develop more robust and accurate conceptions of fluid mechanics.

In summary, the insights gained from Physics Education Research have significant implications for improving students’ conceptual understanding, especially in challenging areas like fluid mechanics. By addressing misconceptions, promoting active learning, and fostering metacognitive skills, PER provides a framework for developing more effective teaching strategies. These strategies not only enhance students' grasp of physical concepts but also contribute to their overall cognitive development in physics education.

2.3.1. Physics education research and its effect on students' conceptual understanding of fluid mechanics

Physics Education Research (PER) has significantly influenced the strategies employed in teaching complex physics concepts, including fluid mechanics. Fluid mechanics, a core area in physics, presents unique conceptual challenges for students due to its abstract nature and the mathematical intricacies involved (Clement, 1982). PER has played a pivotal role in identifying these challenges and developing instructional methods aimed at enhancing students' conceptual understanding.

One of the key contributions of PER to the teaching of fluid mechanics is the identification of common misconceptions that students hold about fluid dynamics and statics. Research has shown that students often struggle with concepts such as pressure, buoyancy, and the behaviour of fluids under varying conditions (Clement, 1982). For example, students frequently confuse the relationship between pressure and depth in a fluid or misunderstand the principle of continuity in fluid flow. PER has systematically investigated these misconceptions and has informed the development of targeted interventions designed to address and correct these misunderstandings (Trowbridge & McDermott, 1981).

Moreover, PER has emphasized the importance of using multiple representations and active learning strategies to improve students' understanding of fluid mechanics. Traditional lecture-based approaches often fail to engage students sufficiently, leading to surface-level learning (Mazur, 1997). In contrast, PER advocates for the use of visual aids, simulations, and interactive problem-solving activities that allow students to visualize and experiment with fluid mechanics concepts in real-time. Studies have demonstrated that when students are engaged in active learning environments, where they can manipulate variables and observe outcomes, their understanding of fluid dynamics and related concepts improves significantly (Hake, 1998).

Additionally, PER has highlighted the role of scaffolding in helping students grasp complex fluid mechanics concepts. Scaffolding involves breaking down complex problems into more manageable steps and providing support as students work through these problems. Research suggests that when instructors use scaffolding techniques, students are better able to connect theoretical knowledge with practical applications, leading to deeper conceptual understanding (Chi et al., 1989).

The integration of multimedia into PER-informed strategies has further enhanced the teaching of fluid mechanics. Multimedia tools, such as simulations and animations, provide dynamic visualizations that help students overcome the abstract nature of fluid mechanics concepts. These tools, when used in conjunction with PER-based instructional strategies, have been shown to reduce cognitive load and improve students' ability to transfer their understanding to new contexts (Mayer & Moreno, 2003).

In conclusion, Physics Education Research has had a profound impact on improving students' conceptual understanding of fluid mechanics. By identifying common misconceptions, promoting active learning, and integrating multimedia tools, PER has contributed to the development of more effective teaching strategies. These strategies not only enhance conceptual understanding but also foster a deeper engagement with the material, ultimately leading to improved learning outcomes in physics education.

2.3.2. Understanding Students' Conceptions in Fluid Mechanics

Students' conceptions play a critical role in their learning and understanding of scientific concepts, particularly in complex subjects like fluid mechanics. These conceptions can be classified into three categories: correct conceptions, alternative conceptions, and null conceptions. Each type of conception significantly influences how students engage with new information and apply their knowledge.

1. **Correct Conceptions**: Correct conceptions reflect a scientifically accurate understanding of concepts. When students hold correct conceptions, they are more likely to apply their knowledge effectively in problem-solving and real-world situations. Research has shown that students with correct understandings are better equipped to integrate new information, build on prior knowledge, and develop deeper conceptual frameworks (Chien-Heng, 2018). For example, a student who correctly understands the principles of buoyancy can apply this knowledge to various fluid mechanics problems, leading to improved learning outcomes.
2. **Alternative Conceptions**: Alternative conceptions, or misconceptions, occur when students possess beliefs or understandings that deviate from scientifically accepted views. These misconceptions can hinder learning, as they may lead to misunderstandings and incorrect applications of concepts (Smith et al., 1993).

For instance, a student might believe that "heavier objects sink faster" without recognizing the role of density and buoyancy in fluid mechanics. Such alternative conceptions can create cognitive barriers, making it difficult for students to grasp more complex ideas or correct their misunderstandings unless explicitly addressed through targeted instruction (Clement, 2000). Research indicates that identifying and confronting these misconceptions is essential for effective teaching, as it allows educators to design interventions that promote conceptual change (Duit, 1991).

3. **Null Conceptions**: Null conceptions refer to a lack of understanding or prior knowledge about a particular topic. Students with null conceptions may not recognize the relevance of fluid mechanics concepts or may be entirely unfamiliar with them. This absence of understanding can impede the learning process, as students have no framework to relate new information to their existing knowledge (DiSessa, 2006). In educational contexts, it is crucial to identify students with null conceptions and provide foundational knowledge to bridge gaps before introducing more advanced content. Without this groundwork, students may struggle to engage meaningfully with the subject matter (Mason, 2000).

In conclusion, correct, alternative, and null conceptions significantly impact students' learning and understanding of fluid mechanics and other scientific disciplines. Effective instructional strategies must consider these conceptions to foster deeper learning and address misconceptions. By tailoring instruction to identify and correct alternative conceptions and provide foundational knowledge for those with null conceptions, educators can enhance students' conceptual understanding and facilitate successful learning experiences.

2.4. Definitions of Fundamental Fluid Mechanics Concepts

Fluid mechanics is a branch of physics that studies the behaviour of fluids (liquids and gases) at rest and in motion. Understanding fundamental fluid mechanics concepts is essential for comprehending more complex phenomena in this field. These basic concepts include fluid properties, pressure, buoyancy, and flow dynamics, all of which are foundational to the study and application of fluid mechanics (Fox et al., 2011).

One of the primary concepts in fluid mechanics is the understanding of fluid properties such as density, viscosity, and surface tension. Density is defined as the mass per unit volume of a fluid and is a critical factor in determining how fluids interact with their surroundings (Fox et al., 2011). Viscosity refers to a fluid's resistance to deformation or flow, a property that significantly influences the flow characteristics of fluids (White, 2011). Surface tension is the cohesive force at the surface of a fluid that causes it to behave like an elastic sheet, affecting phenomena like capillary action and droplet formation (Munson et al., 2013).

Pressure is another fundamental concept, defined as the force exerted by a fluid per unit area. It is a scalar quantity that varies with depth in a fluid and is described by Pascal's Law, which states that pressure applied to an enclosed fluid is transmitted undiminished to all parts of the fluid (Cengel & Cimbala, 2010). Understanding pressure is crucial for analysing fluid statics, including the study of buoyancy, where the Buoyant Force is the upward force exerted by a fluid on an immersed object, as described by Archimedes' principle (Fox et al., 2011).

Fluid flow dynamics, encompassing both laminar and turbulent flow, is another critical area in fluid mechanics. Laminar flow occurs when fluid flows in parallel layers with minimal disruption between them, while turbulent flow is characterized by chaotic changes in pressure and flow velocity (White, 2011). The transition between these flow regimes is often described by the Reynolds number, a dimensionless quantity that predicts the flow pattern in different fluid systems.

In brief, a thorough understanding of fundamental fluid mechanics concepts such as fluid properties, pressure, buoyancy, and flow dynamics is essential for the effective study and application of fluid mechanics. These concepts provide the foundation upon which more complex analyses and applications in various engineering and scientific fields are built.

This study adopted Ghana's curriculum for physics, in senior high school majoring in Physics (CRDD, 2010). Topics involving fluid mechanics concepts for SHS /STEM education cover fundamental areas of physics such as fluid dynamics (fluids in motion and continuity equation), Pascal's principle, Bernoulli's principle, and Archimedes' principle, also known as the buoyant force (Voogt et al., 2019). These four areas are explained in more detail in the section that follows.

2.4.1 Archimedes' principle

According to Ashenafi (2022), the Archimedes' principle was developed by Greek mathematician Archimedes around 250 BC, and states that objects submerged in a fluid experience a buoyant force equal to the upthrust exerted on them. This force pushes them upwards, causing them to appear less in weight when submerged in a liquid.

An extension of this principle states that the weight of the displaced fluid is equal to the weight of the submerged object when fully submerged in a liquid (figure 1).

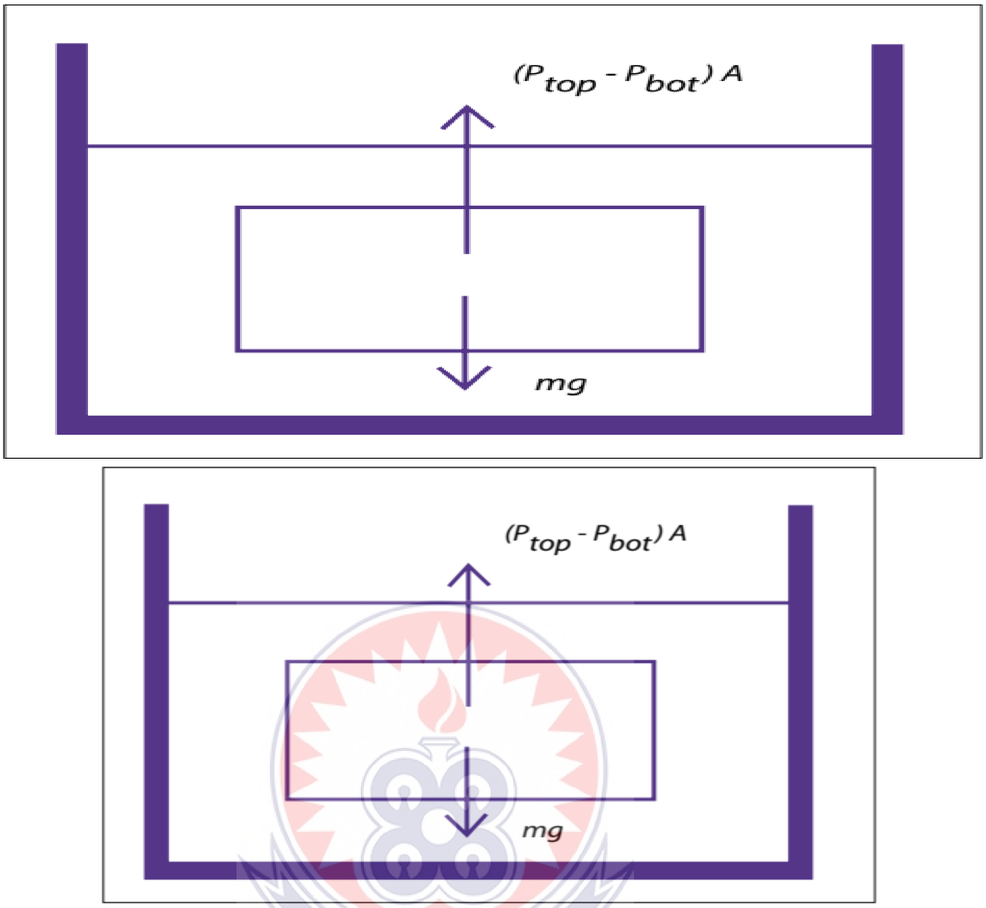


Figure 1: A Submerged Object Surrounded by a Fluid

Source: (Jewett, & Serway, 2008, p 390).

The buoyancy of an object is determined by the difference in fluid pressure between its top and bottom. The free-body diagram in Figure 1 shows three forces: a downward force, the weight (mg), an upward force ($P_{bot}A$), and a downward force ($P_{top}A$). The fluid around the block exerts a net upward force due to the pressure at the bottom being greater than the pressure at the top. The overall force attributed to fluid pressure is equal to the weight of the displaced fluid, denoted as (P_{bot}–P_{top}) A. Buoyancy is the force that causes us to rise as we float. In Figure 2 below, the buoyant force is produced by replacing the fluid's bottom force with a normal force between the surface and the object.

$F_{bouyant} = W_{fluid} = \rho_{fluid} V_{displaced fluid} g$ 1

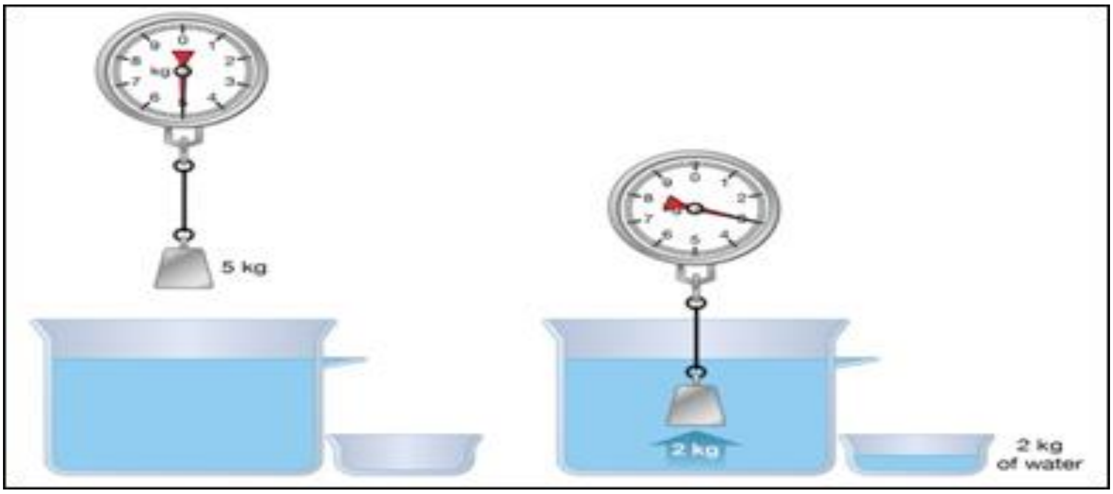


Figure 2: Archimedes Principle

Source: (Jewett, & Serway, 2008, p. 392)

2.4.2 Pascal's principle

Pascal's principle states that pressure applied to a fluid in a container causes equal pressure transmission through the fluid and container walls, a principle effectively used in hydraulic presses as shown in figure 3.

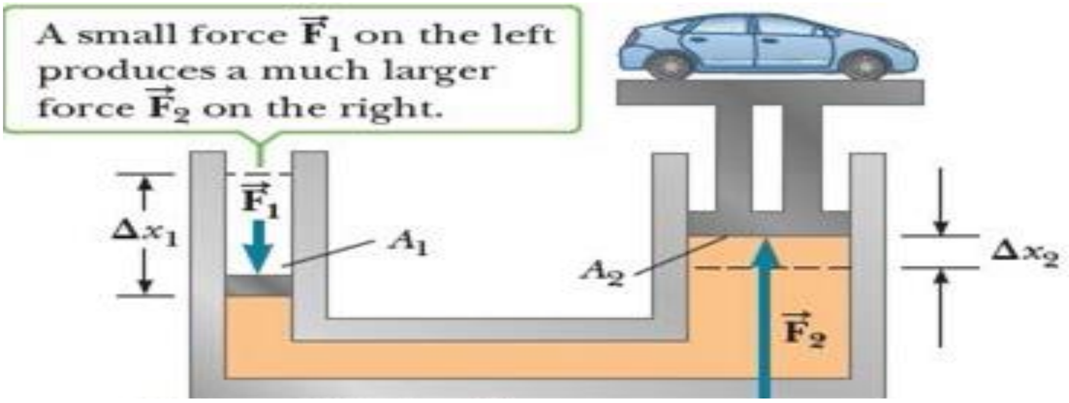


Figure 3: Hydraulic Press

Source: (Serway 2004 p. 393)

A small piston with area A_1 is subjected to a downward force, resulting in pressure P_1. Mathematically expressed as; $P_1 = \frac{F_1}{A_1}$, ……………………………..2

This pressure is evenly distributed throughout the tank, reaching the larger piston on the opposite side. Fluid flows from the smaller to the larger piston, pushing the larger piston when there is a pressure of P_2 given as; $P_2 = \frac{F_2}{A_2}$, ………………………..3

The force acting on the larger piston is equal to F_2.The two pressures are equal even though there are separate forces being applied, according to Pascal's principle. This could mean that:

$$\frac{F_1}{A_1} = \frac{F_2}{A_2} \text{ ………………………}4$$

One of the main ways that Pascal's theory was put to use was the hydraulic press, which was employed for interiors and other openings.

2.4.3. Fluid dynamics

Fluid motion, or hydrodynamic fluids, can be categorised into different types: static fluids, which maintain constant flow, and fluid motion, which can be either compressible or incompressible. Non-viscous fluids, like water, can flow easily, while viscous fluids, like honey, cannot. Incompressible fluids have a constant flow rate, as per the continuity equation.

Flow rate = $\frac{Volume}{Time}$ = Av =Constant …..……………5

The product of the fluid's area and velocity at all points along a tube remains constant. This principle, which states that the volume of water leaving a tube is equal to the volume entering it when there are no leaks, can be observed by observing the flow rate of a garden hose outlet.

2.4.4. Bernoulli principle

Bernoulli's principle was developed by Daniel Bernoulli, an 18th - century physicist's concept that states that fast-moving fluids exert less pressure than slow-moving ones as shown in figure 4, and its mathematical expression is illustrated in the following equation.

$P + \frac{1}{2}\rho v^2 + \rho g y$ = Constant ………………………….6

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

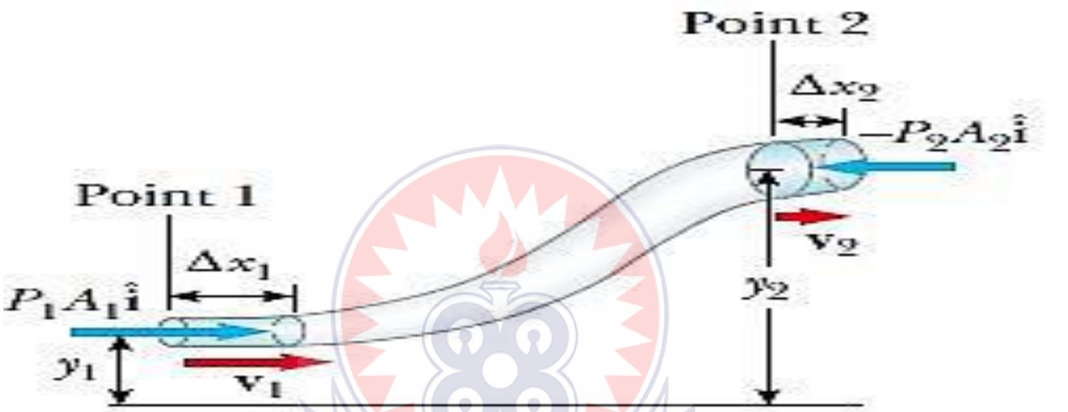


Figure 4: Fluids flowing through pipes of different Cross-Sectional Areas

Source: (Serway, 2004, p. 402).

2.5. Conceptual Difficulties with Fluid Mechanics Concepts

This section discuss the conceptual difficulties students experience with fluid mechanics concepts. These include conceptual difficulties with understanding Archimedes principle, Pascal's principle, fluid dynamics and Bernoulli's principle as follows:

2.5.1. Conceptual difficulties with understanding the Archimedes principle

Archimedes' principle is used to explain buoyancy force, but senior high school students struggle with understanding it and calculating basic things' sinking and floating properties (Chen & Gladding, 2014; Minogue & Borland, 2016). They also struggle to distinguish between weight and density of dissolved substances in fluids, internal force and pressure, volume and mass of materials (Hellström et al., 2017; Stephen, 2021). Students also struggle to accurately assess and calculate the mass of a substance when entirely or partially submerged in a fluid (Loverude et al., 2010). They often use the same formula to explain all three scenarios, making it difficult to differentiate between fully or completely immersed, partially, or floating objects. This makes it difficult for students to answer and compute internal force problems and examine the outcomes and conclusions obtained from solving these problems (Ashenafi, 2022).

2.5.2. Conceptual difficulties with understanding Pascal's principle

Pressure measurement is a fundamental concept in various fields, including gas stations, water, and tire pressure (Walker et al., 2014). It is taught in general science lessons from elementary school through high school, and later in fluid mechanics concepts in physics. However, college students often struggle with pressure variations at different temperatures and the relationship between pressure and volume (Aksit, 2011; Minichiello, et al., 2020). Students struggle with distinguishing between weight and pressure, pressure and temperature, pressure and volume detection, and pressure and force (Karniadakis et al., 2020). The link between pressure and height is also challenging, as students struggle to understand the relationship between pressure and height (Goszewski et al., 2013). Additionally, students struggle with proportional thinking and describe the interaction between pressure and density. Many college students also struggle to recall the unit of pressure and understand formulas representing density and weight (Aksit, 2011).

2.5.3. Problems with conceptual understanding of fluid dynamics

Conceptual understanding of fluid mechanics poses significant challenges for students due to the abstract and mathematically intensive nature of the subject. One of the primary difficulties lies in grasping the non-intuitive principles that govern fluid behaviour, such as the relationship between pressure and depth, the principles of buoyancy, and the complexities of fluid flow, including the distinction between laminar and turbulent flow (Cengel & Cimbala, 2010). Students often struggle with these concepts because they require a departure from everyday experiences and demand a strong foundation in both physics and mathematics (Trowbridge & McDermott, 1981). Additionally, fluid mechanics involves a significant cognitive load, as students must simultaneously understand and apply multiple principles, equations, and physical laws. This cognitive demand can overwhelm students, leading to misconceptions or incomplete understanding of key concepts (Mayer & Moreno, 2003). For instance, students frequently misinterpret the continuity equation or fail to apply Bernoulli's principle correctly when analysing fluid flow (Loverude et al., 2003). These challenges underscore the need for effective instructional strategies, such as multimedia integration, to alleviate cognitive load and enhance conceptual understanding in fluid mechanics.

2.5.4. Conceptual difficulties with understanding the Bernoulli principle

Bernoulli's principle, a fundamental concept in fluid mechanics, often presents significant conceptual challenges for students. The principle, which relates the pressure, velocity, and elevation of a fluid along a streamline, is counterintuitive to many learners because it suggests that an increase in fluid velocity leads to a decrease in pressure, a concept that contradicts everyday experiences (Cengel & Cimbala, 2010). This counterintuitive nature makes it difficult for students to fully grasp the underlying physics.

One common misconception is the misunderstanding of the causal relationship between pressure and velocity. Students frequently struggle to differentiate between cause and effect, often assuming that changes in pressure cause changes in velocity, rather than recognizing that both are interrelated aspects of the same fluid flow condition (Hewitt, 2002). Additionally, students often misapply Bernoulli's equation by neglecting the assumptions under which it holds true, such as steady flow, incompressibility, and the absence of frictional losses, leading to errors in problem-solving and analysis (Muller, 2001).

Furthermore, the abstract nature of Bernoulli's principle makes it difficult for students to visualize and apply it in real-world scenarios. For instance, understanding how Bernoulli's principle explains lift in an airplane wing or the functioning of a Venturi meter requires students to translate theoretical knowledge into practical applications, a task that is often challenging without adequate instructional support (Loverude et al., 2003). Addressing these conceptual difficulties requires targeted instructional strategies, including the use of multimedia tools, to bridge the gap between abstract theory and practical understanding.

2.6. Multimedia in Fluid Mechanics Teaching Approaches

The integration of multimedia in teaching fluid mechanics is crucial for enhancing students' comprehension of complex concepts. Multimedia representation teaching resources, including animations, simulations, and interactive visualizations, play a vital role in making abstract fluid mechanics concepts more tangible. These tools allow for dynamic visualization of fluid behaviour, such as flow patterns, pressure changes, and the effects of varying conditions, which are difficult to grasp through static images or text alone. By utilizing multimedia-based content, instructors can present fluid mechanics through various representations, making it more accessible and engaging for students (Abdurrahman et al., 2019).

Contextual teaching strategies that incorporate multimedia tools, such as virtual labs, video demonstrations, and interactive problem-solving exercises, are particularly effective in this domain. These strategies not only enhance the traditional teaching methods but also require proficiency in ICT to be effectively integrated into classroom activities. For instance, multimedia tools can be used to illustrate mathematical equations and their applications in real-world fluid mechanics problems, thereby bridging the gap between theory and practice. This approach fosters a more immersive learning experience, allowing students to experiment with variables and observe the outcomes in a controlled digital environment (Bakri & Mulyati, 2018).

However, while student-centered learning approaches promote autonomy and active participation, they may not always be sufficient for mastering fluid mechanics, which often requires guided instruction. Multimedia tools can support collaborative learning environments where students work together on simulations or analyse case studies with instructor guidance. This combination of multimedia and collaborative learning aligns with 21st-century educational demands, where the role of the instructor is to facilitate and enhance the learning process rather than merely deliver content (Hattan et al., 2022).

Additionally, fluid mechanics concepts are frequently explored through hands-on laboratory activities, which can be significantly augmented by multimedia resources. Virtual labs and simulations can complement physical experiments, allowing students to visualize the underlying principles before or after conducting the actual experiments. This dual approach not only reinforces the learning objectives but also addresses potential timing discrepancies in lab sessions, ensuring that students remain focused and engaged with the academic material (Ashenafi, 2022; El -Hajj & Budny, 2019).

2.7. Theoretical Framework

The theoretical framework for this study is built on Cognitive Load Theory (CLT) by Sweller (1988), Dual Coding Theory (DCT) of Paivio (1986) and Baddeley's Working Memory Model, Baddeley (2000). These theories explain how cognitive processes occur during learning, especially with multimedia sources, providing insights for instructional design.

2.7.1. Cognitive Load Theory (CLT)

Cognitive Load Theory (Sweller, 1988) posits that learning is constrained by the limited capacity of working memory, which processes current tasks (Reif, 2010). The theory identifies three types of cognitive load: intrinsic (related to the difficulty of the material), extraneous (stemming from the way information is presented), and germane (aiding schema development) (Dominic & Rachel, 2018). Instructional design must manage these loads to prevent overwhelming learners (De Jong, 2010). CLT's role in education focuses on structuring instruction to transfer knowledge from short-term to long-term memory efficiently (Gathercole & Alloway, 2007). Additionally, competency-based education is increasingly valued for developing skills applicable in various contexts (Westera, 2001; Dwivedi et al., 2022).

2.7.1.1. Cognitive Architecture: Memory and Schemas

Sweller et al. (2011) stress that short-term working memory (SWM) is limited, while long-term memory (LTM) stores information permanently and organizes knowledge into schemas (Chien-Heng, 2018). Schemas reduce cognitive load by allowing efficient information processing.

2.7.1.2. Cognitive Load

Cognitive Load Theory (CLT) posits that learning occurs within the limits of working memory, which is constrained in capacity but connected to an unlimited long-term memory. Instructional design must therefore carefully manage the working memory load to avoid overwhelming learners (Pappas, 2014).

Several factors influence cognitive load, including individual characteristics, task difficulty, and environmental interactions. CLT measures cognitive load through performance, mental effort, and mental burden. The mental load is shaped by task and environmental demands, while mental effort reflects the cognitive resources used to complete a task. Performance is influenced by these factors and the cognitive load present during the task (Cowan, 2014).

CLT distinguishes intrinsic, extraneous, and germane cognitive load. Effective instructional design reduces extraneous load while increasing germane load to support schema development (Yang & Farley, 2019). Despite challenges in distinguishing between load types, CLT informs strategies like worked examples, enhancing learning efficiency (Asma & Dallel, 2020).

2.7.1.3 German cognitive load and instructional design

Research suggests that minimizing extraneous load and optimizing germane load enhances learning (Asma & Dallel, 2020). By encouraging active cognitive processing, instructional design can improve learning outcomes while maintaining manageable cognitive load within working memory capacity.

2.7.2. Mayer's cognitive theory of multimedia learning

Mayer (2014) proposed the Cognitive Theory of Multimedia Learning (CTML), suggesting that learning is enhanced when information is presented through both text and graphics. The theory incorporates dual coding and cognitive load principles to explain how verbal and visual systems work together to process information (Mayer, 2014; Keane et al., 2022). Effective multimedia learning requires eliminating unnecessary content and aligning visuals with text (Sweller et al., 2011). Despite the controlled settings of early multimedia research, this study seeks to explore multimedia use in real-world educational contexts (Fredlund et al., 2015; Bernhard, 2010). This approach, combined with cognitive theory, benefits students by accommodating their diverse intelligences, and multimedia can express various concepts through text, drawings, graphs, and equations (Lo, 2012; Eichenlaub & Redish, 2019).

2.7.3. The Dual Coding Theory (DCT) by Allan Paivio

Paivio's Dual Coding Theory (DCT) suggests that human cognition processes verbal and non-verbal information simultaneously. Verbal information deals with language, while non-verbal information relates to images and events (Richard, 2023). DCT emphasizes that both cognitive systems function together, aiding learning through symbols (logos) and mental images.

2.7.4. Working Memory Model of Alan Baddeley

Alan Baddeley, a British psychologist, conducted experiments to understand how the brain processes short-term memory. He was interested in how memories vanish after usage and are not recalled afterward. Some short-term memories can develop into long-term memories (Charlee & Reinadith, 2022). Baddeley's working memory theory is the recognised theory of short-term memory function. The Baddeley study revealed short-term memory to be a multi-party system with several components, leading to the development of the Baddeley model of working memory, according to Charlee and Reinadith (2022).

2.7.4.1. Components of working memory

According to Charlee and Reinadith (2022), Baddeley's working memory comprises the episodic buffer, central executive, visuospatial sketchpad, and phonological loop, each processing data independently while operating in sync with the others.

2.7.4.2. Phonological loop

The phonological cycle is the first element of the Baddeley model of working memory, focusing on the organisation of words and sounds in language. It deals with data from spoken and written language, including information given to a person, mathematical issues, new vocabulary words, and printed addresses (Charlee & Reinadith, 2022).
According to Charlee and Reinadith (2022), the phonological cycle consists of two components: phonological storage and articulatory control. The inner ear stores information temporarily, creating short-term memories during conversations. The articulatory control phase involves the inner voice interpreting and narrating the information, forming and producing words throughout a dialogue.

2.7.4.3. The visual sketchpad

The visuospatial sketchpad stores visual and spatial information, while the phonological cycle deals with spoken and written information. It helps individuals recall the layout of a place or the appearance of a painting, allowing them to remember their location in relation to other objects (Charlee & Reinadith, 2022).

2.7.4.4. The central executive

Charlee and Reinadith (2022) emphasise that the executive core memory is the most crucial component of the Baddeley model of working memory, coordinating all system components. It handles task switching and memory termination, as various memories may be needed for actions. Dreaming and termination of some memories are additional functions of the central executive.

2.7.4.5. Buffer episodes

Charlee and Reinadith (2022) argue that Baddeley's initial description of working memory was incomplete, omitting the relationship between long-term and short-term memory. They include the episodic buffer as a crucial element, facilitating communication between these two types of memory. The episodic buffer functions similarly to computer backup storage, examining how short-term memory can develop into long-term memory.

2.8. Conceptual Framework

Figure 5 reveals the how multimedia tools and Cognitive Load Theory (CLT) learning strategies interacted in the study. The variables, visual processing, auditory processing, and CLT instructional strategies interact to influence learning outcomes in fluid mechanics (Anmarkrud et al., 2019; Bakri & Mulyati, 2018).

The Cognitive Load Theory (CLT) learning framework, figure 5 focuses on the interaction of visual processing and auditory processing as well as instructional strategies to improve learning outcomes. The visual processing involves presenting information through images, videos, and graphics, while the auditory processing uses sounds, speech, and music to reinforce visual content (Abdulrahaman et al., 2020). The Cognitive Load Theory instructional strategies such as split attention, modality principles and segmentation, aim to manage cognitive load effectively by minimising distractions and promoting intrinsic cognitive load. The conceptual framework is summarised in the Figure 5 below.

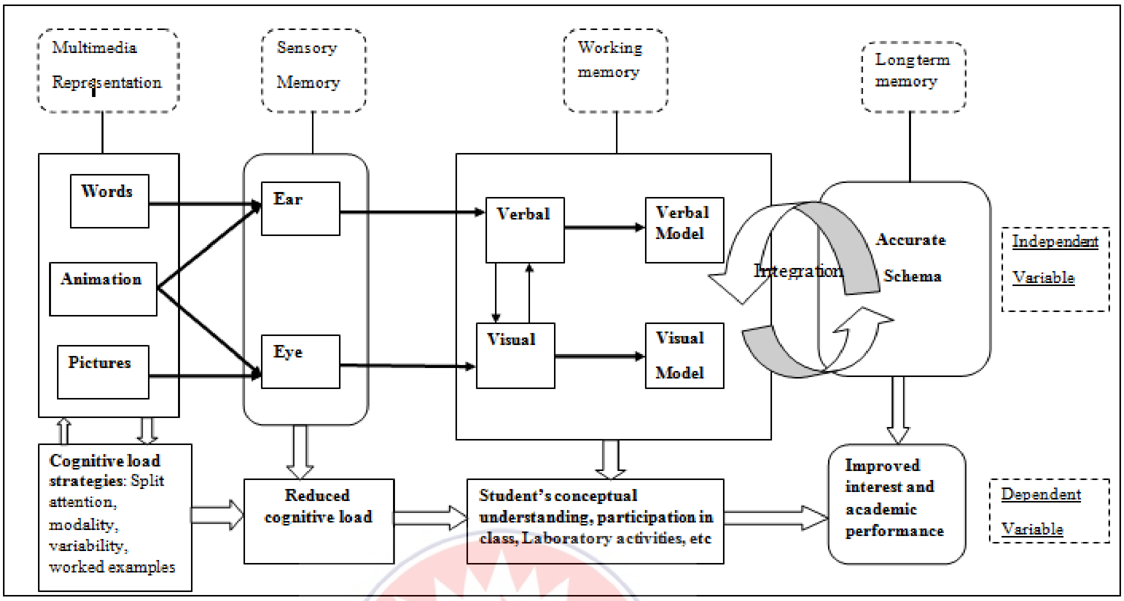


Figure 5: Conceptual Frameworks

Source: (Writer's own construct, 2024)

Pictures, audios, videos, simulations constitute the multimedia representations. The eye and the ear constitute the sensory memory, when working memory elements are integrated, they complement each other to establish accurate schema, leading to improvement in student's conceptual understanding; this is manifested in student's classroom participation and laboratory activities which result in improved interest and performance in learning outcomes in fluid mechanics in physics. The conceptual framework in figure 5, reveals how the visual, auditory and the CLT learning strategies optimises the learning environment by reducing extraneous cognitive load, facilitating intrinsic cognitive load, and enhancing interest and motivation. This leads to better learning outcomes by enabling learners to acquire and retain knowledge more effectively.

2.9. Implications of Cognitive Load Theory of Multimedia Learning

2.9.1 The teaching sequence's cognitive demands based on multimedia representation

The carefully designed series of instructional steps in multimedia representation is influenced by four key factors: spatial contiguity, segmenting, modality, and interpolated assessment. These factors affect cognitive load and learner performance. Cognitive load within this sequence can be managed through various forms, such as text, sketches, diagrams, graphs, and mathematical equations (Eichenlaub & Redish, 2019; Euler & Gregorcic, 2018; Franke, et al., 2019). Relevant cognitive architectures, including dual coding theory (Richard, 2023), the working memory model (Charlee & Reinadith, 2022), cognitive load theory, and multimedia learning theory (Mayer, 2014), play a crucial role in describing memory storage, memory codes, and cognitive activities within the teaching sequence.

2.9.2. The application of the text description strategy

According to studies, written representation offers various advantages, including the ability to convey a broad range of educational content in a condensed amount of time (Ashenafi, 2022; Wong et al., 2011). This type of representation enables students to distinguish between abstract ideas that are closely connected and those that may be deceptive and should only be used in special circumstances.

Learning to write is useful for understanding concepts as well, therefore teaching students to write should come first, followed by teaching them to read and then fix their own errors (Barton & Heidema, 2002). According to Niyitanga et al. (2021), using written approaches to teach difficult physics concepts improves learning. In order to make the necessary links between representations, it also aids in the transformation and interpretation of physics concepts from one representation to another. For instance, it helps in the translation of equations and graphs in order to clarify their understanding. It is also linked to other representational strategies, such as curriculum material simplification and idea clarification for students (Nevenglosky et al., 2019; Lee et al., 2006).

Written representations can also be employed anytime, anyplace, and are a simple technique that can aid in the development of students' problem-solving abilities (Wong et al., 2011). Many students are able to understand and interpret text easily. The fact that this strategy is employed in the classroom means that students are accustomed to it (Fredlund et al., 2015; Kuo et al., 2012; Linder, 2013). Written representation can be utilised to enhance conceptual knowledge in all grades because it is affordable and doesn't always require technology (Barton & Heidema, 2002).

Text has significant limitations despite being valuable. The number of students in a class determines how effective a strategy is (Fuertes et al., 2020). Not all students will learn in the same way, and some approaches may not work for all students (Munna & Kalam, 2021), while some children prefer to listen, others prefer reading (Wong et al., 2011). Text representations cannot entirely replace the idea of algorithms when used in conjunction with them to solve problems (Wong et al., 2011).

According to Nahari and Alfadda (2016), drawing and creating graphic representations of the text were important in earlier years to help students understand the concept discussed. The efficiency of this strategy will be somewhat hampered by the pupils' prior knowledge.

Images, designs, and graphical representations all have unique qualities, and each is covered in more detail below.

2.9.3. The picture representation approach

Imaging is a method of analysing, visualising, and interpreting numerical data, functions, and qualitative structures using visuals and drawings. It is crucial for physics education, as formulas and graphics are ineffective without visuals (Hazari et al., 2010; Tabachneck et al., 2019). According to Tyler (2013) and Raiyn (2016), studies from 2000 to the present have shown the value of using visuals as a tool for supporting visual learners. A picture is worth a thousand words, and it can effectively communicate ideas more than many other methods (Tyler, 2013).

Image visualisation can help students learn and retain physics topics more easily, aid in conceptual development, and help them relate image concepts to existing knowledge. It also helps students understand challenges by identifying changes within the same image (Treagust et al., 2017). However, results from students taking preparatory physics laboratory courses reveal that they often make mistakes when interpreting images (Ashenafi, 2022). Using picture representations has limitations, especially for students with little prior knowledge (Brahmia et al., 2020; Christensen & Thompson, 2012; Eichenlaub & Redish, 2019; Euler & Gregorcic, 2018). Additionally, a student's resilience is greatly influenced by her / his experiences, as Choy and Yeung (2022) suggest. Overall, imaging is a valuable tool for supporting visual learners and fostering a love of learning in physics education.

2.9.4. Diagram representation approach

Diagrams are a popular tool in physics education, helping students understand and solve problems by illustrating complex concepts (Kuo et al., 2012). They are commonly used in mechanics, optics, and ray diagrams, and can be particularly effective for students who are blind (De Cock, 2012; Lia et al., 2018). Schematic representations can convey ideas without using many words, making them an effective method for students (Linder, 2013). Research by Skrabankova et al. (2020) found that diagrams can be effective in explaining electrical circuit principles, as they help students analyse problems more easily, cited by Ashenafi (2022). According to Skrabankova et al. (2020), experts tend to look back at the circuit when solving problems, while novices do not.

Diagrammatic representation is also effective in conveying non-algorithmic concepts and can be used in the classroom to help students solve problems and answer questions (Benjamin, 2015). However, it requires prior experience for students to use them effectively. Despite these benefits, students must have prior experience with diagrams to effectively use them in physics education (Bicer, 2021; Ji-Eun & Sunghwan, 2022).

2.9.5. The mathematical equations representation approach

The use of mathematical equations as a representation tool is highly relevant to the teaching of fluid mechanics, a central focus of this study. Physics education, particularly in areas like fluid mechanics, heavily relies on mathematical formulations to convey complex concepts clearly and effectively (Ashenafi, 2022). Mathematical equations play a crucial role in reducing cognitive load by offering students structured approaches to solving problems, thereby aiding in their conceptual understanding.

In this study, mathematical representations align with the integration of Cognitive Load Theory (CLT) and multimedia approaches. Learners can form deeper connections between theoretical concepts and practical applications by introducing mathematical formulas in tandem with multimedia resources (such as diagrams, videos, and simulations). This combination of multimedia with mathematical equations supports schema-building, a key concept in CLT, which helps students automate their problem-solving processes and reduce cognitive overload when learning fluid mechanics (Romero & Martínez, 2013; Kuo, 2013).

The foundation of science education, especially physics, is rooted in mathematical equations, making them indispensable for students in understanding principles such as Bernoulli's principle**,** Archimedes' principle**,** and Pascal's law**.** These principles require a strong grasp of their mathematical underpinnings to fully comprehend the behaviours of fluids in static and dynamic situations. By integrating multimedia with the mathematical representation approach, this study seeks to improve students' ability to interpret, manipulate, and apply these equations, thereby enhancing their engagement and performance in fluid mechanics.

Thus, incorporating mathematical equations within a multimedia-enhanced framework aligns with the objectives of this study, improving students' conceptual understanding by leveraging multiple representations and minimizing extraneous cognitive load (Christensen & Thompson, 2012).

2.9.6. The use of computer simulation

Computer simulations are a popular teaching tool for Physics, helping students of all ages develop their intellectual understanding (Chen & Gladding, 2014; Romero & Martínez, 2013). However, selecting the most suitable simulations can be time-consuming. Combining simulations with other strategies such as videos, text and verbal explanations is crucial, as they can be used in place of laboratory work and do not directly involve students or require contact with potentially harmful items (Ashenafi, 2022; Kriek & Coetzee, 2021).

Computer simulations are effective in teaching fundamentals of gas and burners, as they do not directly involve learners and do not require them to touch potentially harmful items (Gregorcic & Bodin, 2017; Misaiko & Vesenka, 2014). Kabigting (2021) recommends computer simulations as a useful teaching and learning tool for physics, as they help students understand abstract ideas, understand the effects of forces and pressures on fluid mechanics, and practice critical thinking. In conclusion, computer simulations are a valuable tool for enhancing students' understanding of physics.

2.9.7. The virtual laboratory Approach

Virtual Laboratories offer students a simulated learning environment where they can conduct experiments and explore theoretical topics without physically entering a laboratories (Kharki et al., 2021). This approach can significantly impact students' scientific thinking, critical thinking, creativity, conceptual comprehension, laboratory abilities, motivation, and interest. A study in Indonesia found that virtual laboratories foster students' critical thinking, creativity, conceptual comprehension, laboratory abilities, motivation, and interest (Sasmito & Sekarsari, 2022).

According to Ashenafi (2022), in fluid mechanics a variety of hands-on laboratory exercises are provided by teachers, allowing students to maintain the laboratories and laboratory supplies, advance their technical and scientific equipment handling skills, and achieve classroom goals. A student-centered approach can help learners manage laboratory activities and enhance classroom behaviour. However, educating students about fluid mechanics in a laboratory setting requires careful and sophisticated methods, as the time allowed for the same aim and laboratory experiment sessions may conflict (El - Hajj & Budny, 2019).

A study found that virtual laboratory exercises in physics have a favourable impact on students' perspectives and positive feedback (Aşıksoy & Islek, 2017). Virtual laboratories have been proven to be superior to traditional ones in teaching topics like atmospheric pressure and symposia (Aksit, 2011; Bernhard, 2010). However, in the views of the writer using virtual laboratories may hinder the potential to use a genuine laboratory. According to researches, using virtual laboratories can hinder the potential to use a genuine laboratory by limiting hands-on experience and exposure to real-world experimental nuances, crucial for skill development and safety awareness (Pyatt & Sims, 2012; Potkonjak et al., 2016; De Jong et al., 2013). Internet access is needed in the use of virtual laboratory which could be a hindrance particularly in developing countries like Ghana, where internet access may be limited.

2.9.8. The teamwork approaches

Jorgensen et al. (2020) observed that students often have a limited understanding of team roles, which can lead to misconceptions about their responsibilities within a group. To address this issue, Jorgensen et al used a laboratory kit as the foundation for course activities, focusing on teamwork during a two-hour laboratory session. The training emphasised the importance of identifying typical roles necessary for a team to accomplish its goals and selecting the appropriate members for these roles. A functional resume was utilised as a tool to aid in distributed selection and to identify the unique functions of each team member.

The approach involved creating functionally organised teams to enhance students' understanding of fluid mechanics concepts. Small groups of three students were tasked with identifying roles they believed were most suitable for designing revolutionary technology, with a focus on the specific tasks or duties each team member needed to perform to ensure the team's success. The teams were then prepared to prototype cutting-edge technology based on fluid mechanics ideas (Dixon & Hall, 2013).

Following the training, students were assigned activities that required them to identify a challenge and apply their fluid mechanics expertise to address a socially relevant real-world problem. Throughout the 15-week semester, a learning facilitator was available weekly to provide direction and guidance as students progressed through the activities outlined in the model and the semester concluded with students demonstrating the outcomes of their new technology prototypes through a poster presentation, highlighting the benefits of effective teamwork (Jorgensen et al., 2020).

2.9.9. The video approaches

According to Chen and Gladding (2014), video representation is a teaching approach that involves audio or text information, the order, structure, and content of individual frames. It is beneficial for children who learn more effectively through sight and abstract concepts than words and formulae (McCombs, 2017). Videos help students comprehend relevant concepts and are a quick, effective, and efficient way to teach (Chen & Gladding, 2014).

They foster creativity in the classroom and can help create an independent generation capable of addressing problems (Kural & Kocakülah, 2016). Video projects can boost students' curiosity and are highly effective compared to traditional methods. Videos can be used to explain abstract physics and fluid dynamics ideas, fostering a more independent and capable generating of problem–solving skills (Chen & Gladding, 2014; Geyer & Kuske-Janßen, 2019).

2.9.10. The strategy of using videos and animated visuals

Teaching fluid mechanics concepts online is more effective than traditional lecture methods due to the incorporation of video lessons and online task systems (Fuqua et al., 2021). Technology advancements have made teaching and learning easier, reducing geographical distance, offering practical visual tasks, and allowing students to improve their learning through various senses. According to Fuqua et al. (2021), teachers now have more opportunities to use electronic teaching aids such as PowerPoint, movies, photographs, and laboratory equipment, which are crucial in the instruction of fluid mechanics.

Traditional instructional approaches are ineffective for teaching fundamental fluid mechanics concepts without the aid of technology, as these ideas are made up of time-dependent flow structures that are difficult to solve analytically (Minichiello, et al., 2020). Video-based instruction systems enable teachers to cover more material, free up contact hours for higher-level interactions, and help students demonstrate experimental tasks step-by-step. In an online setting, the instructor participates digitally in topic and exercise discussions, and students have the opportunity to ask questions and receive prompt responses (Minichiello, et al., 2020; Yaacob & Velte, 2021).

Video animation is another digital learning tactic that extends beyond online environments, demonstrating fluid mechanics in a scientific setting. Teachers can use online learning strategies like quizzes, pre-class collaboration, or reading to demonstrate fluid mechanics in a scientific setting. Students can watch a video of the lesson before class and have a sense of what to expect using this form of video animation (Sattar & Labib, 2019).

In conclusion, video-based teaching methods have made it easier for students to understand fluid mechanics concepts, extending beyond traditional lecture methods and incorporating online learning strategies like quizzes, pre-class collaboration, and reading.

2.10. Empirical Framework

The integration of multimedia into Cognitive Load Theory (CLT) has been the subject of extensive research across various regions, with a strong concentration of studies originating from Europe. Cognitive Load Theory, developed by Sweller (1999), focuses on optimizing learning by managing the mental load imposed on learners. In Europe, particularly in Germany, researchers have made substantial contributions to understanding how multimedia can be used to reduce extraneous cognitive load and enhance germane cognitive load (Mutlu-Bayraktar et al., 2019). European studies have rigorously examined the role of modality, signaling, and the seductive details effect in multimedia learning environments (De Jong, 2010; Kalyuga, 2009).

Following Europe, Asia and North America have emerged as key regions contributing to the advancement of CLT in education. In Asia, researchers like Kalyuga (2009) have explored the application of CLT in various educational settings, focusing on multimedia instructional design to minimize cognitive overload. Meanwhile, Mayer and Moreno's (2003) foundational work in the United States, conducted at the University of California, Santa Barbara, developed a research-based framework for multimedia learning. Their studies focused on principles such as coherence, redundancy, and spatial contiguity, all of which align with CLT's goal of reducing unnecessary cognitive load (Mayer & Moreno, 2003; Sweller et al., 2011). In addition, the contributions from Australia, led by scholars such as Ayres (2006) and Paas et al. (2012), have further extended CLT's applicability in diverse educational contexts, particularly in science and technology education.

However, despite the global proliferation of CLT research, Africa remains underrepresented in the literature. As Mutlu-Bayraktar et al. (2019) highlight, a systematic review of studies from 2015 to 2019 showed that the majority of cognitive load studies were conducted in Europe, followed by Asia, America, and Australia, with Africa contributing the least (Mutlu – Bayraktar et al., 2019). This gap is evident when comparing the volume of empirical research in other regions. Although there has been some scholarly interest in the integration of multimedia and CLT in African educational settings, it remains sparse and isolated. For instance, Fiankofi (2018) conducted a study in Ghana's Central Region to assess the impact of multimedia on academic performance in physics at Adisadel College. Similar studies is also conducted by Boateng (Boateng,2024).These studies demonstrated that integrating multimedia in physics instruction enhanced students' understanding of complex concepts, including fluid mechanics, which aligns with findings from studies in more researched regions (Fiankofi, 2018; Boateng, 2024).

Moreover, research from Sub-Saharan Africa has shown the importance of adopting multimedia learning tools in science education. Studies like those by Boakye (2020) and Mensah (2019) have emphasized the role of multimedia in reducing extraneous cognitive load in subjects like physics. These studies suggest that teachers must be trained to incorporate multimedia elements effectively to maximize learning outcomes (Mensah, 2019). Despite these efforts, the overall contribution of African scholars to the global discourse on CLT remains minimal, especially when compared to Europe and Asia, where significant advancements in instructional design have been made (Mupa & Chinooneka, 2015; Abadzi, 2013).

It is crucial to address this disparity by promoting more empirical studies in Africa to explore how CLT can be tailored to suit the unique educational challenges faced by the continent. For instance, challenges related to resource constraints, teacher training, and curriculum development require careful adaptation of CLT principles to the African context (Abadzi, 2013). The Ghana Education Service (GES) has taken some steps towards integrating multimedia into physics teaching, as evidenced by the works of Boakye (2020), Fiankofi (2018), and Badu (2018). However, there is still a need for broader research efforts that examine the effectiveness of these interventions on a larger scale.

Research in other parts of the world has shown that careful instructional design based on CLT can enhance learning, particularly in subjects that require high cognitive demand, such as fluid mechanics (Sweller et al., 2011). However, as Boateng (2024) warns, poorly designed multimedia can lead to increased cognitive load, particularly germane load, which could overwhelm students rather than enhance their learning. This highlights the importance of training educators not only in the use of multimedia but also in the principles of CLT to ensure that instructional design reduces unnecessary cognitive load (Ayres, 2006; Mayer & Moreno, 2003).

In conclusion, while CLT has been well-studied and applied in Europe, Asia, and the Americas, the paucity of research from Africa presents a significant knowledge gap that needs to be addressed. More empirical studies are required to explore how CLT can be effectively implemented in African classrooms to enhance student learning outcomes, particularly in the sciences. Expanding research efforts in this area could lead to better instructional practices that accommodate the cognitive needs of students, reduce cognitive overload, and improve educational outcomes across the continent.

2.11. Knowledge Gap

The literature review highlights significant gaps in Cognitive Load Theory (CLT) research, especially regarding its application in multimedia learning environments. While extensive research has been conducted in Europe, particularly Germany (Mutlu-Bayraktar et al., 2019), and in regions like Asia, America, and Australia (Kalyuga, 2009; Mayer & Moreno, 2003), Africa remains underrepresented. This lack of research in Africa poses a challenge in understanding how CLT can be adapted to diverse educational settings in developing regions. Additionally, most CLT research has focused on higher education, especially in STEM subjects (Paas et al., 2012; De Jong, 2010), leaving a gap in its application at the secondary school level.

Studies in Africa, such as Fiankofi's (2018) research on multimedia in physics instruction in Ghana, indicate that multimedia enhances comprehension of complex concepts like fluid mechanics. However, these findings are limited, and there is a lack of broader empirical research on applying CLT in multimedia learning in Africa (Boakye, 2020; Mensah, 2019). This study aims to fill these gaps by exploring the integration of multimedia and CLT in senior high school physics classrooms in Ghana. It seeks to contribute to the global CLT body of knowledge and provide valuable insights for African educators and policymakers.

2.12. Chapter Summary

Chapter two of the thesis provides a comprehensive literature review on fluid mechanics, cognitive load theory, multimedia integration, and memory. It explores key principles like Archimedes', Pascal's, and Bernoulli's principles, their historical development, and modern applications. The literature review also discusses cognitive load theory, the three types and their impact on instructional design, as well as its impact on learning outcomes.

The chapter also reviews multimedia integration in education, analysing various learning theories and design principles. The chapter synthesises findings on how multimedia tools enhance comprehension and retention of complex scientific concepts. It also discusses the role of memory in learning, discussing sensory, working, and long-term memory. Strategies for improving memory retention, such as dual coding, are explored, with links to improved academic performance in STEM education, especially in Senior High Schools. The chapter critically evaluates previous research and provides a strong foundation for the research, justifying its necessity and guiding its methodology and analysis in subsequent chapters.

CHAPTER THREE

METHODOLOGY

3.0. Overview

The approach of the research project is presented in depth in this chapter. The study's research area, research paradigm, and research strategy are highlighted. The population, sample, sampling methods, instrumentation, and the validity and reliability of the test instruments are all covered in this chapter.

The chapter goes into more detail about the process of collecting data before concluding with the process of analysing that data.

3.1. Study Site

The Lower West Akim (West Akim Municipal) is one of the thirty-three (33) Districts in the Eastern Region of Ghana. It was established by Legislative Instrument (L.I.) 1421 of 1988 and Local Government Act 462 of 1993. The district was elevated to Municipal status in 2008. Asamankese is the Municipal Capital. In 2012, a portion of the Municipality was carved out to create a new district, the Upper West Akim District Assembly. Geographical location and size, the West Akim Municipal lies between longitudes 0 0 25′ West and 0 0 47′ West and latitudes 500 40′ North and 60 0 .0′ North. It shares boundaries with Denkyembour District to the North; Birim South District to the West; Agona, Awutu-Efutu-Senya, and Ga Districts to the South and Suhum Municipal, and Upper West Akim District to the East. The total land area of the Municipality is estimated to be $559km^2$. The Municipal capital, Asamankese, is about 75 km. North-West of Accra, according to West Akim Municipal Assembly (WAMA) (2018). The figure 6 shows the location of the study site, Asamankese in the West Akim Municipality.

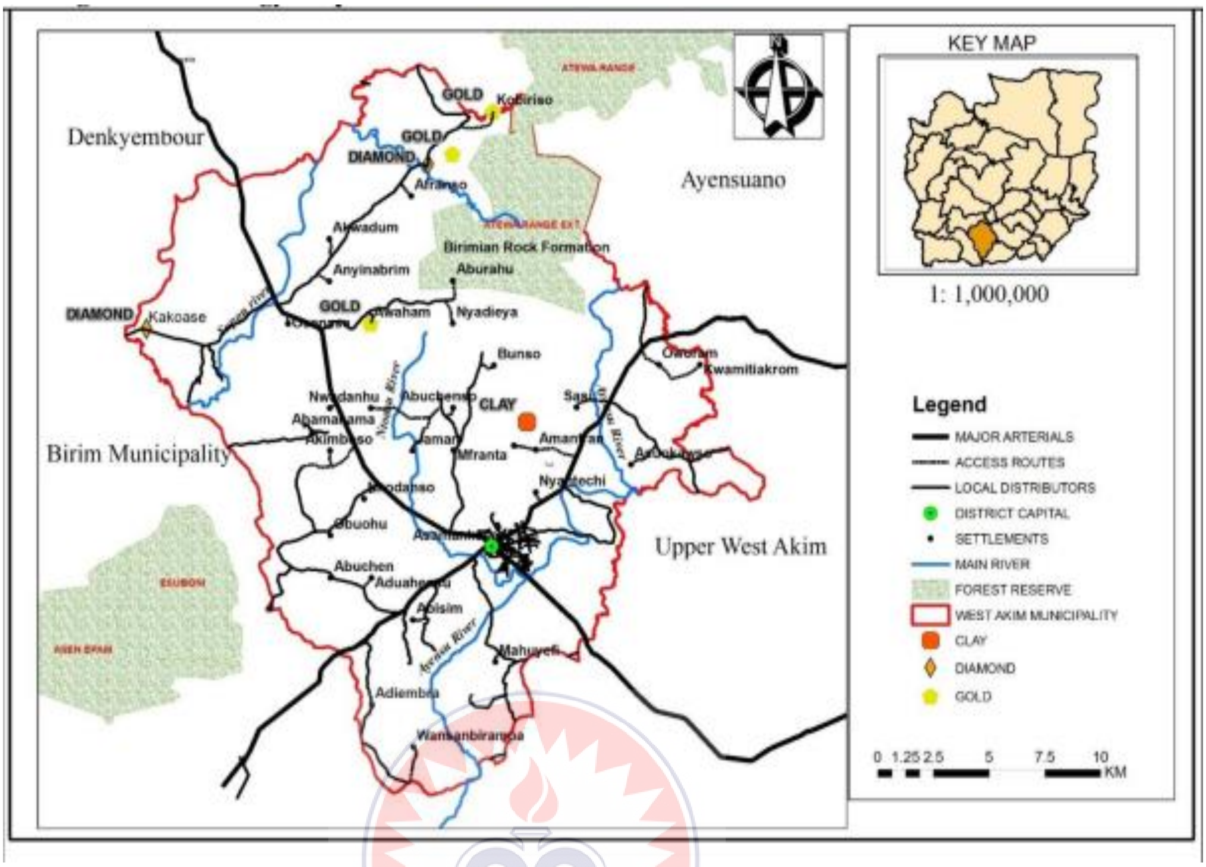


Figure 6: Map of West Akim Municipality

Source: (MPCU Construct, November 2017)

The West Akim Municipal Assembly seeks to mobilise resources in partnership with both the public and the private sectors to develop and grow through the increase in the incomes of its people in its development agenda. The mission statement of the West Akim Municipal Assembly is to proactively improve upon the quality of life of its people by harnessing the resources for the development of the Municipal Assembly. The goal of the municipality is to harness both human and physical resources for the development of social and economic infrastructure to increase employment and productivity to raise the standard of living of the people in the Municipality.

For physical features relief and drainage, the land is generally undulating with heights ranging between 60 meters and 460 meters above sea level. The highest point is around the Atewa Range, located between Pabi-Wawase and Asamankese in the Northern part of the Municipality, most of which is occupied by the Atewa Range Extension Forest Reserve. The Municipality is well-drained by rivers like Ayensu, Ntoasu, Abukyen, Akora, Supon, Obotwene/Ansing, and Adeiso among others.

In terms of household size, in total, there is a household population of 107,095 in the Municipality with an average household per house of 1.7. The average household per house in urban is 2.3 and that of the rural is 1.3. The population per house in the Municipal is 6.8 and the average household size is 4.0. The average household size in the urban (3.7 persons per household) is lower than the rural (4.5 persons per household) areas.

The municipality / district currently has 80 preschools, 104 primary schools, 75 junior high schools 3 senior high schools and 1 vocational school spread through the municipality, according to WAMA(2018).

3.2. Research Paradigm

A research paradigm in social science is a worldview based on philosophical assumptions about the nature of social truth and reality (Ebohon et al., 2021). It consists of a set of beliefs and understandings that guide how problems are identified and addressed within a particular field (Ebohon et al., 2021). This paradigm influences how data is interpreted (Kivunja & Kuyini, 2017). Researchers in social science must consider the methodological aspects of their projects through the lens of these paradigms before deciding on research methodologies and data processing (Kivunja & Kuyini, 2017).

There are various paradigmatic perspectives to choose from in social science research, such as positivism, post-positivism, interpretivism, constructivism, and pragmatism (Ebohon et al., 2021). Pragmatism is advocated as the best paradigm for mixed-methods research (Kaushik & Walsh, 2019). Pragmatism was chosen for this study because it provides a middle ground between interpretive and positivist paradigms (Kivunja & Kuyini, 2017) and focuses on the "what" and "how" of the research challenge (Creswell, 2014). According to pragmatism, knowledge doesn't completely mirror reality, and it prioritises what works and using all available ways to understand the situation (Rehman & Alharthi, 2016; Kaushik & Walsh, 2019). The key principle of pragmatism is an emphasis on experience and the interaction between beliefs and behaviour (Migiro & Magangi, 2011).

The pragmatic paradigm is a suitable choice for this study because pragmatism strikes a balance between theoretical considerations and practical outcomes. It emphasises what works and how to address research challenges effectively, which is vital in real-world applications. This approach aligns with the study's focus on addressing practical issues, and it helps ensure that the research findings can be applied in a meaningful way (Rehman & Alharthi, 2016; Kaushik & Walsh, 2019). Again, it offers flexibility, integrates diverse perspectives, emphasises experience and interaction, and provides an outcome-oriented approach.

3.3. Research Design

The research design is a crucial aspect of any study, as it serves as a roadmap for guiding the investigation (Mankins, 2002; Marczyk et al., 2010; Williams & Chesterman, 2014). It encompasses the methods and procedures required to collect and analyse the necessary data, making it a master plan for the research (Pandey & Pandey, 2015). The research design is essential for establishing a framework that ensures the research objectives and questions are met, taking into consideration factors like available resources and the research's purpose (Jilcha, 2019; Creswell, 2014; Akhtar et al., 2016). Research designs can be categorised into three main types: quantitative, qualitative, and mixed method (Creswell, 2014). The choice of a specific design depends on the goals and characteristics of the problem under investigation (Botha, 2021; Dawadi et al., 2021; Eyisi, 2016; Kim and Soergel, 2005). In the study at hand, a mixed method research approach, specifically sequential explanatory design was employed, which involves combining both quantitative and qualitative approaches to comprehensively address the research problem (Johnson & Christensen, 2020; Johnson et al., 2007).

Sequential explanatory research design, as mixed methods is particularly useful when one style of research alone cannot sufficiently address the research questions. This approach combines and integrates the two "strands" to provide a more in-depth understanding of the research challenge than either approach can achieve individually (Johnson & Christensen, 2020; Creswell, 2014).

The sequential explanatory research design as a mixed method is justified in this study because it focuses on two phase project; firstly, quantitative data collection and analysis, and secondly, qualitative data collection and analysis. This design focuses largely on quantitative data which then informs the qualitative data. This allows for a more comprehensive understanding, addressing diverse research questions, it is a more holistic approach and practical for addressing multifaceted research questions, it also allows for well-rounded investigation of the research problem. It provides the flexibility to use the most appropriate methods for different research questions and enhances the validity and reliability of the findings, ultimately leading to a more robust and meaningful study.

In this study, employing the sequential explanatory mixed methods design ensured that research question 1 was answered both qualitatively and quantitatively, research question 2 was answered quantitatively and research question 3 was also answered using a quantitative approach.

3.3.1. Overall study design

The Figure 7 provides a summary of the design of this investigation. Figure 7 demonstrates how this study used a mixed methodology approach, gathering and analysing both qualitative and quantitative data. However, one group quasi-experimental pretest /post-test design was used for this investigation, which involved employing one intact class as a study group.

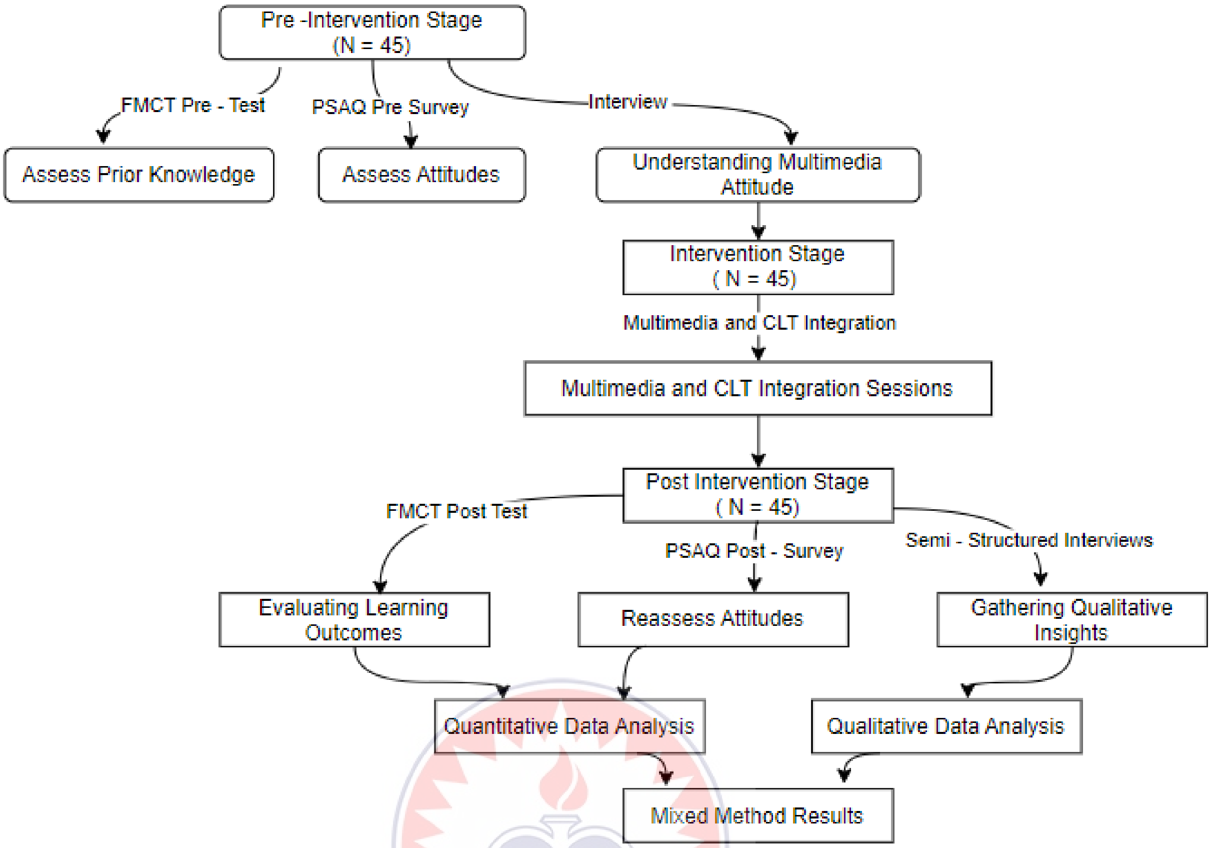


Figure 7: A flowchart of the Overall Study Design

Source: (Writer's own construct, 2024)

Figure 7 illustrates how the participants underwent pre – intervention survey which then followed pre- test to ascertain their entry characteristics and prior knowledge before the intervention. After the pre - test, researcher encouraged the students in pre- intervention survey (Interview) to gauge their attitude toward the use of multimedia in the study of physics prior to the intervention. The study group (N= 45) received treatment throughout the intervention (taught using multimedia and the Cognitive Load Theory), the introduction of the post-intervention exam and completion of a questionnaire to ascertain its implications on students after the intervention, were then used to determine the impact of integrating multimedia into cognitive load theory on students' learning in fluid mechanics.

Students in the study group had the chance to elaborate on their views on physics during the questionnaire's completion process after the usage of the cognitive load theory in a multimedia learning method during the teaching and learning of fluid mechanics. This enhanced the quantitative results and gave a thorough grasp of the Cognitive Load Theory in Multimedia Learning approach's efficacy in the instruction and learning of fluid mechanics.

The figure 7 as well reveals that, semi-structured interviews were conducted with a section of the group (N = 45) who were selected through purposeful sampling based on their survey responses. The semi - structured interviews aimed to help the study group to provide in-depth insights into their experiences and perceptions of multimedia integration into CLT in fluid mechanics education, this enhanced the qualitative result and give clear understanding of the integration of multimedia into Cognitive Load Theory in fluid mechanics learning.

3.4. Population

Any collection of particular people or non-human elements that the researcher is interested in has a population, according to Shukla et al. (2020) as well as Tupasela and Tamminen (2015). A large group of individuals or objects that are the focus of a particular scientific investigation is known as a research population (Casteel & Bridier, 2021). In light of this, Pandey and Pandey (2015) define the research population as all the units that share the same traits and to whom the findings of the study can be applied. In this study, all form 3 physics students at Asamankese Senior High in the West Akim Municipality in Ghana's Eastern Region consisting of 200 students served as the population for the study.

Both tiny and huge populations exist. The accessible population is, in essence, the smaller group, while the larger group is the target audience (Appiah-Twumasi et al., 2020). The phrase "target population" refers, according to Marczyk et al. (2010), to the entire group of individuals or objects that researchers are interested in extrapolating the findings to.

The target population is the theoretically confined, specifically defined subset of potential participants to which the researcher may have access and which most closely resembles the population of interest. The theoretical population, also known as the target population, typically has a variety of characteristics. The entire number of instances or components that fulfill the predefined criteria and are accessible to the researcher as a pool of study subjects or participants is known as the accessible population, according to Appiah-Twumasi (2020). In other words; it is the group that a researcher can actually measure. All form 3, Science A, Physics students at Asamankese Senior High School in the West Akim Municipality in Ghana's Eastern Region served as the study's target and accessible population.

3.5. Sampling and Sampling Technique

According to Majid et al. (2021), it would take a lot of time, money, effort, and labour to study these communities. Casteel and Bridier (2021) claim that because the majority of educational phenomena are composed of a large number of units, it would be impractical, if not impossible, to test, interview, or observe every unit of the population under controlled circumstances in order to derive universally applicable principles. A very small sample of individuals, measurements of items, or occurrences are chosen and evaluated to learn more about the broader population from which they were chosen in order to verify that the data acquired is typical of the full population under study

(Shukla, 2020).The sample, according to Cohen et al. (2018) and Sulak, (2017), it is more condensed group or subgroup. Therefore, the sample is a hand-picked mixture of some components taken from the total population. It is a group of units or a section of the entire population that has been selected to participate in the study and serve as a representative sample of the intended audience (Jilcha, 2019). Sampling is the process of choosing a sample from a population, and sampling methodology refers to the specific procedures or techniques used in this process.

There are essentially two forms of sampling: probability sampling and non-probability sampling. Every unit of the population has an equal and certain probability of being selected in a sample when using probability sampling, which is a sampling approach (Casteel & Bridier, 2021). This comprises stratified random sampling, cluster sampling, multi-stage sampling, and basic random sampling. No unit of the population has a fixed or guaranteed chance of being selected for the sample in non-probability sampling, according to Marczyk et al. (2010). The researcher's choices or willingness can have an impact on the topics they choose to use non-probability. This includes convenience sampling, quota sampling, snowball sampling, and purposeful sampling. However, a researcher's choice of sampling technique in a study is influenced by a number of factors, such as sample size, population diversity, and research design.

A multi-stage sampling method was used in this study since different methods were used to choose participants at various design stages. The multi-stage sampling method used in this investigation is shown in Table 1.

Table 1: Multi-Stage Sampling Procedure Employed in this Study

Stage	Sampling Technique	Activity	Sample Size (N)
Quantitative Phase	Simple Random Sampling	Selection of one SHS 3 class from the Asamankese senior high	1 SHS 3
	Purposive Sampling	Selection of SHS 3 Physics students	
	Simple Random Sampling	Selection of one intact SHS 3 Physics class from Asamankese SHS as the groups	45 SHS 3 Physics students
Qualitative Phase	Purposive sampling	Selection of the study group for qualitative data	45 SHS 3 Physics students

Since it was not possible to employ all of the schools in the West Akim Municipality, SHS 3 students from Asamankese SHS in the municipality was chosen to participate in the study, as can be seen from Table 1. Therefore, one SHS 3 class was chosen to take part in the study using simple random sampling. However, based on Ministry of Education (2010) recommendation that SHS 3 students study fluid mechanics concepts, purposive sampling was employed to choose SHS 3 Physics students. Again, because the chosen school had more than one SHS 3 Physics classes, simple random sampling was used to pick one such class, and the chosen class was exposed to a teaching strategy.

Additionally, the selected intact class was used as study group using simple randomisation. Thus, 45 SHS 3 Physics students served as the sample size.

Purposive sampling was utilised in the qualitative phase to choose SHS 3 Physics students who were exposed to the cognitive load theory in a multimedia learning method. All SHS 3 Physics students in the study group took part in this investigation. In order to assess the qualitative effects of integrating multimedia into cognitive load theory (CLTML) on students' attitudes toward physics and fluid mechanics after exposure to CLTML, this was done by asking students for their in-depth comments. A section of the 45 SHS 3 Physics students were as a result selected, and they took part in the study's qualitative phase.

3.6. Research Instruments

According to McCorvy et al. (2016), Ross et al. (2016) and Pentang, (2023), research instruments are means for acquiring information relevant to the subject. Cohen et al. (2018) identified eight major categories of data-collection instruments: questionnaires, interviews, tests, and personal constructs, with several variations within each. They aid in the collection of unprocessed data, which can then be coded, altered, or recorded for subsequent analysis and interpretation. Three research tools, the Fluid Mechanics Concepts Test (FMCT), Physics Students' Attitude Questionnaire (PSAQ), and Physics Students Semi - structured Interview (PSSI) was used in this study.

3.6.1. Fluid mechanics concept test (FMCT)

The FMCT was a self-developed research tool that addressed some of the fluid mechanics concepts offered in the SHS Physics curriculum. The FMCT, which measured how well SHS 3 Physics students performed on fluid mechanics concepts before and after the intervention, it was coded OEQ – FMCT pre- test /-- and OEQ –

FMCT post - test/ -- for pre-test and post - test respectively which consisted of twelve (12) open-ended questions on the topic (Appendix A and B). Table 2 provides the FMCT's content selection.

Table 2: Content Selection of item for FMCT

Concept	Questions	Questions
Archimedes' principle	1, 2,3	1) How does Archimedes' principle explain why some objects float in water while others sinks? 2) Describe a practical everyday scenario where understanding Archimedes' principle would be useful. 3) What factors influence the buoyant force experienced by an object in a gas or liquid?
Pascal's principle	4, 5, 6	4) How does Pascal's principle relate to the concept of hydraulic systems, and what are some everyday applications that make use of this principle? 5) Explain how Pascal's principle plays a role in the transmission of pressure through confined fluids, and why is it important in various engineering and industrial applications. 6) Given a hydraulic system with a small piston of area 0.005 m^2, calculate the force exerted if a pressure of 20,000 Pa is applied.
Bernoulli's principle	7, 8, 9	7) How does Bernoulli's principle explain the lift generated by an airplane wing, and why is this principle important in aviation? 8) Give an example of how Bernoulli's principle is demonstrated in everyday life, such as in the operation of a household item or in the design of a common tool or device. 9) Explain how Bernoulli's principle is related to the flow of blood in the circulatory system.
Continuity equation	10, 11, 12	10) How does the continuity equation relate to the conservation of mass? 11) What are some practical applications of this equation in fluid dynamics or other scientific fields? 12) A pipe with a cross-sectional area of 0.03 m^2 has water flowing through it at a velocity of 2 m/s. Calculate the volume flow rate.

As can be seen from Table 2, the FMCT covered four main areas of fluid mechanics, with three items drawn from the "Archimedes principle," three from the "Pascal's principle," three from the "Bernoulli's principle," and three from the "Continuity equation." Students' responses to the test items were scored polytomously because the FMCT featured open-ended fluid mechanics test items.

3.6.2. Physics surdents' attitude questionnaire (PSAQ)

The PSAQ was created as a modified version of an instrument created by Appiah-Twumasi et al. (2022), Tuan et al. (2005), and Kamba et al. (2022). The PSAQ contains three (3) attitude dimensions that are intended to gauge students' attitudes regarding using multimedia and Cognitive Load Theory to study physics and fluid mechanics concepts (Appendix D). These attitude dimensions were used to assess students' attitudes toward fluid mechanics concepts and their attitudes about physics using Cognitive Load Theory in Multimedia Learning (CLTML). The following factors were deemed adequate to gauge the attitude of SHS Physics students toward fluid mechanics, these were understanding fluid mechanics, importance fluid mechanics, and further studies in fluid mechanics. Table 3 and Appendix D provide the PSAQ's detailed structure.

Table 3: Detailed Structure of PSAQ

Dimension	Description
Understanding fluid mechanics (UFM) – 4 items	Measures SHS Physics students' attitudes towards general understanding of fluid mechanics concepts
Importance of Fluid Mechanics (IFM) – 4 items	Measures SHS Physics students' attitudes towards the importance of fluid mechanics.
Further studies in Fluid Mechanics (FSFM) – 4 items	Measures SHS Physics students' attitudes towards further studies in fluid mechanics presently and in future

The students' Attitude towards Physics using CLTML contains three dimensions, as indicated in Table 3 and Appendix D. The three dimensions deemed appropriate to assess students' attitude toward studding physics using integration of multimedia into cognitive load theory include "Understanding Fluid Mechanics (UFM)", "Importance of Fluid Mechanics (IOFM)", and "Further Studies in Fluid Mechanics (FSIFM)". The four questions that made up the "Understanding Fluid Mechanics" dimension (UFM1–UFM4) evaluated SHS Physics students' perceptions toward their overall comprehension of fluid mechanics subjects. Four questions (IOFM1–IOFM4) made up the "Importance of Fluid Mechanics" dimension, which measured how SHS Physics students felt about the value of studying fluid mechanics. "Further Studies in Fluid Mechanics" was the last dimension under the students' attitude towards Fluid Mechanics concept. Five elements (FSIFM1–FSIFM5) made up this dimension, which measured how willing SHS Physics students were to learn more in order to comprehend the subject better in the present and the future.

3.6.2.1. Scoring of PSAQ

The PSAQ instrument was a sort of rating scale distinguished by possibilities for closed-ended responses. It was composed of a Likert scale with five possible responses: "Strongly agree ", "Agree", "Neutral", "Disagree," and "Strongly Disagree" (Appendix D). According to Pimentel (2010), response options can be changed into numbers between 1 and 5 for numerical analysis on a five - point Likert scale instrument. According to Table 4, respondents' agreement with attitudinal items on the PSAQ was graded in this study.

Table 4: Scoring Pattern of Items on PSAQ

Level of Agreement	Score
Strongly Agree	5
Agree	4
Neutral	3
Disagree	2
Strongly Disagree	1

According to Table 4, respondents were given a scale of 1 for "Strongly Disagree," 2 for "Disagree," 3 for “Neutral “, 4 for "Agree," and 5 for "Strongly Agree" in regard to attitudinal statements.

3.6.3. Physics Students Semi-structured interview (PSSI)

An interview is a qualitative research method that involves asking questions to collect data. There are several types of interviews, including structured, unstructured, and semi-structured interviews. Semi-structured interviews are often the sole data source for qualitative research projects and are usually conducted in advance. They are organised around predetermined open-ended questions and can occur with an individual or group (George, 2013).

In this study, semi-structured interviews were conducted with a section of the study group, selected through purposeful sampling based on their survey responses. The semi-structured interviews aimed to provide in-depth insights into students' prior conception in the four concepts of fluid mechanics and perceptions of multimedia integration into Cognitive Load Theory (CLT) in fluid mechanics education (Bunmak, 2016). Interviews provide a more detailed exploration of students' prior conceptions, perceptions, motivations, and interests in fluid mechanics concepts. They also help gauge how students perceive the cognitive load theory associated with multimedia-enriched instruction. The use of semi-structured interviews is justified in this study as it allows for a comprehensive exploration of students' prior conception of fluid mechanics concepts, experiences and perspectives regarding the integration of multimedia into CLT. Table 5 provide detailed structure of the PSSIs.

Table 5: Detailed Structure of PSSI

Attribute : Prior conception in fluid mechanics	Participants ID	Description	Interview Questions	Responses
Pascal's Principle	R1	Measure SHS students' prior conception in Pascal's principle.	Q1: Explain how Pascal's principle describes the transmission of pressure in an enclosed fluid?	
	R2	Assess SHS students' prior conception in Pascal's principle	Q2. Explain how Pascal's principle describes the transmission of pressure in an enclosed fluid	
Continuity Equation	R3	Assess SHS students' prior concept continuity equation in fluid mechanics	Q3. Why is it important to maintain the same amount of fluid entering and leaving a pipe system?	
	R4	Measure SHS students prior understanding in continuity	Q4. Explain the principle behind why rivers flow faster in narrower channels than in wider expanses.	
Archimedes Principle	R5	Measure SHS students' prior conception in Archimedes' principle	Q5. When an object is submerged in a fluid, why does the fluid level rise?	
Bernoulli's Principle	R6	Assess SHS student's prior knowledge in Bernoulli's principle.	Q6 A fluid is flowing through a pipe. If the pipe narrows, what happens to the fluid's velocity and pressure according to Bernoulli's Principle?	
	R7	Measure SHS student prior knowledge in fluid low.	Q5. How does water reach your home through pipes?	

Table 5 depicts the detailed structure of the semi-structured interview. From Table 5, the semi-structured interview questions were conducted based on certain attributes. The attributes around which the semi-structured interview questions were conducted include students' prior conception of the four fluid mechanics concepts, these are Archimedes' principle, Pascal's principle, Bernoulli's principle and continuity equation.

3.7. Validity

Validity is an assessment of the accuracy or falsity of the data collected when using an instrument for a study, according to Pandey and Pandey (2015). From a conceptual standpoint, validity, according to Marczyk et al. (2010), tries to address the query "Does the instrument or measurement approach measure what it is supposed to measure?" To assess whether the items on the instruments are acceptable for the given content, this study uses content validity. According to Elangovan and Sundaravel (2021), content validity is vital to confirm that a survey instrument has all the relevant questions and leaves out any that are not necessary for a certain construct domain.

Almanasreh et al. (2019) explain that a panel of experts is used to analyse the items on the instrument and rate them based on their relevance and representativeness to the content area to determine the content validity. As a result, in this study, the FMCT and PSAQ were administered to five experts in the fields of physics and scientific education for evaluation of the items on the instruments to ascertain the relevance in measuring what they wanted to measure. The Lawshe Content Validity Ratio (CVR), developed by Lawshe in 1975, was used to assess the instruments' content validity. One of the most popular techniques for measuring content validity, according to Almanasreh et al. (2019), is Lawshe's Content Validity Ratio (CVR).

Each item on the instruments was rated as "essential" or "not essential" by the panel of CVR method specialists. The content validity index (CVI) was determined for each item on the instrument after items were accepted for inclusion in the final test. The CVI is calculated by dividing the overall number of expert evaluations by the total number of expert essential ratings. The CVI is calculated for the entire instrument after calculating the CVI for each piece. This represents the average of every single CVI (Almanasreh et al. 2019; Ayre & Scally, 2013). The aggregate CVI was then divided by the total number of elements to get the CVRs of the instruments. The Content Validity Ratio and Content Indices for FMCT are shown in Table 6.

Table 7: Content Validity Indices and Content Validity Ratio for Items on FMCT

Item	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Agreement	CVI
1	X	X	0	X	X	4	0.800
2	X	X	X	X	X	5	1.000
3	X	X	0	X	X	4	0.800
4	X	X	X	X	X	5	1.000
5	X	X	X	X	X	5	1.000
6	X	X	X	X	X	5	1.000
7	X	X	X	X	X	5	1.000
8	X	X	X	X	X	5	1.000
9	X	X	X	X	X	5	1.000
CVR							0.956

CVI = $\frac{N_E}{N}$ for the Content Validity Index

CVR = Content Validity Ratio ($\frac{CVR}{N}$).

N = Total number of the experts.

N_E= The number of experts identifying a particular item as essential.

Almanasreh et al. (2019) state that CVR ranges between 1 and -1, with high values of CVR signifying the consensus of experts on the relevance of a certain item in the instrument. According to Almanasreh et al. (2019), the CVR value for FMCT was 0.956, which shows that the instrument is valid, as can be shown from Table 7. Table 8 also presents the Content Validity Ratio and Content Indices for PSAQ

Table 8: Content Validity Ratio and Content Indices for PSAQ

Item	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Agreement	CVI
1	X	X	0	X	X	4	0.800
2	X	X	X	X	X	5	1.000
3	X	X	X	X	X	5	1.000
4	X	X	X	X	X	5	1.000
5	X	X	X	X	X	5	1.000
6	0	X	X	X	X	4	0.800
7	X	X	X	X	X	5	1.000
8	X	X	X	X	X	5	1.000
9	X	X	0	X	X	4	0.800
10	X	X	X	X	X	5	1.000
11	X	X	X	X	X	5	1.000
12	X	X	X	X	X	5	1.000
13	X	X	X	X	X	5	1.000
14	X	X	X	X	0	5	1.000
15	X	X	X	X	X	5	1.000
16	X	X	X	X	X	5	1.000
17	X	X	X	X	X	5	1.000
18	X	X	X	X	X	5	1.000
19	X	X	X	X	X	5	1.000
20	X	X	X	X	X	5	1.000
21	X	X	X	X	X	5	1.000
22	X	X	0	X	X	4	0.800
23	X	X	X	X	X	5	1.000
24	X	X	X	X	X	5	1.000
25	X	X	X	X	X	5	1.000
26	X	X	X	X	X	5	1.000
27	X	X	0	X	X	4	0.800
28	X	X	X	X	X	5	1.000
29	X	X	X	X	X	5	1.000
CVR							0.966

According to Almanasreh et al. (2019), the CVR value for the PSAQ was 0.966, which denotes a viable instrument. This information is shown in Table 8.

3.8. Pilot Study of the Instruments

In order to assess possible research methodology, data collection instruments, sample recruitment strategies, and other criteria, a pilot study is a small study carried out before a larger, more comprehensive investigation (Zailinawati et al., 2006). Prior to using the research instruments and technique in the main study, Zailinawati et al. (2006) state that doing a pilot study helps researchers find potential problem areas and weaknesses in both the instruments and the methodology. Therefore, a pilot study was done in this study at St. Thomas Senior High Technical School in the West Akim Municipality, where students who were not involved in the main investigation shared some of the same features as the research participants.

Johanson and Brooks (2010) advocate using at least thirty (30) representative participants from the community of interest in a pilot study with the goal of performing a preliminary survey or creating a scale. Therefore, the research tools were piloted by 14 third-year SHS Physics students. The reliability of the instrument scores was evaluated using the findings from the pilot study.

3.9. Reliability

Reliability, according to Marczyk et al. (2010), is a measurement approach's consistency or dependability. According to Pandey and Pandey (2015), a dependable instrument generates results that are stable and reliable. To put it another way, a scale or test is said to be dependable if it consistently produces the same result of repeated measurements (Taherdoost, 2021). The internal consistency reliability approach was utilised to assess the validity of the FMCT and PSAQ results from the pilot study. This gauges how closely each item on an instrument measures the same feature of the relevant characteristic (Heale & Twycross, 2015). Cohen's kappa (inter-rater reliability) and Cronbach's alpha were employed in the internal consistency reliability approach.

3.9.1. Internal consistency reliability for FMCT

Students' responses from the pilot study were provided to two raters who scored the items to establish the FMCT's internal consistency reliability. Using the scores from both raters, the consistency of the raters was estimated using Kappa's measure of agreement. To interpret Kappa's measure of agreement for FMCT, McHugh (2012) utilised the scale shown in Table 9.

Table 9: Scale of Interpretation for Kappa Measure of Agreement for FMCT

Kappa Value	Interpretation
≤ 0	No agreement
0.01–0.20	none to slight agreement
0.21–0.40	Fair agreement
0.41–0.60	Moderate agreement
0.61–0.80	Substantial agreement
0.81–1.00	Almost perfect agreement

The internal consistency reliability for FMCT is presented in Table 10.

Table 10: Consistency of FMCT: Internal consistency Reliability

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.632	.330	2.542	.011
N of Valid Cases		14			

According to McHugh's definition of a substantial agreement, Table 10 shows that the value of Kappa's measure of agreement is 0.632. As a result, it was decided to use the FMCT in the primary investigation.

3.9.2. Internal consistency reliability for PSAQ

The scores from the PSAQ pilot study were computed, and the reliability, and consequently internal consistency of the results (Cronbach alpha), was assessed. Table 11 presents the findings.

Table 11: Consistency of PSAQ

Reliability Statistics	
Cronbach's Alpha	N of Items
.763	10

Heale and Twycross (2015) state that Cronbach's alpha result is a number between 0 and 1 and that a dependability score of 0.7 or above is considered satisfactory. Since the PSAQ instrument proved reliable for use in the main investigation, as shown in Table 11, the Cronbach alpha value for the PSAQ scores from the pilot study was 0.763.

3.10. Data Collection Procedure

Data for this study were collected in three phases: pre-intervention, intervention, and post-intervention, using both quantitative and qualitative methods.

The data collection process, consisting of pre-intervention, intervention, and post-intervention rounds, allowed for a comprehensive assessment of the students' conceptual understanding and attitudes toward fluid mechanics before and after the multimedia-based CLT instructional intervention. The combination of quantitative and qualitative methods ensured a thorough analysis of the impact of the intervention on student learning and engagement.

3.10.1. Pre-intervention stage

Permission was requested from the administrators of the participating school, Asamankese Senior High School, during the Pre-intervention phase of the research. It was also advised to ask permission from the Senior Physics tutor and the head of the science department in the school under study. Authorities and students from the sampled school were informed of the advantages and applications of the study's findings while also receiving assurances regarding the privacy of the data and information submitted by the students. As a result, SCHOOL A (taught using the CLTML technique) was designated as the study group for privacy and data entry purposes. The survey was conducted while no noteworthy events were happening at the school.

Following that, pilot research was carried out with SHS 3 Physics students from a separate school (St. Thomas Senior High Technical School), who had not participated in the primary study. After the pilot study, it was assessed whether the results were reliable.

The pre-intervention test (pre - test) was administered to the study groups as part of the subsequent pre-intervention phase. One week's notice was given to the students so they could get ready for the pre - test. The pre - test was utilised to ascertain the entry characteristics of participants in the groups as well as the prior conceptual understanding of fluid mechanics held by SHS Physics students. Following the administration of the pre - test, students were invited to respond to pre – intervention survey (interview) prior to the introduction of the integration of multimedia into the

Cognitive Load Theory teaching and learning approach, this was done to ascertain in depth prior conceptual understanding of the SHS students' in fluid mechanics concepts and attitudes toward physics**.**

3.10.2. Developing and designing an instructional intervention stage

After careful planning and resource mobilisation, the teaching strategies (CLTML) were applied to the groups in six weeks. The identical four fluid mechanics concepts from the SHS Physics curriculum were used to instruct the study group. In the next subsections, intervention techniques for the study groups are covered.

3.10.2.1. Intervention processes for study group

In this study, the study group was exposed to the integration of multimedia into cognitive load theory learning (CLTML) approaches. The usage of the CLTML technique in the study group is highlighted in the following lesson plan (APPENDIX E).

3.10.3. The use of multimedia integration into cognitive load theory in Archimedes' principle

The table 11 shows the lesson plan developed by the researcher to teach during the intervention phase of the study. This lesson plan was used by the researcher to teach Archimedes principle using multimedia tools and CLT instructional strategies. Lesson plans on other concepts are shown in Appendix E.

Table 12: Lesson Plan Developed Using the Multimedia Integration into Cognitive Load Theory Instructional Approach in Archimedes' Principle

LESSON :1

DURATION: 1 hour.

OBJECTIVES: By the end of the lesson, students will be able to;

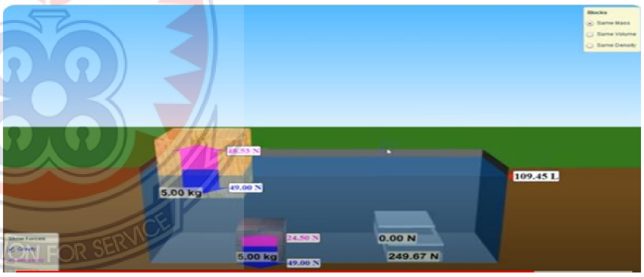
- State Archimedes' principle;
- State buoyancy force;
- Explain the interaction between pressure and Archimedes' principle (buoyancy force);
- Clarify physical quantities such as pressure, P, volume, V, and force, F;
- To demonstrate the applications of Archimedes' principle in real-life situations.

Teaching – Learning Materials: SHS Physics syllabus; textbook (Serway & Jewett, 2008), p. 395- 399; text, pictures, diagrams, video and symbolic or mathematical formulae.

Duration in minutes	Stages	CLTML – Instructional Approaches
5	Introduction	The researcher introduce the topic • Archimedes principle • Buoyancy • Relationship between up thrust and weight of displaced fluid.
40	Presentation	The researcher presented: • Video on a ship / block of wood immersed in water. The researcher provides verbal explanations.

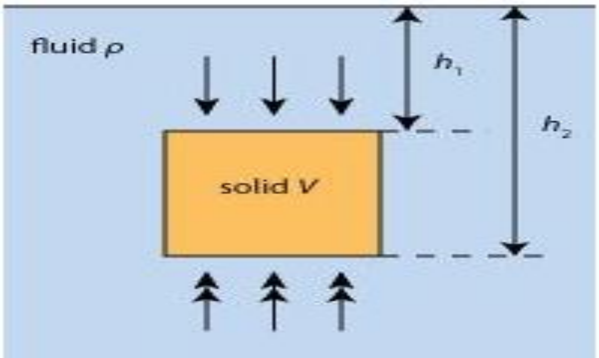
Figure 1: A Ship in Water

- The Statement of Archimedes' Principle, applying



redundancy principles.

- Discusses step by – step (segmentation) with the students the interaction between trust pressure and buoyancy;
- The researcher used simulations to illustrate Archimedes principle, pressure, and buoyancy by employing dual coding and modality principles.

		Figure 2: Archimedes Principle Simulation • The researcher guided students to demonstrate Archimedes' principle by using a block of wood immersed in a fluid. Apply redundancy and contiguity principles as well as dual coding to show them how the block and the fluid interact and the pressure difference between the block and the fluid (Figure 3),  ***Figure 3: A Block of Wood in Water***

		• Explain stage by stage this in terms of Buoyancy force equals up pressure by using the pictures by using segmentation principle; • The researcher led students to evaluate the relationships and the ratio of their density and volume change, using mathematical equations and formulae, by ensuring redundancy and contiguity principles are applied Upthrust =Vρg Weight in air – Upthrust = weight in fluid $p = h \rho g$; Where p – pressure, h – height of fluid column, ρ – density of fluid and g – acceleration due to gravity.
5	Summarisation	Summarise Archimedes' principle and the relationship between pressure, density and height of fluid in Archimedes' principle.
10	Evaluation	A log is suspended from a string and then immersed in a container of water. • What will happen to the wood? • What will happen to the water height? • What will happen when one read the spring balance?

		• The students will now work in their workbooks to complete the activity in their workbooks individually. • Picture 1 (Figure 1 in the lesson plan). This shows the relationship between pressure and Archimedes' principle. • Picture 2 (Figure 3 in the lesson plan) shows buoyancy. • What does picture 1 describe in terms of the relationship between pressure and Archimedes' principle? • What cues are associated with buoyancy? • What do you see in picture 2; is the pressure that the fluids exert on the woodblocks? • Finally, the researcher will give them corrections for their responses so that they get the correct answer.

Lesson plan on Intervention for Archimedes principle

3.11. Getting the Activity Ready

The researcher chose how many pupils he wanted to work in each group. He as well chooses seven multimedia resources (videos, simulations, animation, photos, audio, texts, and mathematical formulas) for the class to study the four concepts in fluid mechanics. The researcher also decided on which Cognitive Load Theory instructional strategies he wanted to use with the students, including Pre-training, Segmentation, Dual Coding, Modality Principle, Redundancy Principle, Contiguity Principle, Expert Reversal, split attention effect and Feedback.

The researcher taught the whole class of the study group, using the selected multimedia and the cognitive load theory strategies for the first four weeks. The researcher then put the students into groups, and assigned specific topics to them for group presentations, for two additional weeks.

3.11.1. Students collaborate in expert and home groups

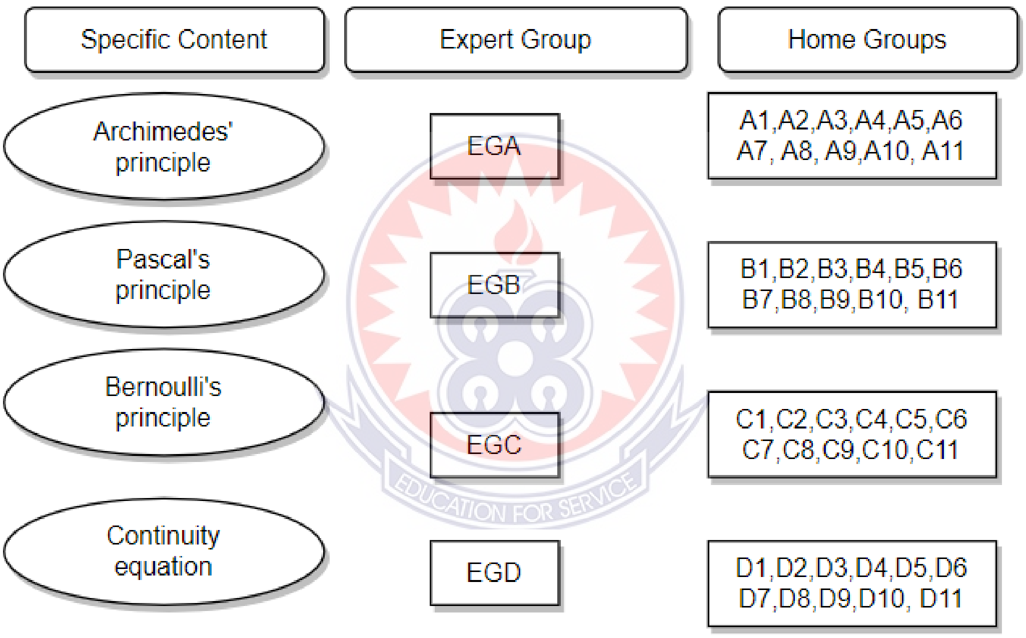


Figure 8: Students in Experts and Home Groups

According to Andreas et al. (2010) and Tieso (2005), the study groups (the CLTML group) were assigned at random into four "Expert Groups (EG)" that comprised EGA through EGD (Figure 8). Each home group in this regard had an average of eleven students studying the same subtopic, as depicted in Figure 8.

Expert Group A (EGA) was tasked with developing a model for an introduction to fluid mechanics that incorporates the Archimedes principle. Similar assignments were made to Expert Group B (EGB), Expert Group C (EGC), and Expert Group D (EGD) for Pascal's Principle, Bernoulli's Principle, and the Continuity Equation, respectively. Small groups of students were in charge of reviewing certain material at this point so they could impart it to their peers.

When students know exactly what material they are expected to learn and share with their classmates in "expert" groups, the groups function more effectively. As a result, the expert groups were frequently given a chart or a list of questions to respond to in their expert groups. It's critical that each group member comprehend the information they are to learn and share with their peers. The researcher examined and approved content prior to it being shared with students in the other groups, preventing the presentation of false or misleading information by students.

Each "Expert" group was led by the investigator as they work with videos, animations, texts, and mathematical formulas to learn the assigned specific topics in fluid mechanics concepts. CLT instructional strategies such as Pre-training, Segmentation, Dual coding, modality principle, Redundancy principle, Contiguity principle, Expert reversal, and feedback were also employed (Anmarkrud et al., 2019; Steele, 2023).

3.11.2. Students meet in teaching groups

Students were divided into "teaching" groups, once "expert" groups demonstrated a thorough comprehension of the concept they discussed, as depicted in Figure 9. Typically, one representative from each expert group made up the "teaching" groups.

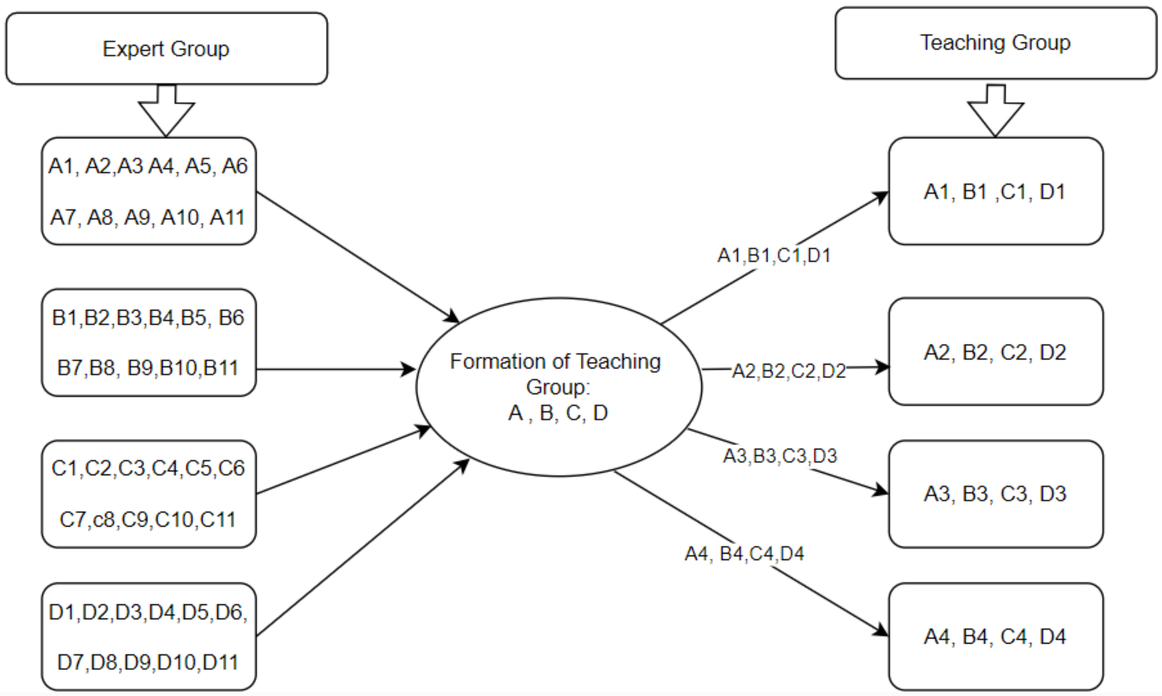


Figure 9: Teaching Group

Expert presented lessons on the prescribed topic in fluid mechanics concepts in turns, integrating the multimedia materials into the CLT instructional methodologies.

3.11.3. Students synthesise and reflect

The "teaching" groups were then given a task that required them to combine the knowledge that had been imparted, such as responding to a more comprehensive question, contrasting texts, or developing a strategy. Students could work in pairs or independently to synthesise the knowledge. Students were also given the chance to design a lesson that required others to respond to a question about fluid mechanics concepts in physics and its applications by integrating multimedia into the cognitive load theory they had just studied.

3.12. Post Intervention Stage

The study groups received advance notification to prepare for the post-intervention test (post - test) after the six-week intervention. The study groups took the post-intervention test (FMCT), which was given by the researcher with assistance from the physics teachers in the participating classes. This was done to assess the evolution of the students' conceptual grasp of fluid mechanics. Following the completion of the post-test, the PSAQ was also given to the study groups using the Likert scale to gauge the student's level of agreement with the use of the multimedia representations.

Additionally, semi-structured individual interviews were also conducted with a section of the participants. The tests and questionnaires that were completed were gathered and scored, and the findings were examined.

3.13. Data Analysis Procedure

Both quantitative and qualitative data were collected for this study to address the research questions. The quantitative data were gathered through students' performance on the Fluid Mechanics Concept Test (FMCT) and their responses to the Physics Students' Attitude Questionnaire (PSAQ), administered both before and after the intervention. The FMCT measured students' conceptual understanding of fluid mechanics, while the PSAQ assessed their attitudes towards the study of fluid mechanics.

To capture the qualitative data, semi-structured interviews were conducted with selected students to gather in-depth insights into their experiences with the integration of multimedia into Cognitive Load Theory (CLT). In addition, open-ended responses from the PSAQ provided further qualitative data, reflecting students' attitudes and perceptions.

The data collected through the FMCT and PSAQ were analyzed using descriptive statistics, including mean, standard deviation, and effect size, to determine students' attitudes and conceptual understanding before and after the multimedia-based instructional intervention. The qualitative data from the interviews and open-ended responses were analyzed using thematic analysis to identify key themes and patterns related to students' learning experiences and attitudes.

3.13.1. Quantitative Data Analysis

The results of the Fluid Mechanics Concept Tests (FMCT pre-test and post-test) and the Physics Students' Attitude Questionnaire (PSAQ) were combined to create descriptive statistics, specifically frequencies, percentages, means, standard deviations, mean differences, and effect size. In order to quantitatively respond to research questions 1, 2 and 3, mean, standard deviation, mean difference, effect size were used.

3.13.2. Qualitative data analysis

The quantitative analysis carried out for research question 1, 2 and analysis of research question 3 was supported qualitatively by thematic analysis, using the Physics Students Semi – structured Interview (PSSI).

3.13.3. Data Analysis for Research Questions 1 and 3

Research Question 1

Research question one aimed to determine the prior conceptions students had about fluid mechanics before the instructional intervention. To address this question, a concept test (FMCT) was administered during the pre-intervention phase. The data collected from this test were analyzed both quantitatively and qualitatively. Quantitative analysis involves the use of frequencies and percentages to measure students' initial understanding, as shown in Table 13 and qualitative analysis involves thematic analysis. This analysis provided insight into the specific areas where students had misconceptions or gaps in their knowledge of fluid mechanics.

Research Question 3

Research Question 3 aimed to determine the effect of integrating multimedia into Cognitive Load Theory (CLT) on students' attitudes towards the study of fluid mechanics. To address this, both quantitative and qualitative data were collected and analyzed.

The Physics Students' Attitude Questionnaire (PSAQ) was administered to students both before and after the intervention. The responses provided quantitative data, which were analyzed using descriptive statistics, including mean, standard deviation, and effect size. Prior to the intervention, the PSAQ results indicated a mean score of 1.98 (SD = 0.689), which was below the hypothetical criterion mean score of 2.5. This score suggested that students held negative attitudes towards the teaching and learning of fluid mechanics before the multimedia-based intervention.

Following the intervention, the data were re-analyzed to assess any shifts in students' attitudes. The analysis was structured around specific themes that measured overall attitudes towards fluid mechanics, as outlined in the PSAQ (Appendix D). To interpret the results, a criterion score of 2.5, as used by Ogunbodede et al. (2022), was adopted. Scores of 2.5 and below were interpreted as reflecting negative attitudes, while scores above 2.5 indicated positive attitudes. The results of students' attitudes prior to the intervention are presented in Table 15.

Additionally, the effect of integrating multimedia into CLT on students' attitudes was determined using effect size analysis, specifically Cohen's d, as proposed by Cohen et al. (2018). This involved calculating the difference between the post-test and pre-test mean attitude scores, divided by the pooled standard deviation (Appendix F). The resulting Cohen's d value was 2.14, which, according to Pallant (2011), signifies a large effect ($d \leq 0.2$ = small effect, $d \leq 0.5$ = medium effect, and $d \geq 0.8$ = large effect). This indicates that the multimedia integration had a significant positive impact on students' attitudes towards the study of fluid mechanics.

The Fluid Mechanics Concept Test (FMCT) provided additional quantitative data regarding students' conceptual understanding of fluid mechanics concepts. Descriptive statistics were used to compare students' performance before and after the intervention. This comparison allowed for an evaluation of how the instructional intervention influenced their understanding of core concepts.

3.14. Chapter Summary

Chapter Three of the thesis provides a detailed description of the research methodology used in the study, outlining the design, sampling techniques, data collection methods, data analysis procedures, ethical considerations, and limitations. The research design aligns with the research objectives and questions, facilitating a structured and systematic investigation. A mixed-methods approach is adopted, integrating both quantitative and qualitative techniques to gain comprehensive insights into the studied phenomenon. Sampling techniques are discussed, with stratified random sampling used to ensure diverse sub-groups are adequately represented.

Data collection methods include surveys and interviews which capture quantitative data and provide measurable evidence of trends and patterns. Ethical considerations are meticulously addressed, with informed consent obtained from all participants and confidentiality maintained throughout the study. The chapter acknowledges the limitations of the study, including potential biases in data collection and analysis and constraints related to the scope and context of the research. By acknowledging these limitations, the researcher provides a transparent account of the study's boundaries, paving the way for future research to address these gaps. In conclusion.

Chapter Three provides a comprehensive overview of the research methodology, detailing the design, sampling techniques, data collection methods, data analysis procedures, ethical considerations, and limitations. This thorough and systematic approach ensures the study's methodological soundness and the credibility and reliability of the findings.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0. Overview

This chapter presents the results of the study group, focusing on senior high school physics students' prior knowledge of fluid mechanics concepts. Their understanding was classified into three groups. Participants used a variety of formats during the needs assessment activity, including equations, drawings, and unwritten responses. The study analysed the results of the needs assessment interviews and examined students' understanding using an open-ended FMCT questionnaire as a pre-test. Sections 4.2 to 4.3.3 detail the qualitative and quantitative findings from the FMCT interviews, pre-test, and open post-test.

4.1. Result for research question 1

Research question 1. What prior conceptual knowledge do students 'hold in fluid mechanics?

Table 13 presents the descriptive statistics such as frequencies and percentages on students' responses to the FMCT items before the intervention.

Table 13: Descriptive Statistics of Prior Conceptions of Students on Fluid Mechanics before Intervention

Concept	Item	Prior Conception					
		CC		AC		NC	
		F	%	F	%	F	%
Pascal's Principle	1	2	4.44%	15	33.33%	28	62.22%
	2	1	2.22%	20	44.44%	24	53.33%
	3	1	2.22%	25	55.55%	19	42.22%
	Average %		**2.96%**		**44.44%**		**52.59%**
Archimedes' Principle	4	1	2.22%	20	44.44%	24	53.33%
	5	1	2.22%	12	26.67%	32	71.11%
	6	1	2.22%	16	35.56%	28	62.22%
	Average %		**2.22%**		**35.56%**		**62.22%**
Continuity Equation	7	2	4.44%	16	35.56%	27	60.00%
	8	1	2.22%	13	28.89%	31	68.89%
	9	2	4.44%	14	31.11%	29	64.44%
	Average %		**3.70%**		**31.85%**		**64.44%**
Bernoulli's Principle	10	3	6.67%	18	40.00%	24	53.33%
	11	1	2.22%	19	42.22%	25	55.56%
	12	3	6.67%	15	33.33%	27	60.00%
	Average %		**5.19%**		**38.52%**		**56.30%**
	Overall average %		**3.52%**		**37.59%**		**58.89%**

Table 13 Descriptive Statistics of Prior Conceptions of Students on Fluid Mechanics before Intervention

Note:

- *CC = Correct Conception (students with an accurate understanding of the concept).*

- *AC = Alternative Conception (students with misconceptions or alternative, non-scientific views).*
- *NC = Null Conception (students without prior understanding or knowledge of the concept).*
- *F = Frequency (the number of students in each category).*

The results presented in Table 13 reveal that greater percentages of students demonstrated null conceptions (NC) and alternative conceptions (AC) on each fluid mechanics concept, while the lowest percentages of students demonstrated correct conceptions (CC). This resulted in higher overall percentages of students demonstrating null conception (NC) and alternative conception (AC) on fluid mechanics in general. Specifically, an overall average participant percentage of 58.89% and 37.59% was observed in null conceptions (NC) and alternative conceptions (AC) respectively, while a very low percentage of students demonstrated correct conception (CC) on fluid mechanics, with an overall average participant percentage of 3.52%.

Table 13 further reveals that the highest percentage of participants who demonstrated correct conception (CC) was observed in "Bernoulli's Principle" with an average participant percentage of 5.19%, while the lowest percentage of participants who demonstrated correct conception (CC) was observed in "Archimedes' Principle" with an average participant percentage of 2.22%. Moreover, "Pascal's Principle" was the fluid mechanics concept where the highest average percentage of participants (44.44%) demonstrated alternative conceptions (AC), while the least average percentage of participants (31.85%) demonstrated alternative conceptions (AC) on "Continuity Equation". The null conception (NC) category saw the highest percentage of participants being recorded in "Continuity Equation" with an average participant percentage of 64.44% while the lowest percentage of participants who demonstrated null conception was recorded in "Pascal's Principle" with an average participant percentage of 52.59%.

To obtain an in-depth understanding of prior conceptions of students in fluid mechanics, qualitative data through semi-structured interviews was conducted to answer this research question qualitatively. Students' responses from the semi-structured interview were analysed as correct conception, alternative conception, and null conception. The content analysis of students' responses was done based on the four major concepts considered under fluid mechanics in this study, which are Pascal's principle, Archimedes' principle, Continuity equation, and Bernoulli's principle.

4.1.1. Pascal's Principle

Teacher: Explain how Pascal's principle describes the transmission of pressure in an enclosed fluid.

In response to this item, students demonstrated a variety of prior conceptual knowledge. Specifically, students' responses were classified as correct conception, alternative conception, and null conception. Representative statements from students are presented below. For confidentiality purposes, the names of respondents were replaced by R1, R2, R3 …….Rn. For instance, in answering this item respondent 1 (R1) stated:

> "*According to Pascal's principle, pressure is transferred in all directions without decreasing when it is applied to any section of an enclosed fluid. For example, when a balloon is inflated, this principle is demonstrated well. As air, or the fluid, is pumped in, the balloon expands uniformly. The balloon expands uniformly as a result of the air molecules' constant pressure against the balloon's*

inner walls, illustrating the fluid's ability to transmit pressure evenly." (Correct conception from R1)

An analysis of the response by R1 indicated a correct conception. The respondent provided a correct explanation of Pascal's principle by demonstrating how pressure applied to a confined fluid (the air in a balloon) causes the balloon to expand uniformly in all directions, which is the basic idea behind Pascal's principle.

Also, respondent 2 (R2) provided a response which was deemed a correct conception. R2 stated that:

"*Sir, consider a water bottle with a tight-fitting cap as one example. When the bottle is squeezed, the internal pressure rises and is evenly distributed throughout the water, applying pressure to every portion of the inside of the bottle. Understanding the behaviour of confined fluids under pressure depends on this uniform transmission of pressure*." (Correct conception from R2)

Starting, R2 described a situation in which a squeeze (pressure) is applied to a water bottle that has a tight-fitting cap. In line with Pascal's principle, which states that a change in pressure applied to a fluid that is enclosed will transfer through the fluid, this action raises the pressure inside the bottle. Squeezing the container causes the internal pressure to rise and distribute evenly throughout the water, as the student accurately noted. The pressure rise is distributed equally in all directions within the fluid, which is a crucial component of Pascal's principle.

Respondent 3 (R3) also provided a response which proved to be an alternative conception. R3 stated that:

> "*I think that the pressure exerted on a fluid decreases because gravity causes things to descend. This means that applying pressure on a bottle of water should cause the force to gravitate toward the bottom, where objects naturally gravitate. Like when you walk on a hose, the pressure flows to the sides, causing the water to spray out*."
>
> (Alternative conception from R3)

According to R3, gravity causes objects to fall, which is the main reason why pressure applied to a fluid decreases. This idea raises questions about how fluid pressure is understood. In reality, pressure in a fluid is not always brought on by gravity; rather, it is created by the force that the molecules of the fluid apply to one another. The student went on to say that pressure should naturally gravitate toward the bottom of a bottle of water since that is where items naturally gravitate. It appears from this that gravity would cause the pressure to build up at the bottle's bottom. However, according to Pascal's principle, pressure in a fluid under pressure is transferred equally in all directions, independent of gravity. The student draws a comparison between the situations of walking on a hose, where water sprays out due to pressure flowing to the sides. Pascal's principle is not in line with this analogy. Stepping on a hose creates localised pressure that pushes the water out from under your foot rather than exerting pressure evenly on the fluid inside.

A similar alternative conception was also demonstrated by respondent 4 (R4) in answering this item. R4 stated that:

> "*Pascal's principle, in my opinion, explains why water either reaches its level or goes downward. The reason for this is that pressure causes the water to flow from areas of high pressure to areas of low pressure; this is similar to how a ball rolls down a slope; it just goes where it is easiest. Maybe, that explains why air flows from a fan or why rivers curve*." (Alternative conception from R4)

An analysis of R4's response revealed that the student made a connection between the principle of Pascal and the reasons water flows downward or reaches a specific level. However, this has more to do with gravity and hydrostatics. Pascal's principle describes pressure transmission in a fluid; the analogy of a ball rolling down a hill depicts potential energy differences instead. The discussion of river curvature and airflow from a fan has more to do with fluid mechanics and other considerations than it does with Pascal's principle.

Another alternative conception was exhibited by respondent 5 (R5). R5 stated that:

> "*As far as I can tell, Pascal's principle mostly deals with liquids. It isn't actually related to gasses or other things, in my opinion. It is as simple as pushing water and letting pressure pass through it. I believe this is the reason we use water to power devices*." (Alternative conception from R5)

Although Pascal's principle applies to all fluids, including gases, the student suggested that it only related to liquids. Pascal's principle applies to all fluids; hence it is erroneous to exclude gases from their use. The larger idea of pressure transmission in a confined fluid is missed when Pascal's principle is reduced to "pushing water and letting pressure pass through it". Although hydraulic systems do make use of Pascal's principle, the statement did not adequately convey the essence of the idea, which concerns the transfer of pressure in fluids. Consequently, while the respondent's statement offered an alternative conception, it did not fully convey the physics-based concepts of Pascal's principle.

In another response, respondent 6 (R6) exhibited a null conception. R6 stated that:

> "*To be honest, in my opinion, pressure has nothing to do with pushing on something. I believe that when you apply enough force, objects just move or squeeze as a result of the force rather than because of the pressure acting on a certain region. Similar to how a ball rolls when you kick it, it is not because of any pressure. It moves because somebody kicks it*." (Null conception from R6)

R6's response ignored the connection between pushing and pressure, which is a basic component of Pascal's principle. The respondent distinguished between force and pressure, whereas pressure is a measurement of force applied across an area. The analogy of a ball rolling when kicked does involve pressure, since the force of the kick applies pressure to the ball's surface, which causes it to move. Since the respondent's answer twists the fundamentals of Pascal's principle, it constitutes a null conception. It rejects the basic idea of Pascal's work—that pressure has an impact on how objects behave when they are under forces.

Another null conception was also exhibited by respondent 7 (R7) in response to this item.

> "*I just believe that the pressure changes instantly and throughout a filled tube when one end is pushed. It is like pressing a button and expecting something to happen right away without thinking about how the pressure actually passes through the material. In my opinion, it is similar to flipping a light switch, which causes the light to turn on immediately*." (Null conception from R7)

R7's response suggests that pressure changes instantly throughout a filled tube, which does not align with Pascal's principle. The comparison to pressing a button and flipping a light switch implies an instantaneous effect, whereas pressure changes in a fluid propagate at the speed of sound in that fluid. As such, the respondent's answer to the item does not carry the ideas behind Pascal's principle.

4.1.2. Archimedes' principle

Teacher: When an object is submerged in a fluid, why does the fluid level rise?

Respondent 8 (R8) provided an answer to this item which was deemed a correct conception. The narration below represents the answer given by R8.

> "Yes, *I remember studying the Archimedes' Principle. According to this principle, the upward force exerted on an object is equal to the weight of the fluid the object has displaced. Therefore, an object that is submerged causes some fluid to be displaced; this fluid that is displaced then produces an upward force, which causes the fluid level to rise. For instance, when you push a ball into a pool and the water level rises around it*". (Correct conception from R8)

Analysing R8's response to this item, one could decipher that the statement accurately states that the buoyant force an object experiences while submerged in a fluid is equivalent to the weight of the fluid the object has displaced. This is the fundamental idea behind Archimedes' Principle. R8 accurately noted that the fluid level rises as a result of the displaced fluid.

In another response to this item, respondent 9 (R9) provided an answer which was considered an alternative conception. The answer of R9 is provided as follows:

> "*The reason the fluid level rises, in my opinion, is that the object's weight draws the fluid up with it. The item draws the fluid to it and draws it upward, rather like a magnet attracts iron. Thus, when a large stone or other heavy object is submerged in water, its weight causes the water's level to rise*". (Alternative conception from R9)

The response of R9 provides a different explanation for why the fluid level rises when an object is submerged. Archimedes' principle is understood traditionally to say that an object displaces a volume of fluid, which causes the fluid level to rise. An upward buoyant force is therefore produced by the displaced fluid, which is equal to the weight of the displaced fluid. This buoyant force raises the fluid level and is responsible for the object's tendency to float when submerged. R9's response deviated from this understanding. According to R9 the object's weight alone is what actually raises the fluid level. Similar to how a magnet draws iron, the object's weight, according to R9, is thought to be "pulling" or "attracting" the fluid upward. This viewpoint, even though it provides an interesting analogy with magnetism, contradicts the interpretation of Archimedes' Principle, which concentrates on the buoyant force produced by the displaced fluid.

In another viewpoint, respondent 10 (R10) demonstrated an alternative conception in expressing a response to this item. The response of R10 is narrated below:

> "*Sir, the reason is that the object creates waves in the liquid. The fluid is forced upward by these waves, which must have somewhere to go, raising the level. An example is how ripples in a pond cause the water level to appear higher when you throw a stone or an object into the pond."* (Alternative conception from R10)

According to Archimedes' Principle, an object, when immersed in a fluid, displaces a volume of fluid, which is equal to the volume of the object. The displaced fluid causes the fluid level to rise. The fluid level rises as a result of the upward buoyant force this displaced fluid produces. The idea put out by the respondent centred on the submerged object's dynamic wave motion. According to R10, the fluid's upward flow is caused by the waves pushing on it. The respondent's answer, which attributes the rise in fluid level to the waves the object creates rather than the buoyant force outlined by Archimedes' Principle, provides an alternative conception for the phenomenon.

Another alternative conception was expressed by respondent 11 (R11). In answering this item, R11 articulated that:

> "*Okay sir, my view is that the object causes the fluid to form a sort of hole, which is why the fluid level rises. The level of the fluid rises as a result of the fluid rushing in to fill that hole. It feels similar to how the dough rises around your finger as you press into it. The object and the fluid experience the same thing*." (Alternative conception from R11)

The response from R11 centred on the fact that the object would cause a 'hole' or void in the fluid, while the surrounding fluid rushes in to fill it. Thus, rather than highlighting the buoyant force outlined by Archimedes' Principle, R11's answer provided an alternative explanation for the rise in fluid level that occurs when an object is submerged.

Respondent 12 (R12) also demonstrated null conception in an attempt to provide an answer to this item. In answering this item, R12 said that:

> "*… Sir, honestly, I do not know. I suggest because the thing occupies space inside the container, it appears fuller. The water level appears to be rising, but maybe this is only the result of reduced space available for water*." (Null conception from R12)

R12's response was deemed a null conception of Archimedes' principle. This is because the respondent's answer ignored the fundamental idea underpinning the rise in fluid level that occurs when an object is immersed. The response only explained a surface-level observation, implying that the object's occupying space is the only reason for the rise in fluid level, without highlighting the buoyant force behind the observed phenomenon.

Respondent 13 (R13) also demonstrated null conception of Archimedes' principle when providing an answer to this item. The response of R13 was that:

> "*Sir, I am not sure of this, but in my opinion, the fluid level does not rise at all. I think it is the way light reflects off the object that causes it to appear different, although it most likely stays the same. It is possible that the object is merely changing the water's appearance by rising*." (Null conception from R13)

One could decipher from the respondent's answer that, R13 had no knowledge of Archimedes' principle prior to the intervention. According to R13, when an object is immersed in a fluid, the fluid level does not rise at all. This is false since it stands in direct opposition to the observed fact that placing an object in a fluid causes the fluid level to rise. The answer provided by the respondent was inaccurate as it implies that the increase in fluid level is just an optical illusion brought on by light bouncing off the object. This renders the respondent's answer invalid since it goes against the accepted theory of buoyancy, making it a null conception of Archimedes' principle.

Similar null conception was exhibited by respondent 14 (R14) in answering this item. R14 expressed that:

> "*Sir, I cannot give an answer to this but maybe the object makes the fluid heavier, so it sinks a bit, making it look like the level rises. It seems like the water rises, but maybe it is just because the object is sinking and displacing the water around it.*" (Null conception from R14)

R14 proposes that the object's ability to make the fluid heavier explains why the fluid level appears to rise when an object is immersed. Per the response from the respondent, this suggests that the fluid's density or weight is influenced in some way by the object's weight. The student continues by suggesting that the fluid appears to rise because it dips slightly as a result of the object's weight. Here, according to R14 the fluid compresses or gets denser in some way because of the object. This is inconsistent with Archimedes' principle, which explains that the buoyant force of the displaced fluid causes the fluid level to rise.

In the same vein, R15 provided a response that was deemed a null conception. In the respondent's view, R15 stated that:

> "*Sir, I am not sure how to respond to this; however, it is possible that the object may make the fluid heavier, causing it to drop slightly and giving the impression that the level has increased. The object below may be the reason for someone to think the water level rises*."
>
> (Null conception from R15)

According to R15**,** the object adds weight to the fluid. This theory suggests that the object's weight influences the fluid's weight in some way. The notion of buoyancy, which is the real cause of the rise in the fluid level that is noticed when an object is immersed, was not taken into account in the response. As a result, the response from R15 was considered a null conception.

4.1.3. The continuity equation

Teacher: Why is it important to maintain the same amount of fluid entering and leaving a pipe system?

In responding to this item, respondent 16 (R16) demonstrated correct conception of the continuity equation. R16's response is narrated below:

> "*Sir, I think it is because of the mass conservation principle in the continuity equation. The mass conservation principle maintains that the amount of fluid entering and exiting a pipe system must be constant. The continuity equation makes sure that everything that enters must exit, maintaining the fluid's overall mass. I think this is important for engineering projects such as chemical pipelines and water delivery systems. Without this equilibrium, the efficiency of the system may be affected by leaks or pressure imbalances*."
>
> (Correct conception from R16)

As R16 has accurately explained, the continuity equation explains that the quantity of fluid entering a system is equal to the quantity leaving it. This is based on the concept of mass conservation, which was highlighted by the respondent. Maintaining the overall mass balance of the system (which is necessary for the efficient operation of many fluids flow-related engineering applications) requires this understanding, as correctly explained by the respondent.

An alternative conception was, however, demonstrated by respondent 17 (R17) in responding to this item related to the continuity equation. The response from R17 was that:

> "Sir, *maybe the aim is to ensure that no fluid is wasted. It can suggest misuse if we have more coming in than leaving out. However, if more is going out than coming in, we may be losing out on important resources. Therefore, balancing it ensures that we are making use of the fluid wisely and not wasting any*." (Alternative conception from R17)

From the response of R17, the continuity equation, a concept that explains that the mass flow rate into and out of a system be equal, was not specifically mentioned in the respondent's answer. Rather, by emphasising resource conservation, fluid efficiency, and the consequences of resource loss or waste, the respondent provides a more comprehensive viewpoint along with ethical arguments for why preserving this equilibrium is crucial. This renders R17's response an alternative conception of the continuity equation.

Another alternative conception of the continuity equation was demonstrated by R18. In the respondent's answer was that:

> "*Oh sir, for me I think that the major reason for balancing the fluid entering and leaving the pipes is to keep them from becoming too full or empty. The pipes could burst from too much pressure if we let more in than out. In a similar vein, having dry pipes is risky if more fluid leaves than enters. Thus, maintaining order is essential to preventing disasters*." (Alternative conception from R18)

Given that R18's response highlighted the significance of balance in fluid flow from a different perspective, the respondent's explanation of the continuity equation can be viewed as an alternative conception. In the respondent's answer, the physical ramifications and safety of the pipes, as well as the possible dangers of excessive pressure or dry pipes, were highlighted rather than the mathematical and scientific aspects of the continuity equation.

Respondent 19 (R19) also demonstrated a null conception of the continuity equation in answering this item. The response of R19 was that:

> "*I do not think caring about the fluid balance is actually necessary. The role of the pipes is to transport water from one place to another. The pipes do not seem to mind if there are more things entering or leaving. After all, they are only pipes. I do not see the big concern as long as the water continues to flow*." (Null conception from R19)

R19's answer presented a null conception of the continuity equation by implying that the imbalance does not affect the pipes themselves and that the balance of fluid entering and exiting a pipe system is not required. This viewpoint ignores the continuity equation's basic ideas as well as the significance of maintaining mass conservation in fluid flow systems.

Respondent 20 (R20) also presented an answer which was also considered a null conception of the continuity equation. The respondent's answer was that:

> "*Sir, in my opinion, I am not sure how much fluid comes out of the pipes and how much fluid is going in. It should not really matter, as long as the system functions properly and does not cause issues. Maybe that is simply one of those details that engineers and scientists concentrate on, but in practice, it does not really matter*."
>
> (Null conception from R20)

The response from R20 shows doubt about the volume of fluid entering and exiting the pipes. This indicates a lack of knowledge or interest in the balance of fluid flow. The respondent's answer suggested that the fluid flow details are unimportant as long as the system seems to be operating as intended. Therefore, the respondent's statement presents a null conception of the continuity equation by downplaying the significance of preserving the balance of fluid entering and leaving a pipe system.

4.1.4. Bernoulli's principle

*Teacher: A fluid is flowing through a pipe. If the pipe narrows, what happens to the fluid's velocity and pressure according to Bernoulli's Principle***?**

Respondent 21 (R21) demonstrated a correct conception of Bernoulli's principle in answering this question. The respondent noted that:

> "Sir, *Bernoulli's Principle states that a fluid's velocity will increase as a pipe narrows. This occurs because the fluid must flow over a smaller area when the cross-sectional area drops, therefore it must*

accelerate to maintain the flow rate. Also, the pressure decreases because the fluid moving more quickly has more kinetic energy than potential energy, which is caused by pressure. So, in a narrowing pipe, pressure decreases and velocity increases." (Correct conception from R21)

In regards to fluid flow in a narrowing pipe, R21's comment illustrates a correct conception of Bernoulli's Principle, which states that a fluid's potential energy or pressure will drop as its speed increases. In line with the ideas presented by Bernoulli's principle, the respondent described how the fluid's velocity increases as a result of mass conservation and how pressure falls as a result of potential energy being converted to kinetic energy.

In providing an answer to this item, respondent 22 (R22) demonstrated an alternative conception of Bernoulli's principle. The response of R22 was that:

"*I think that when the pipe narrows, the fluid's velocity will likely decrease because there will be less space for it to pass through, causing the speed to slow down. Also, I think that the pressure will likely rise since the fluid will be forced into a smaller space, making it more difficult for it to go forward*." (Alternative conception from R22)

When it comes to fluid flow in a narrower pipe, the R22's statement offers a different, but false concept of Bernoulli's Principle. The respondent noted that, in direct opposition to the ideas presented by Bernoulli's Principle, the fluid's velocity decreases and its pressure increases. This renders R22's prior knowledge an alternative conception of Bernoulli's principle.

A Similar alternative conception of Bernoulli's principle was demonstrated by respondent 23 (R23) when providing an answer to this item. The response of the respondent to the item was that:

> "Sir, *I think that the fluid's velocity remains constant if the pipe narrows. The fluid may become more compressed and pressured as a result of being forced into a smaller area, which could cause the pressure to rise*." (Alternative conception from R23)

From the answer given by R23, the respondent thinks that the velocity stays constant and the pressure increases, rather than realising that a narrowing conduit causes a fluid to flow more quickly and at a lower pressure, as Bernoulli's principle suggests.

In another response, respondent 24 (R24) showed a null conception of Bernoulli's principle, as illustrated in the following narration:

> "*I do not think that the pipe narrowing causes no major changes. The fluid's pressure and velocity remain constant since the form of the pipe is irrelevant*." (Null conception from R24)

Respondent 25 (R25) also demonstrated a null conception of Bernoulli's principle, which was similar to R24 when providing an answer to this item. The prior conception of R25 which was deemed a null conception was that:

> "*Sir, I think the narrowing of the pipe should not affect the fluid's pressure and velocity, but I am not sure what occurs in that situation. Maybe, it just continues in the same direction*." (Null conception from R25)

In a similar fashion, respondent 26 (R26) stated that:

> "*If the pipe narrows, I believe the fluid's pressure and velocity stay the same, although I am not sure about Bernoulli's Principle. Maybe, it has no impact on them*." (Null conception from R26)

In reference to fluid flow in a narrowing conduit, the explanations from R24, R25 and R26 were all deemed null conceptions of Bernoulli's Principle. Contrary to the velocity-pressure relationship described by Bernoulli's Principle and the conservation of energy principle, the respondents implied that the form of the pipe has no effect on the fluid's velocity or pressure.

4.2. Research question 2

***Research Question 2: To what extent does the integration of multimedia into cognitive load theory enhance SHS students' conceptual change in fluid mechanics*?**

The extent to which the integration of multimedia into cognitive load theory enhances SHS students' conceptual change in fluid mechanics was determined by comparing the percentage of participants in each category of conception before and after the intervention. Table 13 presents the descriptive statistics such as frequencies and percentages on students' responses to the FMCT items after the intervention.

Table 14: Descriptive Statistics Students' Conceptions on Fluid Mechanics after Intervention

Concept	Item	Students' Conceptions					
		CC		AC		NC	
		F	%	F	%	F	%
Pascal's Principle	1	22	48.89%	13	28.89%	10	22.22%
	2	23	51.11%	12	26.67%	10	22.22%
	3	20	44.44%	13	28.89%	12	26.67%
	Average %		**48.15%**		**28.15%**		**23.70%**
Archimedes' Principle	4	19	42.22%	15	33.33%	11	24.44%
	5	24	53.33%	11	24.44%	10	22.22%
	6	23	51.11%	12	26.67%	10	22.22%
	Average %		**48.89%**		**28.15%**		**22.96%**
Continuity Equation	7	25	55.56%	12	26.67%	8	17.78%
	8	26	57.78%	10	22.22%	9	20.00%
	9	26	57.78%	11	24.44%	8	17.78%
	Average %		**57.04%**		**24.44%**		**18.52%**
Bernoulli's Principle	10	31	68.89%	9	20.00%	5	11.11%
	11	22	48.89%	13	28.89%	10	22.22%
	12	26	57.78%	11	24.44%	8	17.78%
	Average %		**58.52%**		**24.44%**		**17.04%**
	Overall average %		**53.15%**		**26.30%**		**20.56%**

Table 14 Descriptive Statistics of Prior Conceptions of Students on Fluid Mechanics after Intervention

Note:

- *CC = Correct Conception (students with an accurate understanding of the concept).*
- *AC = Alternative Conception (students with misconceptions or alternative, non-scientific views).*

- *NC = Null Conception (students without prior understanding or knowledge of the concept).*
- *F = Frequency (the number of students in each category).*

As shown in Table 14, higher percentages of students' demonstrated correct conceptions (CC) on each fluid mechanics concept, while low percentages of students' demonstrated alternative conceptions (AC) and null conceptions (NC). This resulted in higher overall percentages of students (53.15%) demonstrating correct conceptions (CC), while low percentages of students demonstrated alternative conceptions (AC), with an overall average participant percentage of 26.30%, and null conceptions (NC), also with an overall average participant percentage of 20.56%, on fluid mechanics in general.

In terms of each fluid mechanics concept, Table 13 reveals that after the intervention, the highest percentage of participants who demonstrated correct conception (CC) was observed in "Bernoulli's Principle" with an average participant percentage of 58.52%, while the lowest percentage of participants who demonstrated correct conception (CC) was observed in "Pascal's Principle" with an average participant percentage of 48.15%. Furthermore, "Pascal's Principle" and "Archimedes' Principle" recorded the highest average percentage of participants (28.15%) where students demonstrated alternative conceptions (AC), while the lower average percentage of participants (24.44%) demonstrated alternative conceptions (AC) on "Continuity Equation" and "Bernoulli's Principle". Within the null conception (NC) category the highest percentage of participants was observed in "Pascal's Principle" with an average participant percentage of 23.70% while the least percentage of participants who demonstrated null conception was observed in "Bernoulli's Principle" with an average participant percentage of 17.04%.

To determine the extent to which the integration of multimedia into cognitive load theory enhances students' conceptual change in fluid mechanics, the results before and after the intervention were compared. Figure 10 compares the overall average participant percentage in each category of conception before and after the intervention.

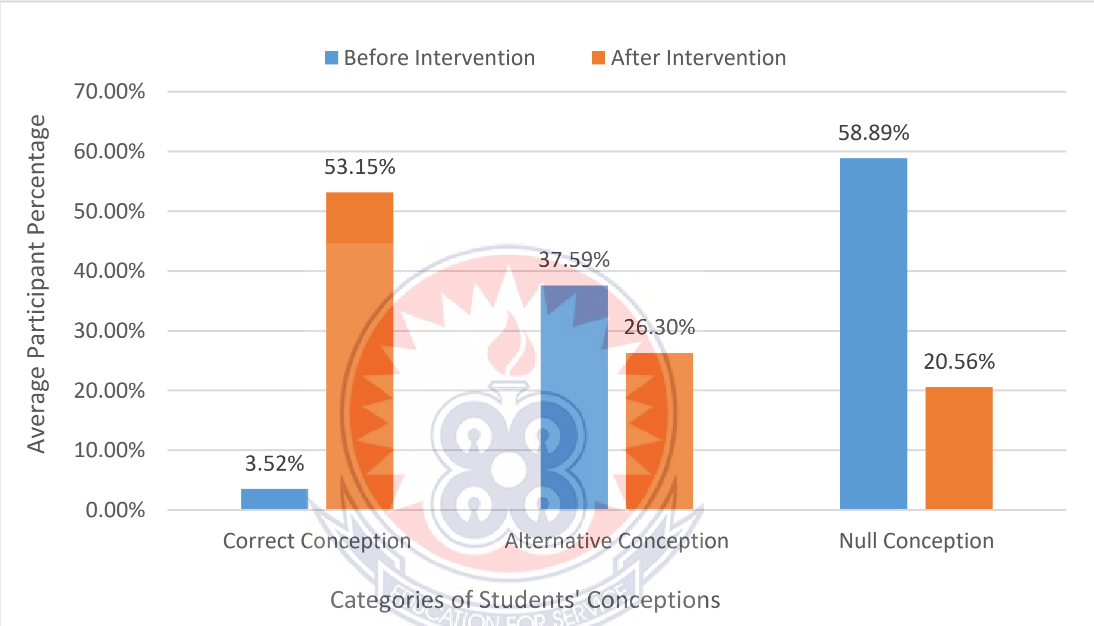


Figure 10: Graphical Representation of Students' Conceptions in Fluid Mechanics before and after Intervention

An inspection of Figure 10 reveals that there was a drastic increase in the average percentage of participants who demonstrated correct conceptions (CC) on fluid mechanics after the intervention from 3.52% to 53.15%, with a percentage difference of 49.63%. Within the alternative conceptions (AC) category, there was also a decrease in average participant percentage from 37.59% to 26.30%, with a percentage difference of 11.29%. Similarly, the null conception (NC) category also saw a drastic decrease in average participant percentage from 58.89% to 20.56%.

4.3. Results for research question 3

***Research Question 3: What is the effect of integration of Multimedia into Cognitive Load Theory on students' attitude towards the study of fluid mechanics*?**

The results of students' attitudes towards the study of Fluid Mechanics before the intervention are presented in Table 15.

Table 15: Students' Attitude towards the Study of Fluid Mechanics (ATFM) before Intervention

Dimension	ITEM	N	Mean	SD	Interpretation
Understanding Fluid Mechanics (UFM)	UFM1	45	2.33	.768	Negative Attitude
	UFM 2	45	2.11	.714	Negative Attitude
	UFM 3	45	2.00	.603	Negative Attitude
	UFM 4	45	2.00	1.044	Negative Attitude
	UFM	**45**	**2.11**	**.504**	**Negative Attitude**
Importance of Fluid Mechanics (IOFM)	IOFM1	45	1.84	.767	Negative Attitude
	IOFM 2	45	2.16	.638	Negative Attitude
	IOFM 3	45	2.04	.737	Negative Attitude
	IOFM 4	45	2.27	.580	Negative Attitude
	IOFM	**45**	**2.08**	**.538**	**Negative Attitude**
Further Studies in Fluid Mechanics (FSIFM)	FSIFM1	45	1.58	.543	Negative Attitude
	FSIFM 2	45	1.89	.611	Negative Attitude
	FSIFM 3	45	1.80	.625	Negative Attitude
	FSIFM 4	45	1.67	.674	Negative Attitude
	FSIFM 5	45	2.02	.657	Negative Attitude
	FSIFM	**45**	**1.79**	**.381**	**Negative Attitude**
Overall Attitude Towards Fluid Mechanics (ATFM)	**ATFM**	**45**	**1.98**	**.689**	**Negative Attitude**

As seen from Table 15, the mean scores of all the items ranged from 1.67 to 2.33, indicating that students expressed negative attitudes on all the items on the PSAQ which measured students' attitudes towards the study of Fluid Mechanics (ATFM) before the intervention. From Table 15, the overall mean score of the items was 1.98 (SD=0.689). Thus, students generally had negative attitudes towards the teaching and learning of Fluid Mechanics before the intervention. Again, the analysis presented in Table 15 revealed that, students expressed negative attitude on all the three dimensions that measured students' attitude toward physics, with "Further Studies in Fluid Mechanics (FSIFM)" being the dimension with the least mean score (mean=1.79, SD=0.381), while "Understanding Fluid Mechanics (UFM)" dimension had the highest mean score (mean=2.11, SD=0.504).

Table 16 also presents descriptive statistics of students' responses from the PSAQ after the intervention.

Table 16: Students' Attitude towards Fluid Mechanics (ATFM) After Intervention

Dimension	ITEM	N	Mean	SD	Interpretation
Understanding Fluid Mechanics (UFM)	UFM 1	45	3.16	.903	Positive Attitude
	UFM 2	45	3.36	.570	Positive Attitude
	UFM 3	45	3.27	.863	Positive Attitude
	UFM 4	45	3.29	.589	Positive Attitude
	UFM	**45**	**3.27**	**.731**	**Positive Attitude**
Importance of Fluid Mechanics (IOFM)	IOFM 1	45	3.42	.657	Positive Attitude

	IOFM 2	45	3.38	.716	Positive Attitude
	IOFM 3	45	3.27	.688	Positive Attitude
	IOFM 4	45	3.42	.583	Positive Attitude
	IOFM	**45**	**3.37**	**.661**	**Positive Attitude**
Further Studies in Fluid Mechanics (FSIFM)	FSIFM 1	45	3.33	.543	Positive Attitude
	FSIFM 2	45	3.49	.503	Positive Attitude
	FSIFM 3	45	3.52	.523	Positive Attitude
	FSIFM 4	45	3.46	.546	Positive Attitude
	FSIFM 5	45	3.64	.484	Positive Attitude
	FSIFM	**45**	**3.49**	**.519**	**Positive Attitude**
Overall Attitude Towards Fluid Mechanics (ATFM)	**ATFM**	**45**	**3.39**	**0.628**	**Positive Attitude**

The results presented in Table 16 shows that the mean scores of all the items which measured students' attitude towards fluid mechanics ranged from 3.16 to 3.64. This indicates that students generally expressed positive attitude on all the items that measured their attitudes towards fluid mechanics after the intervention, with the overall mean score of 3.36 (SD=0.628). Table 15 indicates that, the dimension with the highest mean attitude score after the intervention was "Further Studies in Fluid Mechanics" (mean=3.49, SD=0.519), with "Understanding Fluid Mechanics" having the least attitudinal mean score after the intervention (mean=3.27, SD=0.731).

4.4. Discussion of Results

This section discusses the results presented in this chapter. The results are discussed based on the research questions.

4.4.1. Discussion of results for research question 1

Researchers have suggested that fluid mechanics involves concepts that are frequently confusing and abstract (Koto & Ilhami, 2023; Suárez et al., 2017; Vaidya, 2020), challenging students' preconceived conceptions (Schäfle & Kautz, 2021), which might have explained why higher percentages of students in this study demonstrated alternative conceptions (AC) and null conceptions (NC) in the subject. For example, phenomena such as viscosity, buoyancy, and fluid movement may defy common sense (Suárez et al., 2017), causing students to form alternate, logical-sounding but factually incorrect conceptions. These misconceptions are common among students because they might arise from real-world events or a lack of understanding (Bensley & Lilienfeld, 2017).

Second, traditional teaching strategies that place more emphasis on memory and rote learning than conceptual understanding are frequently used in the teaching and learning of fluid mechanics (Vaidya, 2020). Because of this, students may turn to flimsy methods to get through difficult subjects, which can result in the development of null and alternative conceptions (Kurniawati & Ermawati, 2020) in cases where there is no coherent conceptual framework at all (Brown, et al., 2017; Eysink & Schildkamp, 2021). Therefore, students may find it difficult to fully understand the foundational concepts of fluid mechanics if they do not have enough opportunities for active involvement, experimentation, and conceptual development.

Furthermore, (Brown, et al., 2017; Eysink & Schildkamp, 2021) highlighted that the absence of relevant contexts and real-world connections in the teaching materials might lead to the persistence of misconceptions in fluid mechanics. This means that students may turn to oversimplified or inaccurate explanations that fit better with their pre-existing mental models as highlighted by Piaget (1976), when they are unable to grasp how fluid mechanics principles apply to other scientific fields or to their everyday lives. Insufficient real-world applications and a lack of genuine problem-solving opportunities could increase misunderstandings and impede students' ability to acquire accurate concepts (Pekel & Hasenekoğlu, 2020).

Compared to previous studies, the findings of Suarez et al. (2017), Saputra et al. (2019), and Brown et al. (2017) were supported by this finding. For example, Suarez et al. (2017) found that students wrongfully applied Bernoulli's principle during interviews. Saputra et al. (2019) also revealed that 70.8% of students had alternative conceptions on Pascal's principle, 67.6% on Archimedes' principle, and 55.7% of hydrostatic pressure. Brown et al. (2017) found that engineering students struggled to predict the change in pressure of a fluid flowing through a pipe. Also, students thought that when water travels from a larger to a smaller pipe the pressure increases due to more water being ''squeezed'' or ''compressed'' in the smaller pipe section (Brown et al., 2017).

4.4.2. Discussion of results of research question 2

Cognitive load theory posits that learners have limited cognitive resources available for processing information, and effective instructional design should manage these loads to optimise learning (Sweller et al., 2011). Multimedia, which combines multiple forms of media such as text, images, animations, and videos, can aid in managing cognitive load by presenting information in multiple modalities simultaneously, which can facilitate deeper understanding and conceptual change among SHS students studying fluid mechanics (Santyasa et al., 2018).

In this study, multimedia supported SHS students' conceptual change by providing multiple representations of abstract concepts in fluid mechanics. For example, it was thought that complex phenomena like fluid flow or buoyancy could be challenging to grasp through text alone (Kurniawati & Ermawati, 2020; Vaidya, 2020). However, according to Rudolph (2017),by incorporating visualisations, animations, and simulations, multimedia can offer dynamic representations of these concepts, allowing students to observe fluid behaviour in real-time and interact with virtual environments. This multisensory engagement might have helped students build mental models of fluid mechanics principles more effectively, leading to conceptual change as they integrate new information with their existing knowledge frameworks.

Secondly, multimedia can cater to diverse learning styles and preferences among SHS students (Mutlu-Bayraktar et al., 2019). Not all learners thrive with traditional text-based instruction (Darsih, 2018); some may benefit more from visual or auditory stimuli (Gilakjani, 2012). By providing a variety of media formats, the multimedia employed in this study accommodated different learning styles, allowing students to engage with content in ways that suit their individual preferences. For instance, visual learners might have benefited from watching animations demonstrating Bernoulli's principle in action, while auditory learners preferred listening to narrated explanations of Pascal's principle. This personalised approach to instruction can increase student engagement and motivation (Ceken & Taskin, 2022), leading to more profound conceptual change in fluid mechanics.

Additionally, Ceken and Taskin (2022) highlighted the significance of multimedia to provide contextualised learning experiences that can bridge the gap between abstract theory and real-world applications in fluid mechanics. For example, incorporating case studies and engineering examples might have helped students understand the practical relevance of fluid mechanics principles in various fields such as aerospace engineering, civil engineering, and biomedical engineering. According to Noetel et al. (2022), by contextualising abstract concepts within familiar or meaningful contexts, multimedia makes learning more relevant and accessible to students, motivating them to invest cognitive effort in conceptual change. Furthermore, multimedia can support collaborative learning experiences, where students work together to analyse data, solve problems, and construct explanations collaboratively (Kirschner et al., 2018).By fostering active engagement and social interaction, multimedia, according to Sweller et al.(2011), can enhance the cognitive processes involved in conceptual change, such as reflection, critical thinking, and metacognition.

The finding of research question 2 supports the findings of previous researches including that of Hakim et al. (2018), Hamidah et al. (2012), and Nyirahabimana et al. (2024) who also found the use of multimedia to enhance students' conceptual understanding in physics. Though this study's finding corroborates with previous findings, a different analytical approach was employed compared to the previous studies, in determining the effect of integrating multimedia as a cognitive load reduction strategy to enhance conceptual change in fluid mechanics. Moreover, previous studies have focused on lenses, heat transfer and quantum physics with apparently little or no attention turned to fluid mechanics with respect to conceptual change. Thus, the finding of research question 2 extends previous research by helping to understand the effectiveness of multimedia in the teaching and learning of physics.

4.4.3. Discussion of results of research question 3

The positive attitude recorded after the intervention reveals that integrating multimedia into cognitive load theory might have enhanced students' attitudes toward the teaching and learning of fluid mechanics by making the learning experience more enjoyable, accessible, and effective. According to (Abdulrahaman, et al., 2020), by leveraging multimedia tools to accommodate diverse learning preferences, optimise cognitive resources, foster deeper understanding, and promote engagement, instructors can create an enriching learning environment that inspires curiosity and enthusiasm for fluid mechanics. As students experience success and satisfaction with multimedia-enhanced instruction, their attitudes toward the subject will likely become more positive (Akinbadewa, 2020), leading to increased motivation, retention, and proficiency in fluid mechanics concepts.

This finding is consistent with the findings of Ayasrah et al.(2024), who found the attitudes of SHS students enhanced after the use of computer simulations in the teaching and learning of physics. Also, this finding agrees with the finding of Akinbadewa and Sofowora (2020) who revealed that the use of multimedia instructional materials in secondary biology classrooms improved student engagement and fostered a positive attitude toward learning.

4.5. Chapter Summary

Chapter four evaluates the effectiveness of integrating multimedia into cognitive load theory in teaching fluid mechanics by analysing students' conceptual understanding and attitudes. The chapter begins with a needs assessment that identifies a range of correct, alternative, and null conceptions among students, emphasising the necessity for targeted instructional strategies. Quantitative and qualitative data analysis reveals significant improvements in students' understanding of fluid mechanics concepts post-intervention, indicating the success of the multimedia-integrated approach. The data also show a positive shift in students' attitudes towards the subject, with increased interest and motivation following the intervention. The findings are discussed in the context of existing literature, highlighting the importance of addressing preconceptions and the benefits of multimedia in reducing cognitive load and enhancing learning.

In conclusion, this chapter demonstrates the efficacy of multimedia-integrated instruction in improving both conceptual understanding and attitudes towards fluid mechanics.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0. Overview

In this chapter, the summaries of the findings of the study have been captured. Conclusions, recommendations, and suggestions were noted based on the findings for further research work.

5.1. Summary of Findings

This study aimed to determine the impact of integrating multimedia into Cognitive Load Theory (CLT) on conceptual change and attitude of SHS physics students in the study of learning fluid mechanics in the West Akim Municipality in the Eastern Region of Ghana. Using the explanatory sequential variant of the mixed method research design 45 SHS physics students from Asamankese SHS were used. Students' prior conceptions on fluid mechanics were first determined after which an intervention was designed using multimedia into cognitive load theory to assess the extent to which students' conceptual change was enhanced, as well as its effect on students' attitudes towards the teaching and learning of fluid mechanics.

The findings of this study revealed that a higher percentage of students demonstrated null conception (NC) and alternative conception (AC), with an overall average participant percentage while very low percentage of students demonstrated correct conception (CC) on fluid mechanics. To have a deeper insight into students' prior conceptions on fluid mechanics, qualitative analysis (content analysis) was conducted on students' responses through semi-structured interview. Some alternative conceptions put forth by students were that: "pressure exerted on a fluid decrease due to gravity", "the major reason for balancing the fluid entering and leaving the pipes is to keep them from becoming too full or empty", "fluid's velocity decreases and its pressure increases when it comes to fluid flow in a narrower pipe", as well as "maintaining the same amount of fluid entering and leaving a pipe system is to ensure that no fluid is wasted." Additionally, some null conceptions of students were that: "pressure changes instantly and throughout a filled tube when one end is pushed", "the fluid level does not rise at all when an object is submerged in a fluid", "the balance of fluid entering and exiting a pipe system is not required regarding the continuity equation", and "a fluid's pressure and velocity remain constant in a narrow pipe."

Also, it was found that after the intervention, there was an increase of participants in the correct conception (CC) category, and a drastic decrease of participants in the null conception (NC) category after the intervention. Furthermore, results from Physics Students' Attitude Questionnaire (PSAQ) before and after the intervention revealed that before the intervention, students' demonstrated negative attitude while after the intervention, students demonstrated positive attitude towards the teaching and learning of fluid mechanics. The difference in mean attitude scores before and after the intervention provided a large effect according to Cohen's d interpretation.

5.2. Conclusion

From the findings of this study, it can therefore be concluded that majority of SHS physics students within the West Akim Municipality in the Eastern Region of Ghana possess "alternative conceptions", and "null conceptions" and "no understanding" while very few students possess "correct conception" of fluid mechanics concepts. Moreover, it can be concluded that the integration of multimedia into cognitive load can be effective in enhancing the conceptual change of SHS physics students in fluid mechanics within the West Akim Municipality to a possibly large extent. Also, the integration of multimedia into cognitive load has a positive effect on SHS physics students' attitudes towards the teaching and learning of fluid mechanics within the West Akim Municipality.

5.3. Recommendations

The following recommendations were therefore made from the findings of this study. It is recommended that:

1. SHS physics teachers at Asamankese Senior High should focus on identifying the prior conceptions of SHS physics students in the teaching and learning of fluid mechanics.
2. SHS physics teachers at Asamankese SHS should consider the integrating multimedia into cognitive load theory in facilitating the conceptual understanding of physics students in the study of fluid mechanics.
3. To enhance students' attitude towards the teaching and learning of fluid mechanics within the Asamankese Senior High School, teachers can consider integrating multimedia into cognitive load theory.

5.4. Suggestions for Further Research

The following suggestions were therefore made for further research.

1. Further studies should be conducted on the effect multimedia on students' understanding in other fluid mechanics concepts.
2. The use of control group should be considered in subsequent studies in an attempt to control for other extraneous variables which might have influenced the results of the study.
3. The use of different diagnostic tests should also be considered in identifying students' prior conceptions in fluid mechanics in subsequent studies.

4. Also, the gender perspective of determining SHS physics students' prior conceptions and facilitating their conceptual change using multimedia should be considered.

REFERENCES

Abdulrahaman, M. D., Faruk, N., Oloyede, A. A., Surajudeen-Bakinde, N. T., Olawoyin, L. A., Mejabi, O. V., . . . Azeez, A. I. (2020, November 2). Multimedia tools in the teaching and learning processes: A systematic review. *National Library of Medicine, 6*(11). doi:doi: 10.1016/j.heliyon.2020.e05312

Abdurrahman, A., Setyaningsih, C. A., & Jalmo, T. (2019). Implementing multiple representation-based worksheet to develop critical thinking skills. *Journal of Turkish Science Education, 16*(1), 138 - 155.

Akhtar, S., Shah, S., Rafiq, M., & Khan, A. (2016). Research design and statistical methods in Pakistan Journal of Medical Sciences (PJMS). *National Library of Medicine, 32*(1), 151 - 154.

Akinbadewa, B. O. (2020). The effect of multimedia instructional packages on students' academic achievement in Biology. *International Online Journal of Education and Teaching (IOJET), 7*(4), 1266 - 1281. Retrieved from http://iojet.org/index.php/IOJET/article/view/880

Aksit, F. (2011). Teaching the topic of atmospheric pressure by the experimental method. *New World Academy's E-Journal*, 2210 - 2228.

Almanasreh, E., Moles, R., & & Chen, T. (2019). Evaluation of methods used for estimating content validity. *Research in Social and Administrative Pharmacy, 15*(2), 214 - 221.

Aloraini, S. (2011). The impact of using multimedia on students' academic achievement in the College of Education at King Saud University. *Journal of King Saud University - Languages and Translation, 24*(2), 75 - 82.

Andreas, K., Tsiatsos, T., Terzidou, T., & Pomportsis, A. (2010). Fostering collaborative learning in Second Life: Metaphors and affordances. *Computers & Education xxx* , 1 - 13.

Anmarkrud, Ø., Andresen, A., & Bråten, I. (2019). Cognitive Load and Working Memory in Multimedia Learning: Conceptual and Measurement Issues. *Educational Psychologist, 54*(2), 1 - 23.

Appiah-Twumasi, E., Agyemang, C., Ameyaw, Y., & Anderson, I. (2022). Development and Validation of Questionnaire for Physics Learning Self - Efficacy among Ghanaian Senior High Schools. *East African Journal of Management and Business Studies, 3*(1), 8 - 18.

Appiah-Twumasi, M., Tetteh, B. T., & & Damba, O. (2020). Effects of technology dissemination approaches on agricultural technology uptake and utilization in Northern Ghana. *Science Direct :Technology in Society*, 62.

Ashenafi, S. L. (2022). *The use of multiple representations approach in enhancing thefluid mechanics in undergraduate physics class.* Retrieved Febuary 15, 2023, from https://uir.unisa.ac.za/handle/10500/29785

Aşıksoy, G., & Islek, D. (2017). The impact of the virtual laboratory on students' attitudes in a general Physics laboratory. *International Journal of Online Engineering, 13*(4).

Asma, H., & Dallel, S. (2020). Cognitive Load Theory and its Relation to Instructional Design: Perspectives of Some Algerian University Teachers of English. *Arab World English Journal, 11*(4), 110 - 127.

Ayasrah, F. T., Alarabi, K., K al mansouri, M., & Fattah, H. A. (2024, January). Enhancing secondary school students' attitudes toward physics by using computer simulations. *International Journal of Data and Network Science, 8*(1), 369 - 380. doi:DOI:10.5267/j.ijdns.2023.9.017

Ayre, C., & Scally, A. J. (2013). Critical Values for Lawshe's Content Validity Ratio : Revisiting the Original Methods of Calculation. *Measurement and Evaluation in Counseling and Development*, *47*(1), pp. 79 - 86.

Ayres, P. (2006). Cognitive load theory and instructional design:Recent developments. *Learning and instruction, 16*(4), 389 - 393. doi:https://dio.org/10.1016/jj.learninginstruct,2006,07.009

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Congnitive Science, 4*(11), 417 - 423.

Badu, A. (2018). Multimedia learning and science education in Ghana. *Journal of Education and Practice, 9*(22), 45 - 52.

Bakri, F., & Mulyati, D. (2018). Design of multiple representation e-learning resources for the basic Physics course using a contextual approach. *Journal of Physics :Conference Series, 1013*(1).

Baroth, S. (2021). *Bernoulli's Equation.* Retrieved from Geeks for Geeks: https://www.geeksforgeeks.org/bernoullis-equation

Barton, M. L., & Heidema, C. (2022). *Teaching reading in Mathematics.* Aurora, CO:Mid- continent Research for Education and Learning.

Benjamin, B. R. (2015). *Developing and accessing research-based tools for teachingquantum mechanics and thermodynamics*. Retrieved June 15, 2023, from core.ac.uk: https://core.ac.uk/download/pdf/33562983.pdf

Bensley, D., & Lilienfeld, S. (2017, August 9). Psychological Misconceptions: Recent Scientific Advances and Unresolved Issues. *Journal indexing and metrics*. doi:https://doi.org/10.1177/0963721417699026

Bernhard, J. (2010). Insightful learning in the laboratory some experiences from 10 years of designing and using conceptual labs. *European Journal of Engineering Education, 35*, 271 – 287.

Bernhard, J. (2010). Insightful learning in the laboratory: some experiences from 10 years of designing and using conceptual labs. *European Journal of Engineering Education, 35*, 271 - 287.

Bicer, A. (2021). Multiple representations and mathematical creativity. *Thinking Skills and Creativity*, 42. Retrieved from Thinking Skills and Creativity.

Boakye, K. (2020). Implementing cognitive load theory in Ghanaian senior high school STEM classrooms. *African Journal of Educationa Studies in Mathematics and Sciences, 16*(1), 23 - 32.

Boateng, E. K. (2024, June 26). Integrating Multimedia into Education: A Senior High School Perspective. *ResearchGate*. Retrieved from https://www.researchgate.net/publication/381698598

Botha, M. (2012). Academiv, Activist, or advocate? angly, Entangled and Emerging: A Critical Reflection on Autism Knowledge Production. (A. D. Surtees, Ed.) *Frontiers in psychology, 12*, 1 - 12.

Brahmia, S. W., Olsho, A., Smith, T. I., & Boudreaux, A. (2020). Framework for the natures of negativity in introductory Physics. *Physical Review Physics Education Research, 16*(1).

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). How people learn: Brain mind, experiencem, and school. *National Academies Press*.

Brown, Q., L.C.S.W, Sarvet, A., Shmulewitz, D., Martins, S., Wall, M., & Hasin, D. (2017, January 10). Trends in marijuana use among pregnant and non-pregnant. *HHS Public Access, 317*(2), 207 – 209. doi:doi:10.1001/jama.2016.17383.

Casteel, A., & & Bridier, N. (2021). Describing Pop[ration and Samples in Doctoral Student research. *International Journal of Doctoral Studies (IJDS.org)*, 341-362.

Çeken, R., & Taşkın, H. (2022). Analyzing the relationship between organizational commitment and job satisfaction in the tourism industry. *Journal of Tourism Management Research*, 18 - 25. doi:https://doi.org/10.18488/jou rnal.31.2022.91.18.25

Charlee, I., & Reinadith, P. (2022). *Understanding Working Memory*. Retrieved May 16, 2023, from Study.com: m: https:study.com/acadamy/course/introduction - to -psychology - tutoring - solution.html

Chen, Z., & Gladding, G. (2014). How to make a good animation: A groundedcognition model of how visual representation design affects the construction of abstract Physics knowledge. *Physical Review Special Topics-Physics Education Research, 10*(1).

Chi, M. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self - explanations: How students study and use examples in learning to solve problems. *cognitive Science, 13*(2), 145 - 182.

Chien-Heng, L. (2018). An exploration of the quantitative simulation of schema formation - A case of early childhood chinese literacy learning. *European Journal of Education Studies, 5*(5), 80 - 94.

Choy , M. W., & Yeung , A. S. (2022). Cognitive and affective academic self-concepts: Which predicts. *Vocational Training Council Insttutiona Repository*, 1 - 10.

Christensen, W. M., & Thompson, J. R. (2012). Investigating graphicalrepresentations of slope and derivative without a Physics context. *Physical Review Special Topics-Physics Education Research, 8*(2).

Clayton, P., & Ash, S. (2009, January). Generating, Deepening, and Documenting Learning: The Power of Critical Reflection in Applied Learning. doi:DOI:10.57186/jalhe_2009_v1a2p25-48

Clement , J. (1982). Student's preconceptions in introuctory mechannics. *American Journal of Physics, 50*(1), 66 - 71.

Clement, J. (2000). Model-based reasoning in science and mathematics In Model-Based Reasoning: Science, Technology, Values. *New York: Springer,* 83 - 97.

Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8Th ed.). U K: Routledge: Tyalor & Francis Group.

Coletta, V., & Steinert, J. (2020, February 6). Why normalized gain should continue to be used in analyzing preinstruction and postinstruction scores on concept inventories. *PHYSICAL REVIEW PHYSICS EDUCATION RESEARCH, 16*(010108), 1 - 7.

Cowan, N. (2014). Working Memory Underpins Cognitive Development, Learning,and Education. *National Library of Medicine- NLM, 26*(2), 197 - 223.

Creswell, J. W. (2014). Research Design: Qualitative, Quantitative and Mixed Methods Approaches. (4th, Ed.) *Open Asses*. Retrieved October 13, 2023, from https://www.scirp.org/(S(i43dyn45teexjx455qlt3d2q))/reference/ReferencesPapers.aspx?ReferenceID=1964849

Crouch, C. H., & Mazur, E. (2001). Peer Instruction : Ten years of experience and results. *American Journal of Physics, 69*(9), 970 - 977.

Crowe, C., Elger, D. F., Williams, B. C., & Roberson, J. A. (2009). *Engineering Fluid Mechanics.* (9th, Ed.) United States of America, USA: John Wiley & Sons, Inc.

Curriculum Research and Development Division (CRDD). (2010). *Teaching syllabus for physics.* Accra: Ministry of education.

Darsih, E. (2018). Learner-centered teaching: What makes it effective. *Indonesian EFL Journal, 4*(1), 33 - 42. doi:https://doi.org/10.25134/ieflj.v 4i1.796&#8203

Dawadi, S., Shrestha, S., & Giri, R. (2021). Mixed-Methods Research: A Discussion on its Types, Challenges, and Criticisms. *Journal of Practical Studies in Education, 2*(2), 25 - 36.

De Cock, M. (2012). Representation use and strategy choice in Physics problem - solving Physical. *Review Special Topics-Physics Education Research, 8*(1), 1 - 15.

De Jong, T. (2010). Cognitive Load Theory, educational research, and instructional design : Some food for thought. *Instructional Science, 38*(2), 105 - 134.

De Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. *Science, 340*(6130), 305 - 308. doi:https://doi.org/10.1126/science.1230579

DiSessa, A. A. (2006). A history of conceptual change research: Threads and threads. In *Handbook of Research on Science Education* (pp. 265 - 305). Mahwah, NJ: Lawrence Erlbaum Associates.

Distrik, I. W., Supardi, Z. I., & Jatmiko, B. (2012). The effects of multiple representation - based learning in improving concept understanding and problem - solving ability. *Journal of Physics: Conference Series, 1*, 012044.

Dixon, S. L., & Hall, C. (2013). *Fluid mechanics and thermodynamics of turbomachinery*. Butterworth: Heinemann.

Dominic, S., & Rachel, W. (2018). *Cognitive Load Theory and its application in the classroom*. Retrieved April 12, 2023, from Impact Part of my College: https://my.charted.college/

Duit, R. (1991). On the role of conceptual change in learning science. *International Journal of Science Education, 13*(3), 291 - 301.

Dwivedi, Y., Hughes, L., Baabdullah, A., Ribeiro-Navarrete, S., Giannakis, M., Al - Debei, M., & Dennehy, D. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management, 66*, 102542.

Ebohon, O., Ganiyu, S., & Ajayi, T. (2021). Understanding Research Paradigm in Social Sciences:A critique of Two Papers on Critical Success Factors for BIM Implementation. *Researchgate*, pp. 1 - 20. Retrieved October 6, 2023, from https://www.researchgate.net/publication/354528534

Eichenlaub, M., & Redish, E. F. (2019). Blending physical knowledge with mathematical form in Physics problem-solving. *Mathematics in Physics education*, 127 - 151.

Eichenlaub, M., & Redish, E. F. (2019). Blending physical knowledge with mathematical form in Physics problem-solving. *Mathematics in Physics education*, 127 - 151.

El - Hajj, B., & Budny, D. (2019). *Lessons learned from being a TA in a fluid mechanics course.* Retrieved from http://people.se.cmich.edu/yelam1k /asee/proceedings/2019/1/89.pdf

Elangovan, N., & Sundaravel, E. (2021). Method of preparing a document for survey instrument validation by experts. *National Library of Medicine*.

Elo, S., & Kyngas, H. (2008). *The qualitative content analysis process* (Vol. 62). Jornal of Nursing Management. doi:https://doi.org/10.1111/j.1365-2648.2007.04569.xCitations: 11,388

Elo, S., Kaariainen, M., Kanste, O., Polkki, T., Utriainen, K., & Kyngas, H. (2014, February 11). Qualitative Content Analysis: A Focus on Trustworthiness. *Sage Journal*. doi:https://doi.org/10.1177/2158244014522633

Euler, E., & Gregorcic, B. .. (2018). Discovering variation: learning Physics in a creative digital environment. *European Association for Research on Learning and Instruction (EARLI) Special Interest Group 9 (SIG9) Conference.* Birmingham: EARLI.

Eyisi, D. (2016). The Usefulness of Qualitative and Quantitative Approaches and Methods in Researching Problem-Solving Ability in Science Education Curriculum. *Journal of Education and Practice, 7*(15), 1 - 10.

Eysink, T., & Schildkamp, K. (2021, July 14). A conceptual framework for Assessment-Informed Differentiation (AID) in the classroom. *Journal of Educational Research, 63*(2), 261 - 278. doi:https://doi.org/10.1080/00131881.2021.1942118

Fiankofi, R. K. (2018). Multimedia Usage and Academic Performance of Students in Physics : the Case of Adisadel college, Cape coast, ghana. *University of Cape Coast Institutional Reporsitory*.

Fox , R. W., McDonald, A. T., & Priitchard , P. J. (2011). *Introduction to Fluid Mechanics* (8th ed.). John Wiley & Sons.

Franke, K., Chagas, A. M., Zhao, Z., Zimmermann, M. J., Bartel, P., Qiu, Y., & Euler, T. (2019). *An arbitrary-spectrum spatial visual stimulator for vision research.* Elife, 8.

Fraser, D., Allison, S., Coombes, H., Case, J., & Linder, C. (2006). Using variation to enhance learning in Engineering. *International Journal of Engineering, 22*(1), 102 - 108.

Fredlund, T., Airey, J., & Linder, C. (2015). Enhancing the possibilities for learning variation of disciplinary-relevant aspects in Physics representations. *European Journal of Physics*, 36. doi:36. doi:05500

Fuertes, G., Alfaro, M., Vargas, M., Gutierrez, S., Ternero, R., & Sabattin, J. (2020). Conceptual Framework for the Strategic Management t: A Literature Review - Descriptive. (K. Dincer, Ed.) *Journal of Engineering*, *21*, 1 - 16.

Fuqua, J. L., Wachs, F. L., Nissenson, P. M., Barrios, D. M., & Nguyen, C. (2021). Assessing the influence of an online video tutorial library on undergraduate mechanical Engineering students. *2021 ASEE Virtual Annual Conference Content Access.*

Gathercole, S., & Alloway, T. (2007). *Understanding working memory. A classroom guide. Harcourt Assessment*. Retrieved April 12, 2023, from WM -classroom - guide: https://www.mrc.cbu.cam.ac.uk/wp - content/uploads/2013/01/WM - classroom - guide-pdf

Gengel, Y. A., & Cimbala, J. M. (2010). *Fluid Mechaics : Fundamentals and Applications.* (2nd, Ed.) McGraw - Hill.

George, T. (2013). *Types of Interviews in Research : Guide & Examples*. Retrieved October 27, 2023, from Scribbr: https://www.scribbr.com/methodology/interviews-research/

Gestson, S. L., Lutz, B., Brown, S., Barner, M. S., Hurwitz, D., & Abadi, M. (2018). Developing an understanding of civil Engineering practitioner problem - solving rationale using multiple contextual representations. *ASEE annual conference & exposition.* Retrieved from https://par.nsf.gov/b iblio/10 124330

Geyer, M. A., & Kuske-Janßen, W. (2019). Mathematical representations in Physics lessons. In Cham (Ed.), *Mathematics in Physics education* (pp. 75 - 102). Cham: Springer.

Gilakjani, A. P. (2012). Visual, auditory, kinesthetic learning styles and their impacts on English language teaching. *Journal of Studies in Education, 2*(1), 104 - 113. doi:https://doi.org/10.5296/jse.v2i1.1007:citation[oaicite:10]{index

Goszewski, M., Moyer, A., Bazan, Z., & Wagner, D. (2013). Exploring student difficulties with pressure in a fluid. In AIP (Ed.), *AIP Conference Proceedings. 1513,* pp. 154 - 157. American Institute of Physics.

Gregorcic, B., & Bodin, M. (2017). Algodoo: A tool for encouraging creativity in Physics teaching and learning. *The Physics Teacher, 55* (1), 25 - 28.

Hake, R. R. (1998). Interactive - engagement verses traditional methods: A six - thousand - student surveyof mechanics test data for introductory physics courses. *american Journal of Physics, 66*(1), 64 - 74.

Hakim, L., Liliasari, L., & Priyono, A. (2018). The role of blended learning with quizizz application to improve learning outcomes. *Journal of Physics:*

Conference Series, 1013. doi:https://doi.org/10.1088/1742-6596/1013/1/012075:citation[oaicite:6]

Hamidah, S., Wahyudin, W., & Darhim, D. (2012). The effect of using Moodle in the learning of mathematics in high school. *Journal of Education and Learning, 6*(2), 65 - 72. doi:https://doi.org/10.11591/edulearn.v6i2.129:citation[oaic

Hartini, T. I., & Sinensis, A. R. (2019). The effectiveness of thermodynamic learning is based on multiple representations toward understanding the basic concepts of physical. *Journal of Physics, Conference. Series*, 1157.

Hattan, C., Alexander, P., & Lupo, S. M. (2022). Leveraging What Students Know to Make Sense of Texts: What the Research Says About Prior Knowledge Activation. *Review of Educational Research*, 1 - 46.

Hazari, Z., Sonnert, G., Sadler, P., & Shanahan, M. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching, 47*(8), 978 - 1003.

Heale, R., & Twycross, A. (2015). Validity and reliability in quantitative studies. *Evidence-Based Nursing, 18*(3), 66 - 67. doi:https://doi.org/10.1136/eb-2015-102129:citation[oaicite:3]{index=3}&#8203

Hellström, K., Diószegi, A., & Diaconu, L. (2017). A Broad Literature Review of Density Measurements of Cast Iron. *DiVA, 7*(5), 1 - 20.

Hewitt, P. G. (2002). *Conceptual Physics* (9th ed.). Addison - Wesley.

Hmelo- Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem - based and inquiry learnng : A response to Kirschner , Sweller , and Clark (2006). *Educational psychologist, 42*(2), 99 - 107.

Jewett, J. W., & & Serway, R. (2008). Physics for scientists and engineers with modern Physics. In J. Jewett, & R. Serway (Eds.), *Physics for scientists and engineers with modern Physics* (Vol. 1, p. 390).

Ji-Eun, L., & Sunghwan, H. (2022). Exploration of the Structure of a Word Problem Using Representations. *International Electronic Journal of Elementary Education, 14*(3), 269 - 281.

Jilcha, K. (2019). *Research design and methodology.* Cyberspace: Intech Open. doi:https://doi. org/10.5772/intechopen

Johanson, G., & Brooks, G. (2010). Initial Scale Development: Sample Size for Pilot Studies. *Educational and Psychological Measurement, 70*(3), 394 - 400.

Johnson, R., & Christensen, L. (2020). *Educational Research: Quantitative, Qualitative, and Mixed Approaches* (Vol. 7). Alabama: Sage.

Johnson, R., Onwuegbuzie, A. J., & Turner, L. (2007). Towards a Definition of a Mixed Method of Research. *Journal of Mixed Methods Research*, 112 - 133.

Jong, T. D. (2010). Cognitive load theory, educational research, and instructional design: some food for thought. *Springer Link*, 105 - 134.

Jorgensen, S., Arce-Trigatti, A., Sanders, J. R., & Arce, P. E. (2020). A focus on functional-based teams in the development of prototypes of innovative Technology: Observations from a QEP grant implementation at Tennessee. *American Society for Engineering Education*.

Joshua, M. A. (2017). Continuous assessment for improved teaching and learning: a critical review to inform policy and practice. *UNESCO International Bureau of Education* .

Kabigting, L. D. (2021). Computer Simulation on Teaching and Learning of Selected Topics in physics. *European Journal of Interactive Multimedia and Education, 2*(2), 2732 - 4362.

Kalyuga, S. (2009). Managing cognitive load in adaptive multimedia learning. *Information Science Publishing*.

Kamba, E., Getyengana, K., Mkwanazi, M., Ndlela, S., Mwale, M., & & Chimonyo, M. (2022). Factors infuencing the integration of indigenous and conventional knowledge of water security for livestock. *Tropical Animal Health and Production*, 1 - 9.

Karniadakis, G. E., Raissi, M., & Yazdani, A. (2020). Hidden fluid mechanics: Learning velocity and pressure fields from flow visualizations. *Science, 367*(6481), 1026 - 1030.

Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a Research Paradigm and Its Implications for Social Work Research. *Social Science, 8*(9), p. 255. doi:doi.org/10.3390/socsci8090255

Keane, T., Linden, T., Hernandez-Martinez, P., Molnar, A., & A, B. (2022). Digital technologies: students' expectations and experiences during their transition from high school to university. *Education and Information Technologies, 28*(1), 857 – 877.

Kharki, K. E., Berrada, K., & Burgos, D. (2021). Design and Implementation of a Virtual Laboratory for Physics Subjects in Moroccan Universities. *Sustainability, 13*(3711), 1 - 28.

Kim, S., & Soergel, D. (2005). Selecting and Measuring Task Characteristics as Independent variable. *Proceedings of the American Society for Information Science and Technology, 42*(1), 1 - 17.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2018). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist,discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75 - 86.

Kivunja, C., & Kuyini, A. (2017). Understanding and Applying Research Paradigms in Educational Contexts. *International Journal of Higher Education, 6*(5), pp. 26 - 41.

Koto, I., & Ilhami, D. (2023, March). High-School Students' Conceptual Understanding of Fluid Dynamics Following Online Learning During the Coronavirus Pandemics. 117 - 125. doi:DOI:10.2991/978-2-38476-012-1_16

Kriek, J., & Coetzee, A. (2021). Interaction between teacher and student beliefs when using different Technology tools in a tertiary context. *International Journal of Technology Enhanced Learning, 13*(2), 121 - 138.

Kuo, B. C., Stokes, M. G., & Nobre, A. C. (2012). Attention modulates the maintenance of representations in visual short-term memory. *Journal of Cognitive Neuro Science, 24*(1), 51 - 60.

Kuo, E. (2013). How students blend conceptual and formal mathematical reasoning in solving Physics problems. *Science Education, 97*, 32 - 57.

Kural, M., & Kocakülah, M. S. (2016). Teaching for hot Conceptual Change: towardsa New Model, beyond the Cold and Warm ones. *European Journal of Education Studies, 16*(8), 1 - 34.

Kurniawati, D., & Ermawati, F. (2020). Analysis Students' Conception Using Four-Tier Diagnostic Test for Dynamic Fluid Concepts. *Journal of Physics: Conference Series*, 1 - 7. doi:doi:10.1088/1742-6596/1491/1/012012

Lee, S., Amos, B., & Gragoudas, S. L. (2006). Curriculum Augmentation and Adaptation Strategies to Promote Access to the General Curriculum forStudents withIntellectual and Developmental Disabilities. *Education and Training in Developmental Disabilities, 41*(3), 199 – 212.

Lia, Y., Cycin, R., & Nandang, M. (2018). Problem Solving Skills on Direct Current Electricity through InquiryBased Learning with PhET Simulations. *International Journal of Instruction, 11*(4), 123 - 138.

Linder, M. C. (2013). Biochemistry of copper. *Springer Science & Business Media.*, 10.

Lo, M. L. (2012). Variation theory and the improvement of teaching and learning. *Göteborg: Acta Universitatas Gothenburgensis*.

Loverude, M. E., Heron, P. L., & Kautz, C. H. (2010). Identifying and addressing student difficulties with hydrostatic pressure. *American Journal of Physics, 78*(1), 75 - 85.

Loverude, M. E., Kautz, C. H., & Heron, P. R. (2003). Helping students develop an understanding of Archimedes' principle. Development of research - based instructinal materials. *American Journal of Physics, 71*(11), 1182 - 1190.

Luoma, E. (2022). *How Does A Hydraulic Press Work?* Retrieved from Gizmo Plans: ttps://www.gizmoplans.com/how-does-a-hydraulic-press-work/.

Majid, P., Akbarbegloo, M., Sanaeefar, M., & Mohammadzadeh, M. (2021). Psychosocial care experiences of patients with COVID-19 at home in Iran: A qualitative study. Health & Social Care in the Community. *Wiley Online Library, 30*(1), 264 - 274.

Mankins, J. (2002). Approaches to strategic research and technology (R&T) analysis and road mapping. *Science Direct, 51*(1 -9), pp. 3 - 21.

Marczyk, G. R., DeMatteo, D., & Festinger, D. (2010). *Essentials of research design and methodology* (Vol. 2). John Wiley & Sons.

Mason, J. (2000). Modelling in mathematics education: A comparative approach. In L. F. Press (Ed.), *International Studies in Mathematics Education* (pp. 12 - 23). London: Falmer Press.

Mayer, R. E. (2014). Cognitive Theory of Multimedia Learning. In R. E. Mayer, *Multimedia Learning* (pp. 43 - 71). Cambridge: Cambridge University Press.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia Learning. *Educational Psychologist, 38*(1), 43 - 52. Retrieved from Cognitive Theory of Multimedia Learning(Meyer).

Mazur, E. (1997). *Peer Instruction : A User's Manual* . Prentice Hall.

McCombs, B. L. (2017). Historical Review of Learning Strategies Research:Strategies for the Whole Learner—A Tribute to Claire Ellen Weinstein andEarly Researchers of This Topic. *Educational Psychology, 2,* 1 - 14.

McCorvy, J. D., Olsen, R. H., & Roth, B. L. (2016). Psilocybin for depression and anxiety associated with life-threatening illnesses. *30*(12), pp. 1209 – 1210.

McDermott, L. C., & Redish, E. F. (1999). Resources letter: PER - 1 : Physics Education Research. *American Journal of Physics, 67*(9), 755 - 767.

McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochemia Medica, 22*(3), 276 - 282. Retrieved from https://doi.org/10.11613/BM.2012.031:citation[oaicite:2]{index=2}&#8203

Mensah, S. (2019). Multimedia Instruction and cognitive load in teaching science in Ghanaian high schools. *Ghana Journal of Education and Technnology, 10*(3), 67 - 76.

Migiro, S. O., & Magangi, B. A. (2011). Mixed methods: A review of literature and the future of the new research paradigm. *African Journal of Business Management, 10*(5), pp. 3757 - 3764. doi:doi:10.5897/AJBM09.082

Minichiello, A., David, A., Sarbajit, M., Lori, C., Vladimir, K., Tadd, T., & Aditya, B. (2020). Developing a mobile application-based particle image velocimetry tool for enhanced teaching and learning in fluid mechanics: A design-based research approach. *Comput Appl Eng Educ*, 517 – 537.

Ministry Of Education (MOE). (2010). *Teaching Syllabus for Physics (senior High Schools).* Accra. Ghana: Curriculum Research and Development Division (CRDD).

Minogue, J., & Borland, D. (2016). Investigating Students' Ideas About Buoyancy and the Influence of Haptic Feedback. *Journal of Science Education and Technology*, *25*(2), 187 - 202.

Misaiko, K., & Vesenka, J. (2014). Connecting the dots: Links between kinetic theory and Bernoulli's principle. *Physics Education Research Conference Proceedings, 52*, pp. 257-260.

Mole, E., Southgate, L., Machado, R., Katie M. Snape, K., Primeau, M., & Dafou, D. (2011, May 13). Gain-of-Function Mutations of ARHGAP31, a Cdc42/Rac1 GTPase Regulator, Cause Syndromic Cutis Aplasia and Limb Anomalies. *The American Journal of Human Genetics(AJHG), 88*(5). doi:https://doi.org/10.1016/j.ajhg.2011.04.013

Molee, L. M., Henry, M. E., Sessa, V. I., & Mckinney-Prupis, E. R. (2011, March 1). Assessing Learning in Service-Learning Courses through Critical Reflection. *Journal of Experiential Education, 33*(3). doi:https://doi.org/10.1177/105382590113300304

Muller, R. A. (2001). Misconceptions about Bernoulli's equation. *The Physics Teacher, 39*(7), 379 - 383.

Munna, A., & Kalam, A. (2021). Teaching and learning process to enhance teaching effectiveness: a literature review. *International Journal of Humanities and Innovation (IJHI), 4*(1), 1 - 4.

Munson, B. R., Young, D. F., & Okiishi, T. H. (2013). *Fundamentals of Fluid Mechanics* (7 th ed.). John Wiley & Sons.

Mupa, P., & Chinooneka, T. I. (2015). Factors contributing to ineffective teaching and learning in primary schools: Why are schools in decadence? *Journal of Education and Practice, 6*(19), 2222 - 1735.

Mutlu - Bayraktar, D., Cosgun, V., & Altan, T. (2019). Cognitive load Theory in multimedia learning environment : A systematic review. *ScienceDirect*, 141.

Nahari, A., & Alfadda, H. A. (2016). From Memorising to Visualising: The Effect of Using Visualisation Strategies to Improve Students' Spelling Skills. *Canadian Center of Science and Education, 9*(6), 1 - 14. doi:http://dxdoi.org/10.5539/elt.v9n6p1

Nevenglosky, E. A., Cale, C., & Aguilar, S. (2019). Barriers to effective curriculum implementation. *Research in Higher Education Journal*,, 36.

Nguyen, P., Smith, J., & Zhao, Q. (2019). Foundations of fluid mechanics: Historical perspectives and modern applications. *Journal of Applied Fluid Dynamics, 56*(3), 245 - 258. doi: https://doi.org/10.1016/j.jafd.2019.03.004

Nguyen, T., Nguyen, H., Phan, D., Nguyen, D., Nguyen, B., Nguyen, N., . . . Gibson, M. (2022). Questions on the Genesis and Growth of Coronary Lesions and their Answers Based on Fluid Mechanics Engineering:A New Dynamic Angiography Analysis. *TTU Journal of Biomedical Sciences*, 1 - 11. doi: https://doi.org/10.53901/tjbs.2022.10.art01

Nice CXone Expert and Department of Education. (2022). *Pascal's Principle and Hydraulics.* Retrieved from LibreText - Physics: https://phys.libretexts.org/Bookshelves/University_Physics/Book%3A_University_Physics_

Niyitanga, T., Nkundabakura, P., & Bihoyiki, T. (2021). Factors Affecting Use of Practical Work in Teaching and Learning Physics:Assessment of Six Secondary Schools in Kigali City, Rwanda. *African Journal of Educational Studies in Mathematics and Sciences, 17*(1), 61 - 72.

Noetel, M., Griffith, S., Delaney, O., & Sanders, T. (2022). Online learning and assessment in higher education: A systematic review. *Educational Research, 34*. doi:https://doi.org/10.1016/j.edurev.2021.100404&#8203

Nyirahabimana, E., Uwizeyimana, T., & Uwizeye, I. (2024). Exploring the impact of digital tools on teaching practices in Rwandan secondary schools. *Journal of Educational Technology, 12*(1), 45 - 58. doi:https://doi.org/10.5281/zenodo.123456 7:citation[oaicite:4]{index=4}&#8203

Ocholla, D. N. (2022). A Research Dashboard for Aligning Research Components in Research Proposals, Theses, and Dissertations in Library and Information Science. In D. N. Ocholla, *Handbook of Research on Mixed Methods Research in Information Science* (p. 12). USA: IGI Global. doi:DOI: 10.4018/978-1-7998-8844-4.ch029

Opfermann, M., Schmeck, A., & Fischer, H. E. (2017). Multiple Representations inPhysics and Science Education – Why Should We Use Them? *Research Gate*, 1 - 22. doi:doi: 10.1007/978-3-319-58914-5_1

Ornet, F., Robinson, W. R., & Haugan, M. P. (2008). What makes Physics difficult? *International Journal of Environmental and Science Education, 3*(1), 30 -34.

Paas, F., Renkl, A., & Sweller, J. (2012). Cognitive load theory : A braoder view on the role of memory in learning and education. *Educational Phychology Review*, *24*(2), 225 - 247.

Paas, Merrienboer, V., Fred, C. G., & Jeroen, J. G. (2016). "The Efficiency of Instructional Conditions: An Approach to Combine Mental Effort and performance Measures". Human Factors. *The Journal of the Human Factors and Egornomics Society*, *35*(4), 737 - 743. doi:doi:10.1177/00187208930 3500412

Paivio, A. (1986). *Mental representations : A dual codding approach.* Oxford University Press.

Pallant, J. (2011). *A Step by Step Guide to Data Analysis Using the SPSS Program* (4 ed.). Berkshire, Berkshire: McGraw-Hill, Berkshire.

Pandey, V., Pandey, D., & Singh, N. (2015). Sustainable phytoremediation based on naturally colonizing and economically valuable plants. *Science Direct:Journal of Cleaner Production*, *86*, 37 - 39.

Pappas, C. (2014). *Cognitive Load Theory and Instructional Design*. Retrieved July 10, 2013, from eLearning Industry: https://elearningindustry .com/cog nitiveload-theory-and-instructional-design

Pekel, F., & Hasenekoğlu, I. (2020). *An effective tool to deal with misconceptions: Conceptual change approach.* (V. KRYSTEV, M. S. DINU, R. EFE, & E. ATASOY, Eds.) Sofia: ST. KLIMENT OHRIDSKI UNIVERSITY PRESS.

Pekel, F., & Hasenekoğlu, I. (2020). *An effective tool to deal with misconceptions: Conceptual change approach.* (V. Krystev, M. S. Dinu, R. Efe, & E. Atasoy, Eds.) Sofia: St. Kliment Ohridski University Press.

Pentang, J. T. (2023). Quantitative Research Instrumentation for Educators . *Lecture Series on Research Process and Publication* (pp. 1 - 8). Cabanatuan City, Philippines : Philippines: Wesleyan University - Philippines College of Education.

Piaget, J. (1976). *The grasp of consciousness: Action and concept in the young child (Trans by S. Wedgwood).* Harvard U Press.

Pimentel, J. L. (2010). A note on the Usage of Liker Scaling for Research Analysis. *ResearchGate, 18*(2), 109 - 112. Retrieved from https://www.researchgate.net/publication/331231816

Potkonjak, V. G., Callaghan, V., Mattila, P., Guetl, C. P., & Jovanovic, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers and Education, 95,* 309 - 327. doi:https://doi.org/10.1016/j.compedu.2016.02.002

Pyatt, K., & Sims, R. (2012). Virtual and physical experimentation in inquiry-based science labs: Attitudes, performance, and access. *Journal of Science Education and Technology, 21*(1), 133 - 147. doi:https://doi.org/10.1007/s10956-011-9291-6

Raiyn, J. (2016). The Role of Visual Learning in Improving Students' High-Order Thinking Skills. *Journal of Education and Practice, 7*(24), 115 - 121.

Redish , E. F. (2003). *Teaching Physics with the physics Suit.* John Wiley & Sons.

Rehman, A., & Alharthi, A. (2016). An Introduction to research paradigms. *International Journal of Educational Investigations, 3*(8), pp. 51 - 59. Retrieved October 13, 2023, from https://www.researchgate.net/publication/325022648

Reif, F. (2010). *Thinking and Learning in Scientific and Other Complex Domains. In Applying Cognitive Science to Education.* Cambridge, MA: The MIT Press.

Richard, C. (2023). *Dual Coding Theory (Allan Paivio)*. Retrieved May 16, 2023, from Instructionaldesign.org: https://www.instructionaldesign.org/theories

Romero, C., & Martinez, M. (2013). Achievements of Engineering students on a fluid mechanics course to the use of illustrative interactive simulations. *European Journal*.

Ross, D. B., Cooper, D., Greenlee, M., Laurberg, P., & & Maia, A. E. (2016). *Thyroid : 2016 American Thyroid Association Guidelines for Diagnosis and Management of Hyperthyroidism and Other Causes of Thyrotoxicosis* (Vol. 26). America: Mary Ann Liebert, Inc.

Rudolph, J. W. (2017). Reconsidering the history of science education: A view from the “Big Science” era. *Science Education, 101*(7), 1110 - 1134. Retrieved from https://doi.org/10.10 02/sce.21304

Santyasa, W., Warpala, W., & Tegeh, M. (2018). The Effect of Conceptual Change Model in the Senior High School Students’ Understanding and Character in Learning Physics. *Global Conference on Teaching, Assessment, and Learning in Education (GC-TALE 2017). 42*, p. 8. SHS Web conference. doi:ttps://doi.org/10.1051/shsconf/20184200058

Saputra, N., Juanda, S., Surya, E., & Syahputra, E. (2019). Improving students' critical thinking ability and learning outcomes through problem-based learning n elementary school. *Journal of Physics: Conference Series, 1175*. doi:https://doi.org/10.1088/1742-6596/1175/1/012072

Sasmito, A., & Sekarsari, P. (2022). Enhancing Students' Understanding and Motivation During Covid-19 Pandemic via Development of Virtual Laboratory. *Journal of Turkish Science Education, 19* (1), 180 - 193.

Sattar, A., & Labib, W. (2019). Active learning in Engineering education:Teaching strategies and methods of overcoming challenges. *Proceedings of the 2019 8th International Conference on Educational and Information Technology*, (pp. 255 - 261).

Schäfle, C., & Kautz, C. (2021, June 29). Student reasoning in hydrodynamics: Bernoulli's principle versus the continuity equation. *Physival Review Physics Education Research, 17*(1). doi:https://doi.org/10.1103/PhysRevPhysEducRes.17.010147

Serway, R. A. (2004). *Physics for scientist and engineer*. Monterey, CA: Thomson Brooks/Cole.

Shukla, V., Murhekar, M., & Bhatnagar, T. E. (2020). Prevalence of SARS-CoV-2 infection in India: Findings from the national serosurvey. *Indian Journal of Medical Research, 152*(1 - 2), 48 - 60.

Skrabankova, J., P. S., & Beitlova, M. (2020). Students' Ability to Work with Graphs in Physics Studies Related to Three Typical Student Groups. *Journal of Baltic Science Education, 19*(2), 298 - 316.

Smith, M. U., diSessa, A. A., & & Roschelle, J. (1993). Misconceptions and the learning of science: A conceptual change approach. In *Handbook of Research on Science Teaching and Learning* (pp. 499 - 519). New York, Macmillan.

Soloman, H., & Culatta, C. (2023). *Cognitive Load Theory (John Sweller)*. Retrieved from InstructionalDesign.org: https://www.instructionaldesign.org/theories/cognitive_ load/

Steele, T. (2023, October 22). *Cognitive Load Theory: 7 Instructional strategies you can implement today*. Retrieved from LinkedIn: https://www.linke din.com/pulse/cognitive

Stephen, L. (2021). *Density and its Applications*. Retrieved July 5, 2023, from LibreTexChemistry: https://chem.libretexts.org/Courses/Palomar_Col lege/PC%3A_CHEM100

Suárez, Á., Zavala, G., Kahan, S., & Marti, A. (2017, September 12). Student Conceptual Difficulties in Hydrodynamics. *Physical Review Physics Education Research*, 1 - 12. doi:DOI: 10.1103/PhysRevPhysEducRes.13.020132

Sulak, T. (2017). School climate : the controllable and the uncontrollable. *Educational Studies, 44*(3), 279 - 294.

Sweller, J. (1988). Cognitive load during problem - solving: Effects on learning. *Cognitive science, 12*(2), 257 - 285.

Sweller, J., Ayres, P., & Kalyuga, S. (2011). Cognitive load theory in practice. *Centre for Education Statistics and Evaluation*. Retrieved September 20, 2023, from https://education.nsw.gov.au/

Sweller, J., Jeroen, J. G., Van, M., & Fred, G. W. (1998). Cognitive Architecture and Instructional Design. *Educational Psychology, 10*(2), 251 - 296. doi:doi:10.1023/A

Sweller, J., Merrienboer, V., Pass, F., & Jeroen, J. G. (2019, January 22). Cognitive Architecture and Instructional Design: 20 Years Later. *Springer Link, 31*, 261–292. Retrieved March 14, 2024, from https://link.springer.com/article/10.1007/s10648-019-09465-5

Tabachneck, H. J., Leonardo, A. M., & Simon, H. A. (2019). How does an expert use a graph? A model of visual and verbal inferencing in economics. *Proceedings of the Sixteenth Annual Conference of the Cognitive Science Society*, (pp. 842 - 847). Routledge.

Taherdoost, H. (2021). Validity and reliability of the research instrument; how to test the validation of a questionnaire/survey in a research. *International Journal of Academic Research in Management*, *5*(3), 28 - 36. Retrieved from https://doi.org/10.2139 /ssrn.3205040:citation[oaicite:1]{index=1}&#8203

Thakur, N. (2019). *Fluid in motion*. Retrieved from LibreText Physics: https://phys.libretexts.org/Courses/Prince_Georges_Community_College/PHY_1030%3AGeneral_Physics_

Tianlong, Z. (2017). *Using Multiple Ways to Investigate Cognitive Load Theory in the Context of Physics Instruction.* Retrieved from Purdue University: https://docs.lib.purdue.edu/open_assess_dissertations/1678

Tieso, C. L. (2005). The Effects of Grouping Practices and Curricular Adjustments on Achievement. *Journal for the Education of the Gifted, 29*(1), 60 - 89.

Treagust, D., Duit, R., & Fischer, H. (2017). Multiple Representations in Physics Education. (P. Gilbert, Ed.) *Germany: Springer.*, 10.

Trowbridge, D. E., & McDermott, L. C. (1981). Investigation of student understanding of the concept of velocity in one dimension. *American Journal of Physics, 49*(3), 242 - 253.

Tuan, H., Chin, C., & Shieh, S. (2005). The development of a questionnaire to measure students' motivation towards science learning. *International Journal of Science Education, 27*(6), 639 - 654.

Tyler, R. W. (2013). *Basic principles of curriculum and instruction.* Chicago: University of Chicago Press.

Vaidya, A. (2020, April 13). Teaching and Learning of Fluid Mechanics. *Montclair State University Diital Commons, 5*(2), 49. doi:https://doi.org/10.3390/fluids5020049

Vaidya, A. (2020). Teaching and Learning of Fluid Mechanics. *Montclair State University Diital Commons, 5*(2), 49. doi:doi.org/10.3390 /fluids5

Voogt, J., Pieters, J., & Roblin, N. P. (2019). Collaborative Curriculum Design in Teacher Teamss: Foundations. *Springer Link,* 5 - 18.

WAEC - Chief Examiner. (2011- 2021). *Resume of chief examiner's reports for the science subjects.* Accra: West African Examination Council (WAEC).

Walker, J., Resnick, R., & Halliday, D. (2014). *Halliday and resnick fundamentals of Physics.* New Jersey: Wiley.

WAMA), W. A. (2018). *West Akim Municipal Assembly :Medium Term Development Plan (Mtdp) 2018-2021.* Asamankese - E/R Ghana: West Akim Municipal Assembly.

West Akim Municipal Assembly (WAMA). (2018). *West Akim Municipal Assembly :Medium term development plan (MTDP) 2018-2021.* Asamankese - E/R, Ghana: West Akim Municipal Assembly.

Westera, W. (2001). Competences in education: A confusion of tongues. *Journal of Curriculum Studies, 33*(1), 75 - 88.

White, F. M. (2011). *Fluid Mechanics* (7 th ed.). McGraw - Hill.

Wickens, C. D., Helton, W., Hollands, J., & Banbury, S. (2021). *Engineering Psychology and Human Performance.* (5. th, Ed.) New York: Routledge. doi:https://doi.org/10.4324/9781003177616

Williams, J., & Chesterman, A. (2014). *The Map: A Beginner's Guide to Doing Research in Translation Studies.* New York, NY 10017,USA: Routledge.

Wong, D., Poo, S. P., Hock, N. E., & Kang, W. L. (2011). Learning with multiple representation: an example of a revision lesson in mechanics. *Physics Education, 46*(2), 178.

Wong, K., Wong, Y. L., & Wong, W. K. (2009). An application of cognitive load theory in teaching mechanics. *Education Research International* .

Wulandari, R., & Santoso, R. E. (2019). Measurement of Student's Learning Interests in Fluid Mechanics Subject through Project Based Learning Model Using SCAMPER Strategies. *2nd International Conference on Vocational Educationand Training (ICOVET 2018),* (pp. 242, 215 - 218).

Yaacob, M. R., & Velte, C. M. (2021). *Students perception towards the implementation of asynchronous video lectures and video-based instructionsin experimental fluid mechanics course* . Retrieved from https://catal og.lib.kyushu-u.ac.jp/opac_detail_md/?lang=0&amode=MD100000&bibi d= 4480 719

Yang, H., & Farley, A. (2019). Quantifying the impact of language on the performance of international accounting students: acognitive load theory perspective. *Victoria University : VU Research Repository*, *55*, 12 - 24.

Yang, H., & Farley, A. (2019). Quantifying the impact of language on the performance of international accounting students: acognitive load theoryperspective. Victoria University. *VU Research Repository, 55*, 12 - 24.

Zailinawati, A. H., Schattner, P., & Mazza, D. (2006). Doing A Pilot Study: Why Is It Essential? *National Library of Medicine*, *1*(2 - 3), 70 – 73.

Zarmati, L. (2018, July 24). Teaching History in Australian Museums: Pedagogy and Praxis. *Spriner Link*, 217 – 224.

Zhou, T., Lu, Y., & Wang, B. (2009). Exploring Chinese Users' Acceptance of Instant Messaging Using the Theory of Planned Behaviour, the Technology Acceptance Model, and the Flow Theory. *Computers in Human Behaviour*, 25, 29 - 39.

.

APPENDICES

APPENDIX A

FLUID MECHANICS CONCEPT TEST (FMCT)

Open-Ended Questions on Fluid Mechanics Concepts.

Code: OEQ- FMCT pre – test / …

Instruction: Dear Students please try to answer each question based on your knowledge.

<u>Archimedes' principle</u>

1. How does Archimedes' principle explain why some objects float in water while others sinks, as shown in the figure 1 below?

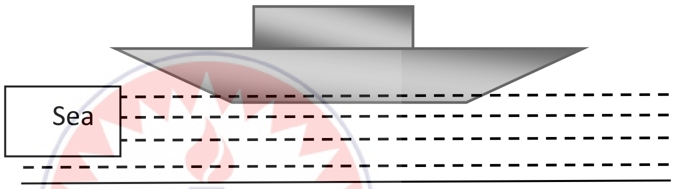


Figure 1

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

2. Describe a practical every day setting where understanding Archimedes' principle is applied?

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

3. What factors influence the buoyant force experienced by an object in a gas or liquid, as shown in figure 2?

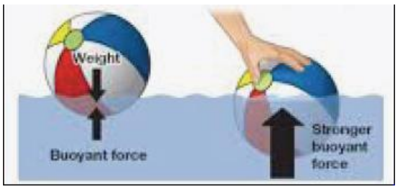


Figure 2

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

<u>Pascal's Principle</u>

4. a) How does Pascal's principle relate to the concept of hydraulic systems, as shown in the figure 3 below?

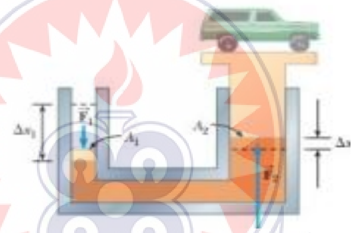


Figure 3

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

b) What are some of the everyday applications that make use of the above principle?

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

5. a) Explain how Pascal's principle plays a role in the transmission of pressure through confined fluids?

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

b) Why is Pascal’s principle important in various engineering and industrial applications?

……………………………………………………………………………….........

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

6. Given a hydraulic system with a small piston of area 0.005 m^2, calculate the force exerted if a pressure of 20,000 Pa is applied.

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…..………………………………………………………………………………

…………………………………………………………………………………

Bernoulli's principle

7. a) How does Bernoulli's principle explain the lift generated by an airplane wing?

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

b) Why is this principle important in aviation?

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

8. Give an example of how Bernoulli's principle is demonstrated in everyday life, such as in the operation of a household item or in the design of a common tool or device?

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

9. Explain how Bernoulli's principle is related to the flow of blood in the circulatory system.

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

<u>Continuity equation</u>

10. How does the continuity equation relate to the conservation of mass?

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

11. What are some practical applications of continuity equation in fluid dynamics or other scientific fields?

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

12. A pipe with a cross-sectional area of 0.03 m^2 has water flowing through it at a velocity of 2 m/s. Calculate the volume flow rate.

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

THANK YOU!

APPENDIX B

FLUID MECHANICS CONCEPT TEST (FMCT)

Open-Ended Questions on Fluid Mechanics Concepts

OEQ– FMCT post – test /--

Instruction: Dear Students please try to answer each question based on your knowledge.

Archimedes' principle

1. a) When an object is immersed into the fluid, two forces act on the object in vertically opposite directions. Name them.

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

b) Write the factors the magnitudes of these forces in (a) above depends.

………………………………………………………………………………………..

………………………………………………………………………………………

………………………………………………………………………………………

2. The figures 1 below shows three identical wooden blocks floating in three different liquids A, B and C of densities $d_1 d_2$ and d_3 respectively. Which of these has the highest density? Give reasons to justify your answer

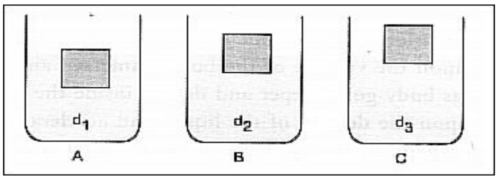


Figure 4

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

3. A ship is loaded in sea water to maximum capacity as shown in fig. 2. What will happen if this ship is moved to river water? Why?

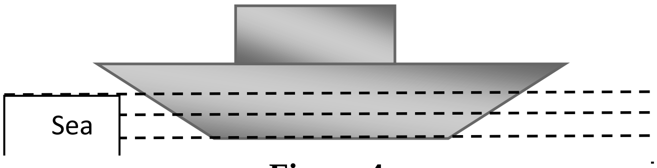


Figure 4

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Pascal's principle

4. In a hydraulic machine, a force of 2N is applied on the piston of area of cross section10cm^2. What force is obtained on its piston of area of cross section100cm^2?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

5. The area of cross –section of the wider tube shown in figure 3 below is800cm^2. If mass of 12kg is placed on massless piston, the difference in heights h in the level of water in the two tubes is?

Figure 5

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………

6. What should be the ratio of area of cross section of the master cylinder and wheel cylinder of a hydraulic brake so that a force of 15N can be obtained at each of its brake show exerting a force of 0.5N on the pedal?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

Bernoulli's principle

7. What does Bernoulli's principle state?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

8. A wind with speed 40m/s blows parallel to the roof of a house. The area of the roof is 250m^2. Assuming that the pressure inside the house is atmospheric pressure, the force exerted by the wind on the roof and the direction of the force will be (ρ_{air}=1.2kgm^{-3})

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

9. State two practical applications of Bernoulli's principle.

i. ………………………………………………………………………………………

…………………………………………………………………………………………

ii. ……………………………………………………………………………………………

……………………………………………………………………………………………

Continuity equation

10. Water flows in a horizontal tube as shown in figure 4. The pressure of water changes by700Nm^{-2}between A and B where the area of cross section is 40$cm^2$and 20cm^2, respectively. Find the rate of flow of water through the tube. (Density of water =1000kgm^{-3})

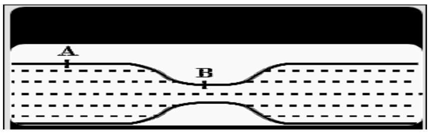


Figure 6

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

11. A horizontal pipe of non-uniform cross-section allows water to flow through it with a velocity 1$ms^{-1}$when pressure is 50 kPa at a point. If the velocity of flow has to be 2 ms^{-1}at some other point, what will the pressure at that point?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

12. A pipe with a cross-sectional area of 0.04 m^2 has water flowing through it at a velocity of 3 m/s. Calculate the volume flow rate.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

THANK YOU!

APPENDIX C

TABLE OF STUDENTS' PERFORMANCE FORM FLUID MECHANICS CONCEPT TEST (FMCT)

The tables, A1 and A2 below show the results of students' test scores from the pre-intervention test and the post-intervention test scores.

Table A1: Pre - Pre-Intervention Test Score on FMCT for 45 students

Students	Archimedes principle	Pascal's principle	Bernoulli's principle	Continuity equation
1	4	5	2	4
2	0	4	6	7
3	6	6	0	1
4	2	4	0	6
5	5	6	1	0
6	3	4	2	5
7	4	7	1	0
8	1	6	2	5
9	3	5	1	4
10	1	1	6	2
11	2	5	7	3
12	5	5	4	0
13	2	6	0	6
14	2	5	2	0
15	0	0	6	8
16	1	6	0	2

17	2	4	3	0
18	5	3	2	3
19	0	6	6	9
20	7	4	0	1
21	2	5	3	0
22	1	5	3	2
23	2	5	2	6
24	1	6	5	0
25	0	4	4	3
26	6	5	5	1
27	5	8	3	5
28	2	3	5	8
29	4	6	2	3
30	5	0	3	7
31	4	5	1	0
32	1	2	4	1
33	3	6	5	3
34	4	6	7	4
35	2	0	5	7
36	3	2	0	2
37	0	1	5	8
38	3	2	1	3
39	2	4	2	5
40	1	6	3	2

41	0	4	2	4
42	8	5	3	5
43	1	4	2	3
44	2	6	8	2
45	0	7	2	0

FMCT = Fluid Mechanics Concept Test

Table A2: Post - Post-Intervention Test Score on FMCT for 45 students,

Students	Archimedes principle	Pascal's Principle	Bernoulli's principle	Continuity equation
1	9	7	9	8
2	7	9	5	7
3	5	6	8	8
4	1	8	9	6
5	9	9	2	8
6	7	6	8	7
7	5	8	9	2
8	8	9	5	8
9	9	4	8	7
10	7	8	7	9
11	8	1	9	8
12	6	9	1	9
13	9	3	8	5
14	4	6	7	9
15	7	9	9	7

16	9	7	6	8
17	6	8	8	9
18	7	5	9	5
19	8	9	2	8
20	9	3	8	7
21	3	8	7	9
22	7	9	6	4
23	9	2	9	8
24	8	5	7	9
25	2	9	8	1
26	9	8	9	7
27	8	5	6	8
28	4	9	4	9
29	9	4	8	6
30	8	8	9	2
31	3	9	5	9
32	9	7	9	3
33	6	6	8	6
34	8	9	3	9
35	9	7	7	7
36	8	5	9	4
37	6	9	8	0
38	9	0	9	5
39	4	7	7	9

40	7	9	4	8
41	8	4	7	9
42	5	7	6	6
43	6	5	7	9
44	7	8	5	6
45	8	7	6	9

FMCT = Fluid Mechanics Concept Test

APPENDIX D

PHYSICS STUDENTS' ATTITUDE QUESTIONNAIRE (PSAQ)

Here are several attitude scales that explore students' attitudes towards the study of Fluid Mechanics. Please give your opinion on the following items by ***circling*** *to indicate your response. The options are:* ***SA=Strongly Agree, A=Agree, D= Disagree SD= Strongly Disagree***

Table 1: Table C: Physics Students' Attitude Questionnaire (PSAQ)

Dimension	S/N	Items	Response			
Understanding Fluid Mechanics	**UFM1**	I struggle to understand the concepts in Fluid Mechanics	**SA**	**A**	**D**	**SD**
	UFM 2	I easily explain scientific terms in Fluid Mechanics	**SA**	**A**	**D**	**SD**
	UFM 3	I can easily explain the physics in fluid flow using computer simulations	**SA**	**A**	**D**	**SD**
	UFM 4	I get good scores in Fluid Mechanics questions	**SA**	**A**	**D**	**SD**
Importance of Fluid Mechanics	**IOFM1**	I see Fluid Mechanics as a necessary topic to study in Physics	**SA**	**A**	**D**	**SD**
	IOFM 2	The topics I study in Fluid Mechanics are vital for my career as a professional in Physics	**SA**	**A**	**D**	**SD**

	IOFM 3	Knowledge of Fluid Mechanics helps me make sense of the technology and industry	**SA**	**A**	**D**	**SD**
	IOFM 4	Knowledge of Fluid Mechanics will help me learn about the technological and industrial world in a global context	**SA**	**A**	**D**	**SD**
Further Studies in Fluid Mechanics	**FSIFM1**	I spend more time reading further in Fluid Mechanics after lessons for more knowledge	**SA**	**A**	**D**	**SD**
	FSIFM 2	When I do not understand a topic in Fluid Mechanics, I find relevant resources that will help me	**SA**	**A**	**D**	**SD**
	FSIFM 3	I have discussions with my classmates when I do not understand anything in Fluid Mechanics	**SA**	**A**	**D**	**SD**
	FSIFM 4	When new information that I have learned in Fluid Mechanics conflict with my previous understanding, I try to understand why.	**SA**	**A**	**D**	**SD**

	FSIFM 5	I would like to study a branch of Physics in Fluid Mechanics at higher education	**SA**	**A**	**D**	**SD**

THANK YOU!

APPENDIX E:

INTERVENTION IN FLUID MECHANICS CONCEPTS

Table E -2: Intervention in Pascal's Principle

Lesson Plan Developed by integrating Multimedia into Cognitive Load Theory

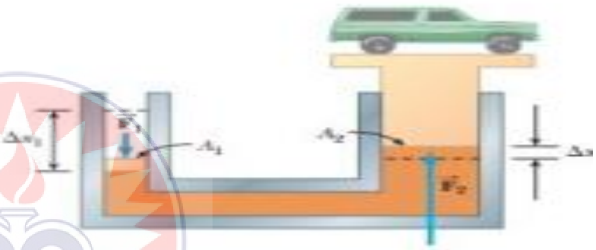
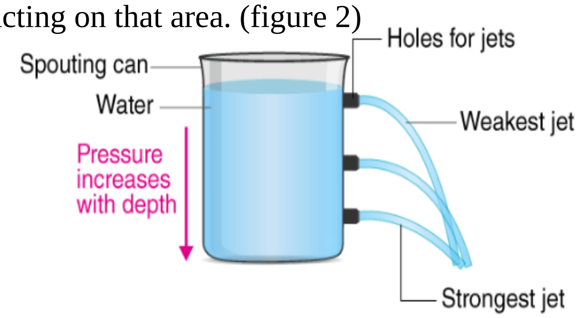
Instructional Approach in Pascal's Principle

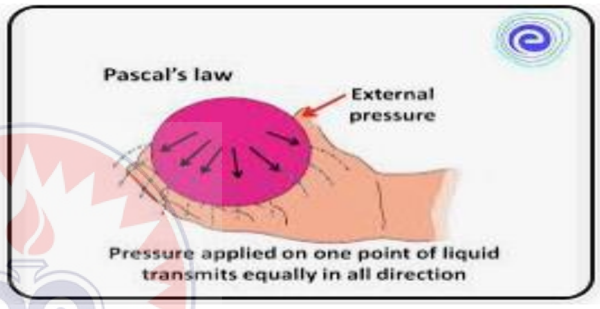
<table>
<tr><td colspan="3">LESSON :1

DURATION: 1 hour.

OBJECTIVES: By the end of the lesson, students will be able to;

• State Pascal's principle, and explain that pressure in fluid increases with depth.
• Understand that at a point within a fluid, the force acts in all directions away from the point with the same magnitude in each direction.
• Understand that an increase in pressure applied to a fluid in any direction increases the magnitudes of the force that acts at the point in the fluid.
• Use the formula, $\frac{F_1}{A_1} = \frac{F_2}{F_2}$ to determine the magnitude of forces applied to objects by fluid and vice versa
• To demonstrate the applications of Pascal's principle in real-life situations.</td></tr>
<tr><td colspan="3">Teaching – Learning Materials: SHS Physics syllabus; textbook (Serway & Jewett, 2008), p. 395- 399; text, pictures, Computer simulations, diagrams, video, and symbolic or mathematical formulae.</td></tr>
<tr><td>Duration in minutes</td><td>Stages</td><td>CLTML – instructional approaches</td></tr>
<tr><td>5</td><td>Introduction</td><td>The researcher introduces the topic
• Pascal's principle, pressure in fluid increases with depth.</td></tr>
</table>

		• Pressure at a point in a fluid is the same at all point • Relationship between pressure on an area and force acting on that area
40	Presentation	The researcher presents: • Video on how pressure in fluid increases with depth. (Figure 1). The researcher give verbal explanations to support the video(dual coding)  **Figure 7: Pressure in fluid increases with depth** • The Statement of Pascal's' Principle, by applying redundancy principles • Discusses step by – -step with the students the interaction between pressure on an area and force acting on that area. (figure 2)  **Figure 9: Pressure on an area and force acting**

		• The researcher guides students to use simulations to illustrate Pascal's principle, pressure and force • The researcher guides students to demonstrate that pressure in a fluid at a point is the same, as using a balloon, or water in a bottle. Therefore, showing them how the fluid pressure acts equally in all direction (Figure 3), using segmentation, split - attention and contiguity principles.  **Figure 8** • Applying the redundancy and contiguity principle, the researcher guides students to evaluate the relationships between pressures and forces acting on an area by using mathematical equations and formulae, as in fig. 4. Pressure on an area is given by, $P=\frac{F}{A}$, $\frac{F_1}{A_1} = \frac{F_2}{F_2}$

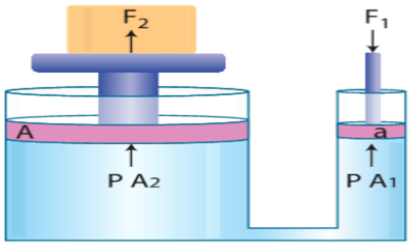
<table>
<tr><td></td><td></td><td>

Figure 9: Pascal’s law</td></tr>
<tr><td>5</td><td>Summarization</td><td>Summarise Pascal’s principle and the relationship between pressure and force</td></tr>
<tr><td>10</td><td>Evaluation</td><td>The students work in their workbooks to complete the activity in their workbooks individually.
A spouting container with three holes at the sides is filled with water, as shown in fig 1.
What will happen to the water, when the spouting can is filled to the brim?
How will you describe the water jets?
What conclusions can you drawn on your observation in fig 1?
What does picture 4 describe in terms of the relationship between pressure, force, F and area, A?
In fig. 3, what cues are associated with force exerted by the hand on the balloon?
What can you say in picture 2; about the small force exert on the small piston?
Finally, the researcher will give them corrections for their responses so that they get the correct answer.</td></tr>
</table>

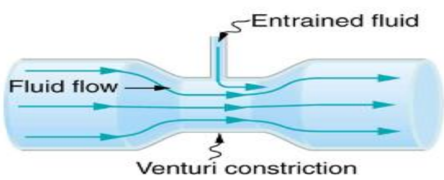
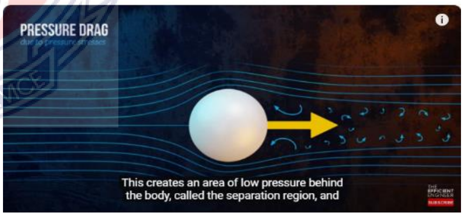
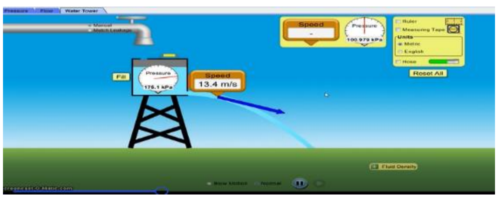
Table E - 1 : Intervention on Bernoulli's Principle

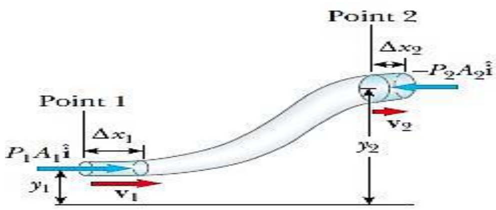
Lesson Plan Developed by integrating Multimedia into Cognitive Load Theory Instructional Approach in teaching Bernoulli's Principle

<table>
<tr><td colspan="3">LESSON :1

DURATION: 1 hour.

OBJECTIVES: By the end of the lesson, students will be able to;
State Bernoulli's principle;
Explain briefly, the concept of streamline flow.
State the law of conservation of energy in fluid flow
Apply mathematical formulation of Bernoulli's equation.
To demonstrate the applications of Bernoulli's principle in real-life situations.</td></tr>
<tr><td colspan="3">Teaching – Learning Materials: SHS Physics syllabus; textbook (Serway & Jewett, 2008), p. 395- 399; text, pictures, Computer simulations, diagrams, video, and symbolic or mathematical formulae.</td></tr>
<tr><td>Duration in minutes</td><td>Stages</td><td>CLTML – instructional approaches</td></tr>
<tr><td>5</td><td>Introduction</td><td>The researcher introduces the topic
Bernoulli's principle
Concept of streamlined flow
Conservation of energy in fluid flow
Bernoulli's equation and applications</td></tr>
<tr><td>40</td><td>Presentation</td><td>The researcher presents:</td></tr>
</table>

		• Video on how objects fly or flow through a fluid such as air plane. The researcher provide verbal explanations to the video. • The Statement of Bernoulli's' Principle by employing modality and contiguity principle.  **Figure 1: Bernoulli's principle** Discusses step by – -step (segmentation) with the students the interaction between pressure and velocity/ speed of flow of fluid for a streamlined body, as in fig. 2.  **Figure 2: Flow of an object** • The researcher guides students to use simulations to illustrate Bernoulli's principle, pressure, and buoyancy, (fig. 3), by using modality principle and dual coding.  **Figure 3: Bernoulli's principle**

		• The researcher guides students to demonstrate Bernoulli's' principle by using simulations and a streamlined body like an inflated balloon or streamlined-shaped body in a fluid, as in Fig. 4 • Using segmentation, redundancy and contiguity principle the researcher explained how the streamlined body in fluid interacts and the pressure difference between the body and the fluid. • Using segmentation, expert reversal and redundancy principles , the researcher guides students to evaluate the relationships between  **Figure 4** pressure, density, and volume change by using mathematical equations and formulae.(fig.5)  **Figure 5** $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

		• Discuss with students some practical applications of Bernoulli's principle.
5	Summarization	Summarise Bernoulli's principle and the relationship between pressure, volume, and density of fluid.
10	Evaluation	• Water is flowing in a fire hose with a velocity of 1.0 m/s and a pressure of 200 kPa. At the nozzle, the pressure decreases to atmospheric pressure (101,300 Pa). Assume that there is no change in height. Using the Bernoulli equation, answer the following questions. Take the density of water as $1000 kgm^{-3}$ • What will happen to the speed of water exiting the nozzle? • What will happen to the speed of water, if the height is raised at the exit end of the nozzle? • What will happen when the height of the entry of the nozzle is raised above the exit end? • The students will now work in their workbooks to complete the activity in their workbooks individually. • Picture 1 (fig. 1), what happens to the speed of flow at the venture constriction? • Picture 2, what relationship can you established between pressure and velocity of fluid flow?

		• Finally, the researcher will give them corrections for their responses so that they get the correct answer.

Table E- 2: Intervention on Continuity Equation (Fluid Flow)

Lesson Plan Developed by integrating Multimedia into Cognitive Load Theory Instructional Approach in teaching continuity equation / Fluid flow

LESSON :1

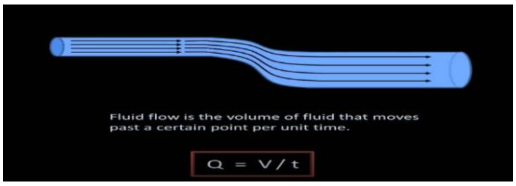
DURATION: 1 hour.

OBJECTIVES: By the end of the lesson, students will be able to;

- Briefly define fluid low and continuity equation
- State at least one significance of continuity equation
- Explain briefly how the equation is derived from conservation of mass principle.
- To demonstrate the applications of continuity equation in real-life situations.

Teaching – Learning Materials: SHS Physics syllabus; textbook (Serway & Jewett, 2008), p. 395- 399; text, pictures, Computer simulations, diagrams, video and symbolic or mathematical formulae.

Duration in minutes	Stages	CLTML – instructional approaches
5	Introduction	The researcher introduces the topic • Fluid flow and general form of continuity equation • Explanation of the terms involved in continuity equation. Thus, fluid density, velocity and cross – sectional area. • Relationship between fluid density, velocity and cross – sectional area.

40	Presentation	The researcher presents: • Video on fluid flowing in pipes of non- uniform cross – sectional areas. The researcher provides verbal explanations to support the video.  **Figure 1: Video on continuity equation** • The researcher explained fluid flow and continuity equation, using redundancy and modality principles. • Discusses step by – -step (segmentation) with the students the concept of fluid flow.  **Figure 2: Fluid Flow** • The researcher discusses step by step with the students the various parameters involved in the continuity equation, by employing redundancy principles.

<table>
<tr>
<td></td>
<td></td>
<td>

- Discusses step by step with students how to derive the continuity equation with the students from conservation of mass principle.
- The researcher guides students to use simulations to illustrate the principle of conservation of mass of fluid and the deductions of continuity(fig. 3)

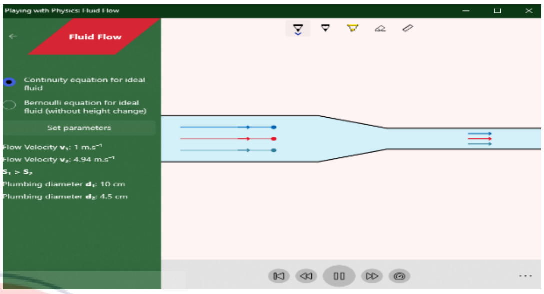


Figure 3: Fluid flowing in non – uniform pipe

- Employing segmentation, redundancy and modality principles the researcher guides students to deduce the continuity equation mathematically from conservation of mass principle.

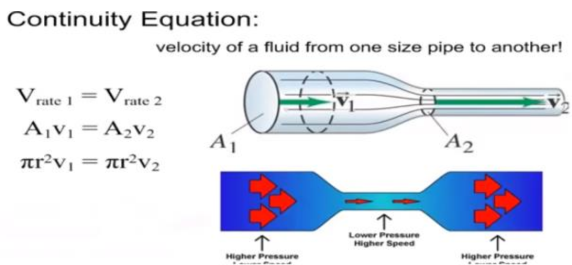


Figure 4: Continuity equation is given as

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

$$Av = \text{Constant}$$

$$A_1 v_1 = A_2 v_2$$

This is continuity equation

</td>
</tr>
</table>

		• The researcher led students to discuss some practical applications of continuity equation.
5	Summarization	Summarises continuity equation and the relationships between fluid density, velocity and cross – sectional area.
10	Evaluation	• What do we mean by the term fluid flow? • What happens to the velocity of flow when fluid flows through non – uniform pipes, as in fig 2? • What happens to the speed of flow, when the cross – sectional area at the exit end of the flow pipe is smaller than the entry end of the pipe? • State one practical application of continuity equation. • The students will now work in their workbooks to complete the activity in their workbooks individually. • What happens to the velocity of the fluid in picture 3, if the cross – sectional area at A_1 is equal to A_2 of the pipe? • Finally, the researcher will give them corrections for their responses so that they get the correct answer.

APPENDIX F

COHEN'S D FORMULA

$d = \frac{M_1 - M_2}{\sqrt{\frac{S_1^2 + S_2^2}{2}}}$

Where $\sqrt{\frac{S_1^2 + S_2^2}{2}}$ = pooled standard deviation

M_1 = Post-test mean of the experimental group

M_2 = Pre-test mean of the experimental group

S_1^2 = post-test standard deviation of the experimental group

S_2^2 = pre-test standard deviation of the experimental group

d= calculated Cohen's *d*

LAWSHE'S FORMULA

CVI = $\frac{N_E}{N}$ for the Content Validity Index

CVR = Content Validity Ratio ($\frac{CVR}{N}$).

N = Total number of the experts.

N_E = The number of experts identifying a particular item as essential.